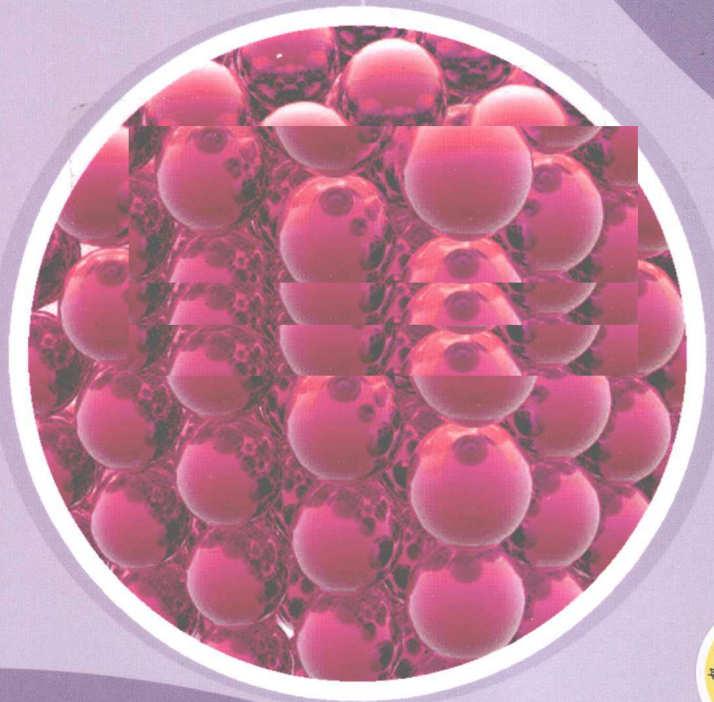
高等院校材料类专业教材

材料专业英语

CAILIAO ZHUANYE YINGYU

范积伟 主编



机械工业出版社
CHINA MACHINE PRESS

高等院校材料类专业教材

材料专业英语

主　编　范积伟
副主编　席艳君　王艳芝
参　编　张小立　赵慧君　曲良俊

机械工业出版社

本书课文和阅读材料全部选自近年来英、美等国材料科学专业教材和专业刊物，共55篇，涵盖了金属材料、陶瓷材料、高分子材料、复合材料、生物医学材料、纳米材料和工程应用等内容。所选文章题材多样，内容新颖，学科前沿知识丰富，融知识性和趣味性于一体。为了提高读者的科技英语翻译和写作水平，每一章都附有有关科技英语翻译及写作技巧的内容。读者可在掌握材料专业英语和翻译及写作技巧的同时进一步学习材料专业的有关知识。

本书可作为普通高等院校材料科学与工程类专业本科生、研究生的专业英语教材，也可供材料科学研究人员、工程技术人员学习和参考。

图书在版编目（CIP）数据

材料专业英语/范积伟主编. —北京：机械工业出版社，2010.4
高等院校材料类专业教材
ISBN 978-7-111-30261-2

Ⅰ.①材… Ⅱ.①范… Ⅲ.①材料科学—英语—高等学校—教材 Ⅳ.①H31

中国版本图书馆 CIP 数据核字（2010）第 055190 号

机械工业出版社（北京市百万庄大街 22 号 邮政编码 100037）
策划编辑：邝 鸥 何月秋 责任编辑：刘本明
版式设计：霍永明 责任校对：李 娜
封面设计：马精明 责任印制：乔 宇
北京瑞德印刷有限公司印刷（三河市胜利装订厂装订）
2010 年 5 月第 1 版第 1 次印刷
184mm×260mm · 15.75 印张 · 387 千字
0001—3000 册
标准书号：ISBN 978-7-111-30261-2
定价：35.00 元

凡购本书，如有缺页、倒页、脱页，由本社发行部调换

电话服务
社服务中心：(010)88361066
销 售 一 部：(010)68326294
销 售 二 部：(010)88379649
读者服务部：(010)68993821

网络服务
门户网：http://www.cmpbook.com
教材网：http://www.cmpedu.com

封面无防伪标均为盗版

前　言

材料是人类物质文明的基础，新材料是社会不断发展进步的一大支柱，新材料的研究开发极大地促进了工业发展和社会进步。英语作为一种重要的全球化的交流工具，发挥着重要的作用。学好英语，尤其是专业英语，是学生、学者和工程技术人员获取科研信息、掌握学科发展动态、参加国际学术交流的基本前提。材料学科涉及广泛的研究领域，具有很强的学科交叉性，日新月异的新材料发展使得材料学科的专业英语学习尤为重要。为此，我们编写了本书，希望能对从事材料科学与工程的工程技术人员、研究生、本科生的专业英语水平的提高有所帮助。

本书分为8章，每一章含3～4节，分别对应于材料科学的不同领域。前7章中，每一节均由一篇课文和一篇阅读材料组成。阅读材料提供了与课文对应的背景知识或者是课文的续篇，从而进一步拓展了课文的内容。全书共29节，课文及阅读材料共计55篇，涵盖了金属材料、陶瓷材料、高分子材料、复合材料、生物医学材料、纳米材料和工程应用等内容，涉及面广，学科全面。本书附录A为化学元素的中英文对照表。附录B为新版元素周期表。另外，英美科技文章中经常出现的非公制单位往往使读者感到困惑，为此，附录C给出了英美度量衡系统与公制系统之间的关系。附录D列出了本书的主要词汇。

本书具有以下几个特点：

1. 知识面广，趣味性强。涉及材料科学相关专业的各类知识，论述的概念清楚、准确、简练。

2. 内容丰富、新颖。55篇文章全部选自近年来出版的原版英文教科书、科技报告、专业期刊和著作，内容新颖，学科前沿知识丰富，特别突出在纳米技术和生物医学材料方面的进展。

3. 词汇量大，词汇表实用。本书既可作为材料专业的英语教科书，又可用于自学。为了提高读者的科技英语翻译和写作水平，每一章都附有有关科技英语翻译及写作技巧的内容。

本书由范积伟担任主编，席艳君、王艳芝担任副主编。第1、6、8章由范积伟编写，第2章及科技翻译和写作技巧部分由席艳君编写，第3章由赵慧君编写，第4章由曲良俊编写，第5章由王艳芝编写，第7章由张小立编写，全书由范积伟统稿。本书在编写过程中，得到了中原工学院教务处、材料与化工学院领导及同仁的支持和帮助，在此表示衷心的感谢。

编　者

Contents

前言

Chapter 1 Introduction to Materials Science and Engineering …… 1

1.1 What Is a Material? …… 1

1.2 Classification of Materials …… 5

1.3 Fundamental Properties of Different Kind of Materials …… 11

科技英语翻译技巧（一）：词义选择和引申 …… 16

Chapter 2 Metals and Alloys …… 18

2.1 Atomic Arrangements and Imperfects in the Atomic Arrangement …… 18

2.2 Thermal Equilibrium Diagram …… 24

2.3 Casting …… 30

2.4 Nonferrous Alloy …… 37

科技英语翻译技巧（二）：数词 …… 43

Chapter 3 Ceramics …… 45

3.1 Introduction to Ceramics（Ⅰ） …… 45

3.2 Novel Ceramic Processing Routes（Ⅰ） …… 52

3.3 Advanced Ceramics（Ⅰ） …… 59

3.4 Clean Energy through Ceramics（Ⅰ） …… 67

科技英语翻译技巧（三）：常见多功能词 as 的用法 …… 77

Chapter 4 Polymer Materials …… 80

4.1 Polymers …… 80

4.2 Methods for Synthesis of Polymers …… 85

4.3 Processing of Polymers …… 91

科技英语翻译技巧（四）：常见多功能词 it 的用法 …… 96

Chapter 5 Composites …… 98

5.1 Composite Basics—Material System …… 98

5.2 Introduction to Carbon Fiber Composites …… 109

5.3 Three-Dimensionally Reinforced Preforms and Composites …… 118

5.4 The Uses of Composite Materials …… 128

科技英语翻译技巧（五）：关连词引导的句型翻译技巧（I） …… 138

Chapter 6 Biomaterials …… 140

6.1 Biomaterials and Biomaterials Science …… 140

6.2 Traditional and New Generation Biomaterials …… 145

6.3 Examples of Biomaterials Applications …… 149

6.4 The Future of Biomaterials …… 154

科技英语翻译技巧（六）：关连词引导的句型翻译技巧（II） …… 159
Chapter 7 Nanotechnology and Nanomaterials …… 161
7.1 What Are Nanomaterials? …… 161
7.2 What Is Nanotechnology? …… 165
7.3 Nano-Crystalline Metal and Nano Metal Foam …… 171
7.4 Applications of Nanotechnology …… 177
科技英语翻译技巧（七）：并列句和复合句 …… 186
Chapter 8 Recent Advances in Materials Science and Technology and Future Trends …… 188
8.1 Recent Advances in Materials Science and Technology …… 188
8.2 Trends in Materials Science and Technology (I) …… 191
8.3 Trends in Materials Science and Technology (II) …… 196
科技英语写作技巧 …… 201
Appendixes …… 203
Appendix A Chemical Elements …… 203
Appendix B Periodic Table of Elements …… 207
Appendix C The Metric, British and U. S. Systems …… 208
Appendix D Glossary …… 209

Chapter 1 Introduction to Materials Science and Engineering

1.1 What Is a Material?

From a practical **standpoint**, we know that all material objects are essential for a human being to build things. This definition includes solids, but also liquid (e. g., liquid crystals that create LCD displays), and even gases for more specific situations[①]. Really, every raw material used by industry could be included in this classification, but we use the word "material" in a restricted sense: We think about materials whose properties might not be an exact image of those that their elements possess. Thus, we especially concern ourselves with how elements are structured in macroscopic bodies, with how treatments are used during the elaboration of materials, or with the physicochemical aggregation of different elements—all activities that condition the properties of the materials we generate.

The selection, modification, and elaboration of materials to satisfy our needs merge in the foundations of human culture[②]. From the very beginnings of prehistory, humans have manipulated substances so that they would be more useful. To create more useful materials, our **forebears** wanted to understand and control the composition of materials, and they often succeeded in modifying a material's behavior and properties and in predicting the effects of such manipulations.

This task developed over time, beginning as a **handcraft** that employed empirical and speculative knowledge. The history of materials science and engineering had already begun in the Stone Age when stones, wood, clay, and leather began to be **manipulated.** In the Bronze Age, mankind discovered the value of temperature and used it to modify materials by thermal treatments or by adding other substances. Yet, in spite of technological improvements, materials science remained empirical until the end of the nineteen century. Materials science, as we now understand it, began with the appearance of **Mendeléev's** periodic table. Since that time, some properties of elements that are related to their position in the periodic table began to be explained scientifically[③], and these results became incorporated in the annals of science. Since the end of the nineteen century, the introduction of chemistry and physics, calculus, and modern experimentation have brought the use and profits of materials to a mature status. Currently, thanks to more reliable knowledge of the structure of matter, we can design new materials atom by atom, to achieve the properties we want. At last we

have materials that not only satisfy our requirements, but also permit us to create new ones that were **hitherto** unthinkable.

Thanks to this science, we can even **speculate** about using new, alternative materials to solve **socioeconomic** problems by avoiding the decimation of natural resources or trying to reach long ranges **sustained** economic development. Conversely, the solution of unsolved problems improves our theoretical knowledge as well as the scope of materials in science and engineering.

Materials scientists must analyze how the structure and composition of materials related to their properties, and the effect of the method of preparation of a material. Materials engineers examine the preparation, selection, and application of materials **in agreement with** known and desired properties. Engineers also incorporated technical and structural analysis and examine key concerns: **energetic**, economic, **ecological**, aging.

For materials science and engineering, changes in physicochemical properties in response to a **stimulus** are highly significant. These properties can be classified into groups according to the kind of stimulus: mechanical, thermal, electromagnetic (throughout the spectrum), chemical, and scattering. In brief, mechanical properties, such as deformation and fracture, among others, are responses to applied mechanical forces. Thermal properties, like thermal conductivity and heat capacity, are affected by heat fluxes or temperature changes. Electrical properties such as the dielectric constant or conductivity occur in response to electromagnetic fields. In a similar sense, optical properties, such as the **refractive index** or absorption, among others, respond to electromagnetic fields having high frequency. Chemical properties, like the chemical **affinity**, are responses to the existence of **reagents** in the environment, and the scattering properties are responses to the impact of particles depending on the material's structure.

(Selected from *An Introduction* to *Materials Science*,
by W. González-Viñas, and H. L. Mancini, 2005)

Questions

1. What is a material? Please describe it by using your own words.
2. In history, at which stage had the materials science and engineering begun?
3. What do materials scientists need to analyze?
4. Please describe some properties of materials.
5. In general, what is the materials engineers' job?

New Words and Expressions

1. standpoint *n.* 立场，观点
2. forebear *n.* 祖先，祖宗
3. handcraft *n.* 手工，手艺
4. manipulate *v.* 操作，使用，利用
5. Mendeléev 门捷列夫（1834—1907），发现化学元素周期律的俄国科学家

6. hitherto *adv.* 迄今，至今
7. speculate *v.* 推测，思索
8. socioeconomic *adj.* 社会经济学的；*n.* 社会经济学
9. sustained *adj.* 持续不变的，相同的
10. in agreement with 符合……，和……一致
11. energetic *adj.* 积极的，精力充沛的
12. ecological *adj.* 生态学的，社会生态学的
13. stimulus *n.* 刺激，促进因素，刺激物
14. refractive index 折射率
15. affinity *n.* 亲合力，密切关系，相似（性）
16. reagent *n.* 试剂，反应力，反应物

Notes

① This definition includes solids, but also liquid (e. g., liquid crystals that create LCD displays), and even gases for more specific situations.

参考译文：这个定义包括固体也包括液体（例如液晶显示屏），在特定情况下甚至包括气体。

② The selection, modification, and elaboration of materials to satisfy our needs merge in the foundations of human culture.

参考译文：选择、改性和加工材料以满足我们的需求是人类文明的基础。

句中 the selection, modification, and elaboration of materials to satisfy our needs 构成主语。

③ Since that time, some properties of elements that are related to their position in the periodic table began to be explained scientifically,...

参考译文：从那时开始，元素的一些性质是与它们在元素周期表中的位置有关才得以有科学的解释，……

Reading Material

Materials and Materials Science

Materials have accompanied mankind **virtually** from the very beginning of its existence. Among the first materials utilized by man were certainly stone and wood, but bone, fibers, feathers, shells, animal skin, and clay also served specific purposes.

Materials were **predominantly** used for tools, weapons, **utensils**, shelter, and for self-expression, that is, for creating **decorations** or jewelry[①]. The increased usage and development of ever more **sophisticated** materials were paralleled by a rise of the **consciousness** of mankind. In other words, it seems to be that advanced civilizations generally invented and used more **elaborate** materials. This observation is probably still true in present days.

Materials have been considered of such importance that historians and other scholars have named certain ancient periods after the material which was predominantly utilized at that respective

time[②]. Examples are the Stone Age, the Copper-Stone Age (**Chalocolithic** Period), the Bronze Age, and the Iron Age. The Stone Age, which is defined to have begun about 2.5 million years ago, is divided into the **Paleolithic** (Old Stone Age), the **Mesolithic** (Middle Stone Age), and the **Neolithic** (New Stone Age) phases. We will consider on the following pages mostly the Neolithic and Chalocolithic periods. Surprisingly, these classifications do not include a Ceramic Age, even though pottery played an important role during extended time periods.

The names of some metals have entered certain linguistic usages. For example, the **Greeks** distinguished the Golden Age (during which supposedly peace and happiness **prevailed**) from the Silver Age. Rather than being descriptive of the materials that were used, these distinctions had more **metaphorical** meanings. Specifically, gold has always been held in high **esteem** in the eyes of mankind. Medals for outstanding performances (sport events, etc.) are **conferred** in gold, silver, or bronze. Specific wedding anniversaries are classified using gold, silver, and iron.

Until very recently, the **mastery** of materials has been achieved mainly by **empirical** means or, at its best, by a form of **alchemy.** Only in the nineteenth and twentieth centuries did systematic research lead to an interdisciplinary field of study that was eventually named materials science.

(Edited from *Understanding Materials Science: History, Properties, Applications*, by R. E. Hummel, 2004)

Questions

1. What are the first materials that were utilized by ancient people?
2. How can we subdivide Stone Age?
3. Could you name some ancient periods?

New Words and Expressions

1. virtually *adv.* 事实上，实质上
2. predominant *adj.* 支配的，主要的，突出的
3. utensils *n.* 器具
4. decoration *n.* 装饰，装饰品
5. sophisticated *adj.* 高级的，完善的，久经世故的
6. consciousness *n.* 意识，知觉，觉悟
7. elaborate *adj.* 精心制作的，详细阐述的；*n.* 精心制作，详细描述
8. Chalocolithic *adj.* 铜石并用时代的
9. Paleolithic *adj.* 旧石器时代的
10. Mesolithic *adj.* 中石器时代的
11. Neolithic *adj.* 新石器时代的
12. Greek *n.* 希腊人，希腊语；*adj.* 希腊的，希腊语的
13. prevaile *v.* 流行，盛行，获胜，成功
14. metaphorical *adj.* 比喻性的

15. esteem *v.* 把……看作，尊重，认为；*n.* 尊敬，尊重
16. confer *v.* 授予，赠与，协商，交换意见
17. mastery *n.* 掌握
18. empirical *adj.* 实验的，经验的，经验主义的
19. alchemy *n.* 炼金术，魔力

Notes

① . . . , and for self-expression, that is, for creating decorations or jewelry.

参考译文：……并且为自我表现所用，即创造装饰品或珠宝。

句中 that is 是“即”“就是”的意思。

② Materials have been considered of such important that historians and other scholars have named certain ancient periods after the material which was predominantly utilized at that respective time.

参考译文：材料被认为是如此重要，以至于历史学家和其他学者用在那个时期最主要使用的材料来命名该历史时期。

句中 such. . . that 意为“如此……以至于……”。

1.2 Classification of Materials

The phase of a material-which defines its **macroscopic** presentation-characterizes the material's properties and depends on external variables like temperature and pressure[①]. This phase can be modified when external parameters are changed. If we want to **assert** that a sample is of a certain type, we have to specify, **apart from** the material, the interval of environmental conditions in which its phase is stable. For example, we cannot say that aluminum is a conducting material without specifying the temperature at which it acts like a conductor; this is because at temperatures lower than 1.19K aluminum reveals a superconducting phase with quite a different **phenomenology** from the conducting one. Often this is not enough. **Metastable** states appear because of a material's **degradation**, hence allowing a sample of a material that is stable under certain conditions to **coexist** with another sample in another phase under the same conditions. As an example, carbon in normal conditions can naturally coexist in allotropic forms like diamond and graphite. It is not sufficient to indicate the environmental conditions; data about the sample's history are also required. In this example the pressures and temperatures applied to the carbon atoms and their duration are required for unambiguous determination of the phase of a sample. Without analyzing such problems, we list below some possible classifications.

The most general materials classification consists of dividing them into simple materials and **composites**. Composites are formed of more than one different type of material. After this simple classification, it is common to classify materials according to their different properties; hence, for example, as follows.

- Components:

— Simple elements; **monoatomic** and **polyatomic**.

— Compounds: **diatomic**, **polyatomic**, macromolecular (organic and inorganic).

— Mixtures. These correspond to composites and can be of different chemical compounds or of different phases of the same compound[②]. Blends can be either homogeneous or heterogeneous. The division of mixtures is made with reference to the following scales: atomic, microscopic, **mesoscopic**, macroscopic(various). For example, it is not enough to assert that a granite sample is **heterogeneous**; it is has to be stated that it is heterogeneous at the 1mm scale, which is homogeneous at 1km scale.

- Type of bond:
  — Ionic (insulators, ceramics, metal-**monometal**). Bond energy 3-8eV/atom.
  — Ionic-covalent.
  — Covalent (polymers, ceramics, and so on).
  — Metallic (metallic materials). Bond energy from 0.7(Hg) to 8.8eV/atom (W).
  — Van de Waals: fluctuating induced **dipole** (H_2, Cl_2, and so on) with bond energy of 0.1eV/atom, induced dipole-polar molecule (e.g., HCl) with bond energy of 0.1eV/atom, permanent dipole or hydrogen bond (e.g., H_2O, NH_3) with bond energy of 0.5eV/atom.
  — **Pseudo bond** or physical bond (sticky materials).
- Electrical properties:
  — Metallic or conducting, including principally metals and metallic alloys. In conductors the electrical resistance R is low but increases as the temperature rises.
  — Semimetallic. In these, the electrical resistance R is appreciable, but there are 10^{-4} fewer electrons than in the metallic materials. Again, the resistance R grows as the temperature increases.
  — Semiconducting. They have an appreciable electrical resistance R that diminishes if the temperature rises.
  — Insulating or dielectrics. They have a high electrical resistance R.
  — Superconducting. Their electrical resistance is $R \approx 0$.
- Arrangement of components:
  — **Monocrystalline.**
  — **Polycrystalline.**
  — Glassy materials, which present short-range order.
  — **Quasicrystalline.**
  — **Semicrystalline.**
  — **Partial** order. For example, the materials may have positional order (the mass centers of the components, have an ordered disposition) but not orientational order (the components, necessarily anisotropic here, do not have an ordered orientation).
  — **Amorphous.**
  — Composite (see the classification according to the components).

Because of the existence of many such nonequivalent classifications and of intermediate materials, the classifications above are of limited value[3]. We assume, usually, the following classification, but for our convenience and for **didactic** reasons sometimes we will use either one or another of the preceding classifications.

(Selected from *An Introduction to Materials Science*, by W. González-Viñas, and H. L. Mancini, 2005)

Questions

1. What is a compound?
2. What are the electrical properties of materials?
3. How many different bonding types are there?
4. What is the resistivity of an insulator?

New Words and Expressions

1. macroscopic *adj.* 宏观的，肉眼可见的
2. assert *v.* 断言，声称
3. apart from 远离，除……之外
4. phenomenology *n.* 现象学
5. metastable *adj.* 亚稳态的
6. degradation *n.* 退化，降级
7. coexist *v.* 共存
8. composite *n.* 复合材料，合成物；*adj.* 合成的，复合的
9. monoatomic *adj.* 单原子的
10. polyatomic *adj.* 多原子的
11. diatomic *adj.* 二原子的，二价的
12. mesoscopic *adj.* 介观的，准微观的
13. heterogeneous *adj.* 异质的，不同种类的
14. monometal *n.* 单金属
15. dipole *n.* 偶极子
16. pseudo bond 假键
17. monocrystalline *n.* 单晶，单晶质
18. polycrystalline *adj.* 多晶的；*n.* 多晶体
19. quasicrystalline *adj.* 准结晶的；*n.* 准结晶体
20. semicrystalline *adj.* 半晶质的；*n.* 半结晶体
21. partial *adj.* 部分的，局部的，偏爱的
22. amorphous *adj.* 无定形的，非晶（形）的
23. didactic *adj.* 说教的，教诲的

Notes

① The phase of a material-which defines its macroscopic presentation-characterizes the material's properties and depends on external variables like temperature and pressure.

参考译文：材料的相结构决定了该材料的宏观表现，表征了它的性能，同时也取决于像温度和压力这样的外部变量。

② These correspond to composites and can be of different chemical compounds or of different phases of the same compound.

参考译文：这对应于复合材料，可以是不同的化合物或同一化合物的不同相。

③ Because of the existence of many such nonequivalent classifications and of intermediate materials, the classifications above are of limited value.

参考译文：因为存在许多这样的不等分类和存在于分类之间的材料，上述分类只有有限的价值。

Reading Material

Electronic Materials Age

Stone Age-Bronze Age-Iron Age-what's next? Some individuals have called the present era the space age or atomic age. However, space exploration and nuclear reactors, to mention only two major examples, have only little impact on our everyday life. Instead, electrical and electronic devices (such as radio, television, telephone, **refrigerator**, computers, electric light, CD players, electromotors, etc.) **permeate** our daily life to a large extent. Life without electronics would be nearly unthinkable in many parts of the world. The present era could, therefore, be called the age of electricity. However, electricity needs a medium in which to **manifest** itself and to be placed in service①. For this reason, and because previous eras have been names after the material that had the largest impact on the lives of mankind, the present time may best be characterized by the name **Electronic Materials Age**.

We are almost constantly in contact with electronic materials, such as conductors, insulators, semiconductors, (ferro) magnetic materials, optically **transparent** matter, and **opaque** substances. The useful properties of these materials are governed and are characterized by electrons. In fact, the terms electronic materials and electronic properties should be understood in the widest possible sense, meaning to include all phenomena in which electrons participate in an active (dynamic) role. This is certainly the case for electrical, magnetic, optical, and even many thermal phenomena. In contrast to this, mechanical properties can be mainly interpreted by taking the interactions of atoms into account②.

We have already known that electrons can be considered to part of an atom which, in an elementary description, orbit the atomic core. Some of these electrons, particularly those in the outermost **orbit** (i.e., the valence electrons), are often only loosely bound to their **nuclei**. Therefore, they disassociate with relative ease from their core and then combine to form "sea" of electrons.

These free electrons govern many of the electronic properties of materials, particularly in conductors. In other cases, such as in insulators, the electrons are bound somewhat stronger to their nuclei, and thus, under the influence of an alternating external electromagnetic force, may oscillate about their core. This constitutes and electric dipole can be discussed in the electronic properties of dielectric materials.

Now, to our knowledge, nobody has so far seen an electron, even by using the most sophisticated equipment. We experience merely the actions of electrons, for example, on a television screen or in an electron microscope. In each of these instances, the electrons seem to manifest themselves in quite a different way, that is, in the first case as a particle and in the latter case as an electron wave. Accordingly, we shall use the term "wave" and "particle" as convenient means to describe the different aspects of the properties of electrons. This is called the "**duality**" of the manifestations of electrons. A more complete description of the wave-particle duality of electrons and a **quantum**-mechanical treatment of electron wave can be found, for example, in the book, Electronic Properties of Materials.

At the end, we may **ponder** the question of when the electron, as we know and understand today, was actually discovered. The particle nature of electrons was suggested in 1897 by the British physicist J. J. Thomson who experimented with "cathode rays" at Cavendish Laboratory of Cambridge University. These **cathode rays** were known to consist of an invisible radiation that emanated from a negative electrode (called a cathode) which was sealed through the walls of an **evacuated** glass tube that also contained at the opposite wall a second, positively charged electrode. It was likewise known at the end of nineteenth century that cathode rays travelled in straight lines and produced a glow when they struck glass or some other materials. J. J. Thomson noticed that the path of these rays could be deflected by magnetic or electric fields, and that cathode rays traveled slower than light and transported negative electricity. In order to settle the **lingering** question of whether cathode rays were "vibrations of the ether" or instead "streams of particles," he **promulgated** a bold **hypothesis**, suggesting that cathode rays were "charged corpuscles which are miniscule constituents of the atoms." This proposition—that an atom should consist of more than on particle—was startling for most people at the time. Indeed, atoms were considered since **antiquity** to be indivisible, that is, the most fundamental building blocks of matter. The charge of these "corpuscles" was found to be the same as that carried by hydrogen ions during **electrolysis** (about 10^{-19}C). Further, the mass of these **corpuscles** turned out to be 1/2,000th the mass of the hydrogen atom.

A second hypothesis brought forward by J. J. Thomson, suggesting that the "corpuscles of cathode rays are the only constituents of atoms," was eventually proven to be incorrect. Specifically, E. Rutherford, one of Thomson's former students, by using a different kind of particle beam, concluded that the atom resembled a tiny solar system in which a few electrons orbited around a "massive" positively charged centre. Today, one knows that the electron is lightest stable elementary particle of matter and that it carries the basic charge of electricity.

In 1924, de Broglie, who believed in a unified creation of universe, introduced the idea that electrons should also possess wave properties[3]. In other words, he suggested, based on the hypothe-

sis of a general reciprocity of physical laws, that electrons, similarly as light, should display a wave-particle duality. In 1926, Schrodiger cast this idea in a mathematical form. Eventually, in 1927, Davisson and Germer and independently in 1928, G. P. Thomson (the son of J. J. Thomson), discovered electron diffraction by a crystal which experimentally proved the wave nature of electrons.

(Edited from *Understanding Materials Science: History, Properties, Applications*, by R. E. Hummel, 2004)

Questions

1. What age can we call the present era?
2. What are the electronic materials?
3. List some electrical and electronic devices in your home.
4. Why electrons are so important in electronic materials?
5. So far, could we see any electron?

New Words and Expressions

1. refrigerator *n.* 电冰箱，制冷器，冷藏库
2. permeate *v.* 充满，渗透，透过，弥漫
3. manifest *v.* 出现，表明，证明；*adj.* 显然的，明白的；*n.* 旅客名单，载货单
4. transparent *adj.* 透明的，显然的，明晰的
5. opaque *adj.* 不透明的，不传导的
6. orbit *n.* 轨道，势力范围；*v.* 绕……轨道而行，沿轨道飞行，进入轨道
7. nuclei nucleus 的复数形式
8. duality *n.* 二元性，对偶性
9. quantum *n.* 量子，量子论，量
10. ponder *v.* 沉思，考虑
11. cathode ray 阴极射线
12. evacuate *v.* 疏散，撤出，排泄
13. linger *v.* 拖延，逗留，游移
14. promulgate *v.* 发布，公布，传播
15. hypothesis *n.* 假设
16. antiquity *n.* 古代，古物
17. electrolysis *v.* 电解，电蚀
18. corpuscle *n.* 微粒，粒子，血球

Notes

① However, electricity needs a medium in which to manifest itself and to be placed in service.
参考译文：然而，电需要一种方式来证明它本身的存在而且在被使用。

② In contrast to this, mechanical properties can be mainly interpreted by taking the interac-

tions of atoms into account.

参考译文：与此相反，力学性质可以被认为主要是原子间的相互作用。

③ In 1924, de Broglie, who believed in a unified creation of universe, introduced the idea that electrons should also possess wave properties.

参考译文：1924 年坚信宇宙统一论的德布洛伊提出了电子应该也具有波动性这一观点。

1.3 Fundamental Properties of Different Kind of Materials

Although the properties of the materials in each category can sometimes vary, properties broadly accepted as defining the categories are the following[①]:

- Metallic materials:
  - — They are build up of metallic elements or of compounds of metallic elements.
  - — They have many unlocalized electrons in the so called condition band.
  - — They are good thermal and electrical conductors. They are opaque to visible light.
  - — They are usually strong and plastic.
- Ceramic materials:
  - — They are chemical compounds of the type metal + nonmetal[②].
  - — They are generally good electrical and thermal insulators.
  - — They are stronger than metallic and polymeric materials at high temperatures and in chemically **aggressive** environments.
  - — They are hard and brittle.
- Polymeric materials:
  - — They are compounds, generally organic, in the form of long chains.
  - — They have low density.
  - — They are flexible or elastic or both.
- Semiconductor materials:
  - — They have properties intermediate between conductors and insulators.
  - — They have properties that are extremely sensitive to impurities and to temperature.
- Composites:
  - — They are composed of more than one type of material.
  - — They are designed to obtain better properties or combinations of properties. For example, glass fiber is as resistant as glass filament and as flexible as the polymer that forms it. Another example is adobe. Adobe, a mixture of clay and straw (up to 30%), has been employed in making bricks and in making bricks and in primitive buildings. Composites also serve as new materials in the aerospace industry. Together, these are two technological ends of composites[③].
  - — They are designed by taking into account typical targets of materials engineering. As an example, the aims of the aerospace industry are first to reduce operating costs (i. e., to

reduce the mass of structures to increase the payload); and second to raise the fatigue limit, stiffness, and thermal shock resistance. It is almost impossible to attain both aims with simple materials, so one must take into account composites like graphite-epoxy, among others.

(Selected from *An Introduction to Materials Science*, by W. González-Viñas, and H. L. Mancini, 2005)

Questions

1. What kind of properties do metallic materials possess?
2. What are ceramic materials?
3. Please describe the polymer materials.
4. What are semiconductor materials?
5. Could you give some examples of composites?

New Words and Expressions

1. aggressive *adj.* 进取的，主动的，好斗的，有闯劲的，侵略性的
2. resistant *adj.* 抵抗的，有抵抗力的
3. filament *n.* 细丝，灯丝
4. straw *n.* 稻草，麦秸
5. adobe *n.* 砖坯，土坯
6. stiffness *n.* 硬度，刚度，坚硬
7. graphite *n.* 石墨
8. epoxy *n.* 环氧树脂；*adj.* 环氧的

Notes

① Although the properties of the materials in each category can sometimes vary, properties broadly accepted as defining the categories are the following.

参考译文：虽然在每一类别中材料的性质有时可以不同，广为接受的定义类别的性质如下所列。

② They are chemical compounds of the type metal + nonmetal.

参考译文：它们是金属 + 非金属型的化合物。

③ Together, these are two technological ends of composites.

参考译文：合起来，这是复合材料应用的两个极端。

Reading Material

What Does the Future Hold?

Very few people, if any, probably would have predicted 50 years ago what kind of materials

would dominate our technology today. Who would foresee the computer revolution and this the **preponderance** of silicon in the electronics industry[①]? How many scientists or engineers **prognosticated** the laser and its impact on communication, data processing, data storage, and thus on optical materials? Was there anybody who foretold, 50 years ago, the impact of **superalloys**, of composites, or of graphite fibers as important materials? Were ceramics not essentially perceived as clay and sand; that is, could anybody anticipate high-tech ceramics, including high T_c-superconductors, heat-resistant tiles (for space shuttles), silicon carbide engine parts, etc.? And finally, how many people could visualize 50 years ago the impact of plastics as one of the prime materials of the resent day, or an **accentuation** on recycling and environmental protection?

On the other hand, nearly "everybody" predicted only 20 years ago that composites and ceramics for high-temperature engines would be the materials which would enjoy healthy growth rates in the years to come. This, however, has not happened. One of the major funding agencies in the United States (ARPA[②]) has recently stated that the past 30 years have not brought the expected progress in the structural ceramics, brittle matrix composites, or **intermetallics**. It is said that these "**exotic**" materials may probably never be used in critical parts such as **turbine blades** because they are too brittle, and a balance of properties may probably never be achieved. A 50% cut in support for the ensuing projects is therefore anticipated. Instead, a **resurgence** of substantial interest in metal research may boost, for example, nickel-based superalloys (e. g., Ni-Al) which are often coated with μm-thick **heat barriers**. These coatings, consisting, for example, of **zirconia** or Ni-Cr-Al-Y are anticipated to prevent the **respective** alloys in turbine blades from melting or creeping. In other words, a change in research support from "exotic" materials to new alloys is presently thought to be more in the national interest. In essence, a shift form structural materials (such as ceramics, composites, etc.) to functional materials (such as smart materials, electromagnetic materials, and optical materials) will probably take place in the next couple of years. Specifically, future funding is anticipated for the development of compact lasers, **holographic** data storage, thermoelectric materials (used for cooling of high T_c superconductors, **microprocessors**, short wavelength **IR** detectors, etc.) and for smart materials (which involve a series of sensors that control actuators). Further, a shift from empirical materials selection towards one based on model calculations and on a fundamental understanding of the physics and chemistry of materials science will probably take place. Finally, the exploration of **nanostructures** will probably play a major role in future research funding.

Still, "predictions are quite difficult to make, particularly if they **pertain** to the future[③]." As an example, a U. S. **congressman** suggested at the end of the last century that the patent office should be abolished. "since all major inventions have been made already." Moreover, it has been shown more than once that extrapolations of resent knowledge and accomplishments into the years which lay ahead were flatly wrong. Thus, **utmost** care needs to be exercised when projections are made. While the substantial improvement of these properties during the past 20-40 years is certainly impressive, it probably would be wrong to assume that a similar sharp rise would continue in the next decade or two. Indeed, certain limitations exist when, for example, **atomistic** dimensions are reached. This may **stifle** further progress as long as the same conventional methods are applied. In

other words, new, **innovative** concepts are needed instead and probably will be found.

(Edited from *Understanding Materials Science: History, Properties, Applications*, by R. E. Hummel, 2004)

Questions

1. How many people had correctly predicted the materials that would dominate our technology today?
2. Can you distinguish structural materials and functional materials?
3. Which exploration will play a major role in future research funding?
4. What did the U. S. congressman suggest at the end of the last century?

New Words and Expressions

1. preponderance *n.* 优势，多数
2. prognosticate *v.* 预言
3. superalloy *n.* 超合金，超耐热合金
4. accentuation *n.* 强调，重读
5. intermetallic *adj.* 金属间（化合）的
6. exotic *adj.* 外来的，奇异的
7. turbine blade 涡轮叶片
8. resurgence *n.* 苏醒
9. heat barrier 热障
10. zirconia *n.* 氧化锆
11. respective *adj.* 分别的，各自的
12. holographic *adj.* 全息的
13. T_c 居里温度
14. microprocessor *n.* 微处理器
15. IR 红外线（infrared）
16. nanostructure *n.* 纳米结构
17. pertain *v.* 属于，适合
18. congressman *n.* 国会议员，众议员
19. utmost *n.* 极限，最大可能性；*adj.* 极度的，极端的
20. atomistic *adj.* 原子论的
21. stifle *v.* 抑制，窒息
22. innovative *adj.* 创新的，革新的

Notes

① Who would foresee the computer revolution and this the preponderance of silicon in the electronics industry?

参考译文：谁预见到了计算机革命以及硅在电子工业中占优势？

② ARPA（Advanced Research Projects Agency）（美国国防部）高级研究计划署。

③ “predictions are quite difficult to make, particularly if they pertain to the future.”

参考译文：“预言难以给出，特别是能正确预见未来的预言。”

科技英语翻译技巧（一）：词义选择和引申

1. 词义的选择

科技英语中往往存在着一词多义现象，因此，要想真正理解科技论文的含义，必须准确把握词汇，这就需要将科技论文中专业词汇用准确的词义表达出来。

（1）非常专业的词汇。这些词汇虽然常见，但与常用的意思完全不同，如：

The next step for exposed film is to be treated with a developer solution.

对于曝光胶片来说，下一步就是用显影液进行处理。（译为“显影”，不译“开发”）

The developing of the film is to produce a negative of the image.

胶片进行显影的目的就是制备图像的底片。（译为“底片”，不译“负面的”）

（2）同一个词汇具有多种意思。多种意思都很常见，必须仔细加以鉴别，在不同场合选择不同的词义，比如“free”。

This construct is called the free electron model of metallic bonding.

这种结构叫做金属键自由电子模型。（译为“自由的”）

Polishing should be continued until the surface is free from scratches.

接着进行抛光直到表面没有划痕。（译为“没有”）

Figure 4.7 shows a member, fixed at one end, and on which a downward vertical force F is exerted at the free end.

图 4.7 显示了工件一端固定，另一个自由端施加一个向下垂直的作用力 F。（译为“自由的”）

Above 0.8% carbon, free Fe_3C appears in the structure and the tensile strength starts to decrease.

碳的含量高于 0.8%[⊖]，结构中会出现游离的 Fe_3C，抗拉强度开始降低。（译为“游离的”）

The specimen was cut for free.

样品免费切割。（译为“免费”）

（3）普通词汇也存在词义选择的问题。翻译中时时都要注意所选用的词义是否符合实际，尤其看是否符合中文表达习惯。

Solar energy seems to offer more hope than any other source of energy.

太阳能似乎比其他能源更有前途。（不译“提供更多希望”）

Most polymeric materials are poor conductors of electricity.

大部分高分子材料具有差的导电性。（译为“差的”，不译“穷的”）

2. 词义的引伸

选择词义是从几个词义中选择一个恰到好处的词义。而词义引伸是在原来词义的基础上把词义适当加以引伸，从而达到确切表达原文的目的。

（1）词义的转译。即有些词汇不能一字一句直译，要根据实际情况，进行适当的调整。

⊖ 书中出现的表示含量的数值，均指质量分数，以后不一一注出。

Ferrite contains a maximum of 0.0218% carbon.

铁素体中的碳含量最高可达0.0218%。(转译改变句子的主谓结构)

Steels with less than 0.77% carbon are known as hypo-eutectoid steels.

我们知道含碳量低于0.77%的钢是亚共析钢。(被动形式转译为主动形式)

Soft metals creep at room temperature, but most metallic materials only show the effect at higher temperatures.

软金属在室温蠕变，而大部分金属材料只在高温下蠕变。("effect"不直接译为"效果"，转译成它所对应的事物或事件)

(2) 词量的增减。

The most important was how to improve the strength of the material.

最重要的事是如何提高材料的强度。(补充英语中省略的词)

The term creep refers to the slow plastic deformation that occurs with prolonged loading usually at elevated temperature.

蠕变是指在高温下持续加载而发生的缓慢的塑性变形。(介词省略不译)

In assessing the behavior of a metal under stress, especially at elevated temperature, it is necessary to consider the time factor.

评价金属应力性能，特别是高温下的应力性能，必须考虑到时间因素。("in"介词省略不译；"特别是高温下的应力性能"补充了词语，使得句子更清晰完整；"it"形式代词省略不译)

Any substance is made of atoms whether it is a solid, a liquid, or a gas.

任何物质，不论是固体、液体还是气体，都由原子组成。(冠词省略不译)

Chapter 2 Metals and Alloys

2.1 Atomic Arrangements and Imperfects in the Atomic Arrangement

Lattice and Crystal Structure

The first level of atomic structure involves the arrangement of atoms. This level can have varying degrees of order or **periodicity** in the arrangements, from no order to long range order. A **monatomic** gas at high temperature and low pressure is an example of disorder or no order. An atom could be anywhere within the enclosing volume and have no particular **spatial** relationship with any of the other atoms[①]. Single crystals have long range order throughout (except at the surface) and are characterized by a repeating (periodic) arrangement of several atoms or molecules.

Most solid materials have structures somewhere in between, having regions of short or long range order. Amorphous solids have structures similar to liquids and generally have **isotropic** (the same in all directions) properties while crystalline solids usually have **anisotropic** (not the same in all directions) properties. Although it may seem to be advantageous to have isotropic properties, the properties of an amorphous material may not be sufficient for a given application. Designing with anisotropic materials requires the consideration of the directional nature of the material's properties.

Time, temperature, and bonding all play important roles in the development of atomic arrangement. As a simple example, a molten **unary** (one element or component) metal will freeze (solidify) below its melting temperature which depends on the strength of the bonds between atoms. The form of the solid will depend on the bonding between atoms as well as the cooling rate at which the melt solidifies. If the rate is very fast the atoms will not have time to form a periodic arrangement resulting in an amorphous structure. If the cooling rate is slow enough a single crystal can form.

In a liquid, the average interatomic distance is fixed (liquids do not expand to fill the available volume as gases do), and there is often local order due to polarization and Van der Waals forces. They may produce a short-range, or local, order. In some cases, rapid cooling of the liquid can lock this atom arrangement into a rigid solid, producing an amorphous or glassy structure.

In most solids (particularly metals and ceramics), the atoms are arranged in regular patterns that surround each atom with the same number of neighbors as other similar atoms with the same in-

teratomic distances and directions[2]. These are determined by the types of bonds that hold the atoms together and by the atomic or ionic radii.

The long-range repetition of the same atomic arrangement is conveniently described by a regular grid-like pattern called a lattice. This array of points provides a structure that repeats endlessly through space with the same atom or group of atoms associated with each point.

The basic repetitive unit of structure in the three-dimensional grid is called the unit cell. The shapes of unit cells that occur in nature are those that can be stacked together to fill three-dimensional space. Just as equally sized five-sided polygons or equally sized seven-sided polygons cannot be used to tile a plane, only a few specific shapes can be stacked together to fill three-dimensional space, and these are the basis for the study of crystal structures.

Defects in Atomic Arrangements

Crystal structures are ideally characterized by a lattice and a basis, a periodic arrangement of atoms or molecules. However, in real crystalline materials there are typically imperfections or 'defects' present. These defects can be categorized by their dimensionality.

Dimensions	Defect Type
0	Point
1	Line
2	Surface
3	Volume

Although the term defect generally carries negative connotations, you will see that depending on the material, defects can enhance material properties. The mechanical properties of steel are controlled by various defects, including point (**substitutional** alloying elements and **interstitial** carbon atoms), line (dislocations) and surface (grain boundaries) defects. The yield strength can be increased dramatically by the presence of point defects through alloying or an increase in dislocations through a process known as cold working. A grain refining treatment which reduces grain size increases the amount of grain boundary (a planar defect) area per unit volume, which increases the strength by increasing the amount of disordered area which impedes the motion of dislocations. An understanding of how processing conditions affect the defect structure of a material and how (and which) defects affect properties can be used to determine the appropriate processing path to obtained the desired properties or how operating conditions will affect properties[3].

1. Point defects

A point defect is a localized imperfection that disrupts the lattice. **Vacancies**, interstitial atoms, and large or small (relative to the surrounding atoms) substitutional atoms are all point defects. So are Schottky and Frenkel defects which are a combination of two vacancies (of different ions) or of a vacancy and interstitial which occur in pairs and stay close together in the structure because of the need for charge balance or to minimize lattice strain. The properties of materials may be controlled by intentionally creating and controlling point defects through heat treatment, strain hard-

ening, solid solution strengthening, and other related processes. Point defects hamper the movement of dislocations by disrupting the atom positions and making the slip planes **bent** or **bumpy**, and therefore strengthen the material. They also affect optical and electrical properties and diffusion rates.

In the perfect lattice, all of the atoms line up evenly and there is no distortion. However, most lattices include a tiny fraction of imperfections. Although they are numerically few, they control many of the properties of the material.

When an atom is missing from the lattice, there is a vacancy. If another atom manages to squeeze in between the normal sites, it is called an interstitial atom. Other atoms may also take the place of the regular atom. These substitutional atoms may be either larger or smaller than the surrounding atoms.

Carbon atoms are quite small (a radius of 0.071 nm). Such small atoms often occupy interstitial positions in metal lattices. Interstitial carbon is of vital importance in strengthening iron, and controlling it is a major purpose in the heat treatment of steels (alloys of iron and carbon).

Iron is an **allotropic** metal, meaning that its crystal structure changes with temperature. Above 910℃, the structure is **FCC**. The largest site between the iron atoms has a radius of 0.052 nm, somewhat smaller than the carbon atom. A maximum of about 2.1% carbon by weight can dissolve in FCC iron, limited by distortion of the lattice due to the presence of the interstitial atoms. Below 910℃, the iron structure changes to **BCC**. Even though this is a less close-packed structure, the largest available interstitial site is smaller than in FCC; only about 0.026 nm. Because of the greater lattice distortion the atoms cause, less carbon can be dissolved in the BCC iron (a maximum of about 0.02%). Heat treating steels often involves heating the alloy so that it transforms to FCC and dissolves all the carbon, then cooling it so that the carbon atoms are either trapped in the BCC structure (causing distortion) or forcing the atoms out of solution to form iron carbides.

2. Dislocations

Dislocations are line imperfections where the three-dimensional lattice is **offset**. There are two extreme cases—the **screw dislocation** and the **edge dislocation**—and most real dislocations are mixtures of these types. The presence and movement of these imperfections provide ductility (deformability) of the specimen and can lead to failure of a material. Controlling the number of dislocations in material by forming the object and by heat treatment is an important tool for the control of the properties of the material④.

Although they are **essentially** lines with extremely small diameters (essentially the size of an atom), dislocations can actually be seen because the atoms near them are displaced slightly. We can see an actual dislocation moving through a material using a **Transmission Electron Microscope**. The dislocation shows up as a short, curved, dark line which can be seen moving through the otherwise transparent lattice of this Germanium sample and leaving behind a straight step on the specimen surface.

(Selected from *Essential of Material Science and Engineering*, D. R. Askeland and P. P. Phule, 2005)

Questions

1. Describe the imperfects in the atomic arrangement.
2. What is interstitial solid solution?
3. Explain the reason that line imperfections effect the properties of the material.
4. Describe change of crystal structure of iron with temperature.

New Words and Expressions

1. periodicity *n.* 周期，周期性，间歇性
2. monatomic *adj.* 单原子的
3. spatial *adj.* 空间的
4. isotropic *adj.* 各向同性的
5. anisotropic *adj.* 非均匀的，各向异性的
6. unary *adj.* 一元的
7. substitutional *adj.* 替代的；置换的
8. interstitial *adj.* 间隙的，填隙的，中间的
9. vacancy *n.* 空，空格点，空位，缺额
10. bent *adj.* 弯的，曲折的
11. bumpy *adj.* 颠簸的，不稳定的
12. allotropic *adj.* 同素异形的
13. offset *v.* 偏移，偏转；*n.* 错位，错移，位置偏移
14. FCC 面心立方的（Face Centered Cubic）
15. BCC 体心立方的（Body Centered Cubic）
16. screw dislocation 螺形位错，螺线位错
17. edge dislocation 边缘位错，刃形位错
18. essentially *adj.* 实质上，本质上
19. Transmission Electron Microscope 透射电子显微镜

Notes

① An atom could be anywhere within the enclosing volume and have no particular spatial relationship with any of the other atoms.

"have" 的主语为 "an atom"，"and" 连接两个并列的成分。

参考译文：在封闭体系中原子可以达到任何地方，和体系中的其他原子没有任何特殊的空间关系。

② In most solids (particularly metals and ceramics), the atoms are arranged in regular patterns that surround each atom with the same number of neighbors as other similar atoms with the same interatomic distances and directions.

参考译文：在大部分固体（特别是金属和陶瓷）中，原子以有序的方式排列，每个原子与其他原子具有相同数量的临近原子，且其他的相同原子具有相同的原子间距和方向。

③ An understanding of how processing conditions affect defect the structure of a material and how (and which) defects affect properties can be used to determine the appropriate processing path to obtained the desired properties or how operating conditions will affect properties.

"how" 引导的两个句子是介词 "of" 的宾语从句，译为 "对……的掌握（或了解）"，"the appropriate processing path" 是句子主干真正的宾语 "how operating conditions will affect properties" 是宾语并列成分。翻译本句，需要添加一些词语。

参考译文：加工条件如何影响材料的缺陷结构，以及缺陷如何影响材料的性能，掌握这些内容可用于确定恰当的加工方式以便获得需要的性能，且可用来判断加工条件对性能的影响。

④ Controlling the number of dislocations in material by forming the object and by heat treatment is an important tool for the control of the properties of the material.

"动词 + ing" 引导的句子是主语从句。"tool" 译为 "方法"，不译为 "工具"。

参考译文：通过加工成型和热处理来控制材料中的位错，是控制材料性能的一种很重要的方法。

Reading Material

Mechanism of Deformation and Diffusion

Mechanism of Deformation

Applying a shear force to a sample can cause a dislocation to move, producing overall deformation. The movement of a dislocation produces a step, one atom high, at the surface or at a grain boundary. If you take a paper clip and bend it back and forth, you can feel a roughness on the surface before it breaks. This is the result of millions of these "steps" coming to the surface. Strengthening a material can be accomplished by placing obstacles in the path of the moving dislocation. A precipitate particle in the matrix, for example, either stops the dislocation completely or forces it to "climb over" which requires energy (it happens more easily at higher temperatures which is why materials "creep" under load at high temperature).

Slip is a process by which a dislocation produces deformation in a material. When a shear force acts along the direction of the Burger's vector, the dislocation can move. The direction of that movement is the slip direction. Slip occurs most easily on densely packed atom planes and in the most densely packed directions.

Surfaces and Grain Boundaries

Atoms at the surface of a crystal are not as strongly held in position because there are no atoms surrounding them. This affects electrical and chemical properties.

Most materials consist of many small crystalline regions, called grains that form independently with different orientations. The surfaces of these grains are the boundaries that form when the growing crystals run into each other. The atomic arrangement is imperfect along these internal surfaces. If two lattices meet at a small angle, the boundary can be considered as an array of edge dislocations.

A large-angle boundary may have local stresses because of the atom mismatch. In any case, it

might seem that such boundaries would weaken material, but in fact, the opposite is true. In a material containing dislocations, the grain boundaries represent places that the dislocations can begin or end and can be consumed or created. A small grain size produces many boundaries, and dislocations can move only a short distance before encountering a boundary. As shown in the detail, reducing the grain size produces increased yield strength.

Atom and Ion Movements in Metals (Diffusion)

Diffusion is the primary method by which atoms "mix" in materials. It can be used to introduce selected atoms into materials. Examples include "doping" of semiconductors with atoms to control conductivity and carburization of steels to harden the surface.

The periodic arrangements of atoms can fill space. In most materials, the vast majority of atoms occupy such ideal surroundings but a very tiny fraction of the atom sites, often less than one in a million, do not. Defects in crystals may be points (e. g. , a vacant site), lines (e. g. , a dislocation), or surfaces (e. g. , a grain boundary).

Even though they account for few of the atom sites, they usually dominate the properties of the macroscopic specimen. By being able to move in the lattice, vacancies produce diffusion, and dislocations produce deformation. Introducing these defects and controlling their number and arrangement provide a powerful tool for the materials engineer to design and create new materials with desirable combinations of properties[①].

Fick's First Law

To calculate D (the diffusion coefficient), you use the equation:

$$D = D_0 \exp \frac{-Q}{RT}$$

where Q, R, T, and D_0 were described in the previous section. It is important to remember that D depends on both D_0 and Q. A species can have a lower Q than another but still have a slower diffusion rate if its D_0 is lower than the other's. These constants can be read from tables or graphs.

Vacancy Diffusion

Vacancy diffusion is the most common method for the motion of atoms within material. Any of the atoms adjacent to a vacant site in the lattice can move into that site with relatively little effort. This leaves a vacancy at its previous location, and the procedure can be repeated. Other bulk diffusion mechanisms in which atoms must swap positions are much more difficult. Imagine a packed lecture hall with every seat filled, and consider how hard it is for people to move around. If a few seats are left empty and people can shift into those seats, motion becomes much easier. Hence, vacancy diffusion is much faster than such swapping methods.

Effects of Structure on Diffusion

The activation energy depends upon the availability of "space" for an atom to move into and the bonding of the atoms. It's harder to move around in a room crowded with football players holding hands than it is to move in a room with the same number of small children each sitting quietly on the floor[②]. In the same way, close-packed structures with strong atomic bonds have very high activation energy. Structural factors affecting diffusion: Materials in column A will generally have a lower acti-

vation energy (Q) than those that fit column B, other things being equal.

(Selected from *Essential of Material Science and Engineering*, Donald R, Askeland, Pradeep P. Phule, 2005)

Questions

1. Describe mechanism of deformation and diffusion.
2. Describe effects of diffusion on structure performance.
3. What is Fick's First Law?

New Words and Expressions

1. deformation *n.* 变形，畸变
2. diffusion *n.* 扩散，传播
3. shear force 切应力
4. boundary *n.* 边界，边界线
5. slip *v.* 滑，滑动，滑接，滑致畸变，滑脱
6. swap *n.* & *v.* 交换，调动
7. periodic *adj.* 周期的，定期的
8. activation energy 活化能
9. yield strength 屈服强度

Notes

① Introducing these defects and controlling their number and arrangement provide a powerful tool for the materials engineer to design and create new materials with desirable combinations of properties.

参考译文：对工程师来说，利用缺陷并控制其数量和排列，对设计和开发新型材料以获得性能的匹配是一个非常有效的方法。

② It's harder to move around in a room crowded with football players holding hands than it is to move in a room with the same number of small children each sitting quietly on the floor.

"it"是一个形式主语，真正的主语是"to"后面的内容。句子应用了比较级"harder... than"。

参考译文：一个房间里挤满了拉着手的足球运动员，一个房间里地板上安静地坐着同样人数的小孩子，前者与后者相比移动的难度更大一些。

2.2 Thermal Equilibrium Diagram

Eutectic Phase Diagrams

Phase diagram is an important tool in the development of materials and processes. Material

properties can be enhanced by the addition of point defects such as substitutional or interstitial atoms in a metal. These additions can inhibit the movement of dislocations thereby increasing the strength. The most commonly used phase diagrams are of the temperature versus composition type for multicomponent systems (at one atmosphere of pressure). These can be divided into two main categories, **equilibrium** and metastable phase diagrams. The equilibrium diagram illustrates the effects of temperature and composition on the phases present in a material under equilibrium conditions, the thermodynamically stable phase. However, in most cases an extremely long period of time is required to achieve thermodynamic equilibrium. Most materials including steel are produced in a state of metastable equilibrium. It may require thousands of years to obtain the stable phases and for most practical purposes the metastable phase is of interest.

The phases present in a multicomponent system will depend on several factors including time, temperature, pressure, composition, chemical potential, electronic structure (bonding) and crystal structure. The composition and amount of each phase can be determined by using the lever rule on a phase diagram. If insufficient time is allowed for the stable or metastable phases to be produced throughout the material the phase diagram can be used to at least determine such things as the first solid to form and the last liquid to solidify①.

A phase diagram is like a map. If the temperature and the amount of added alloy are known, then one can easily find out what phases are present. Note that just like a map, the location tells you the present state of things but not how you got there. The phase diagram is also a "state diagram" that does not depend on history (heating, cooling, changing composition by adding a component, etc.).

As an alloy is cooled, the phase diagram can help us visualize the solidification process. When the temperature reaches the **liquidus line**, the first solids begin to form. We can find the composition by drawing a tie line at the liquidus temperature. As the alloy cools, diffusion must take place. Because of this diffusion, the composition of each phase will follow its respective solidus or liquidus line. To achieve the final equilibrium structure, sufficient time must be permitted in order for diffusion to produce the compositions given by the phase diagram. Changes in the composition of each phase and the process of solidification occurred.

Also during solidification, latent heat of fusion is removed from the solid-liquid interface. This removal of heat produces a cooling curve that displays a change in slope at the solidus and liquidus temperature. In order to obtain this cooling curve, the cooling rate must be extremely slow.

1. Composition and amount (Lever Rule)

The COMPOSITION of each phase present in a two-phase sample is determined from the intersection of the tie line (the horizontal line at the given temperature) with the solidus and liquidus lines. These intersections tell you the percent of alloying element in each phase, solid or liquid. This percentage may be represented in either weight percent or atomic percent. The lever rule will tell you the AMOUNT of solid or liquid in a two-phase region, not its compositions. The tie line can be thought of as a "see-saw" with the original composition of the alloy being the fulcrum. The AMOUNT of any phase is the length of the OPPOSITE END of the see-saw divided by the length of the

entire see-saw.

$$\text{Percent of Phase Present} = \frac{\text{Opposite Arm of See-saw}}{\text{Length of Entire See-saw}} \times 100\%$$

2. Eutectic phase diagrams

The eutectic transformation, $L \rightarrow \alpha + \beta$ is shown by a "downward-pointing V" of lines on the diagram. On cooling, the liquid phase forms a mixture of two solid phases. The example is Pb-Sn (Fig. 2.1).

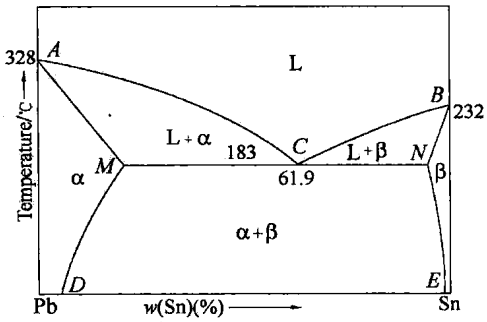


Fig. 2.1 Pb-Sn thermal equilibrium phase diagram

The lead-tin phase diagram includes everyday materials (solders) and contains a simple eutectic, making it a good diagram to explain the four types of microstructures that form in these alloys, depending on their composition.

The first type is alloys that contain less than 19% Sn, the maximum extent of the lead-rich single-phase. These alloys solidify as they cool from the liquid to produce a single solid solution. However, tin and lead have limited solubility, and upon further cooling, the **solvus line** is reached. This line represents the maximum solubility of tin in the lead-rich phase. Once the alloy cools past this line, some tin will precipitate to form a new tin-rich phase. This may take the form of fine particles **dispersed** in the matrix, or in some cases, might be concentrated at the boundaries between grains. ② The same process would occur at the other side of the diagram for alloys containing less than 2% Pb in Sn, forming the tin-rich phase first.

In the lead-tin system, the alloy that contains 61.9% Sn has the **eutectic** composition. When the temperature is above 183℃, the alloy is completely liquid. Upon reaching this temperature, the eutectic reaction begins. During solidification, a thermal arrest, or plateau, will be displayed in the cooling curve. Two solid phases are formed during this reaction: the lead-rich alpha (α) and the tin-rich beta (β). The compositions of these phases are the two endpoints of the eutectic line (19% Sn and 98% Sn, respectively). These two phases will grow in a lamellar, or plate-like, structure. The product of these two phases, together, is called the eutectic microconstituent. This process is called eutectic solidification.

The microstructure controls the strength of a eutectic alloy. The primary, or proeutectic, phase is typically soft and ductile. Many thin lamellae are stronger than a few thick layers. The amount of eutectic microconstituent will also affect the strength of the alloy. The binary system of lead and tin (solder) provides an example of the relationship between microstructure and properties of a eutectic forming alloy.

Eutectoid Phase Diagram

The eutectoid reaction is a solid-state reaction similar to the eutectic but where one solid phase transforms into two solid phases. A good example of this type of reaction is found in the iron-iron

carbide phase diagram (Fe-Fe_3C) (Fig. 2.2). Pure iron forms different crystal structures, depending on the temperature (allotropy). At high temperatures (above 1390℃), iron forms a BCC structure called δ. At lower temperatures, iron forms the FCC structure called austenite or γ. Below 910℃, iron transforms again to the BCC structure called ferrite or α. **Cementite**, Fe_3C, is a **stoichiometric** compound.

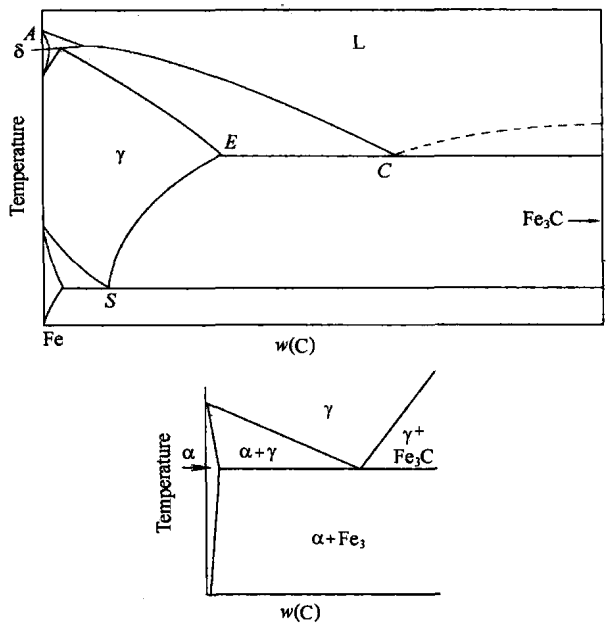


Fig. 2.2 Fe-C thermal equilibrium diagram

By controlling the amount, size and morphology of cementite, we can control the amount of dispersion strengthening. In this system, the alloy containing 0.77% carbon corresponds to the eutectoid composition. By heating this alloy above 727℃ and allowing it to cool slowly, one can observe the eutectoid reaction. The final structure is a lamellar one called **pearlite** containing and Fe_3C. The lamellar structure arises for the same reason as in the eutectic transformation.

Steels that contain more than 0.77% C are called **hypereutectoid**, and steels that contain less than 0.77% C are **hypoeutectoid** (hyper = above, hypo = below).

In hypoeutectoid steels, as the alloy cools, **ferrite**, the primary microconstituent, begins to form at the grain boundaries of the austenite. Ferrite continues to grow until the eutectoid temperature is reached. At the eutectoid temperature the remaining austenite undergoes the eutectoid reaction (note the thermal hold while this takes place) and transforms into pearlite. The final structure contains the continuous proeutectoid microconstituent, ferrite, surrounding islands of pearlite. These steels are ductile because the primary ferrite can be deformed.

Hypereutectoid steels transform in the same way except that cementite is the primary microconstituent. This is a hard, brittle phase, so the mechanical properties of hypereutectoid steels are very different (they are used, for example, in ball bearings).

The lever rule also applies to the eutectoid transformation in the Fe-Fe_3C phase diagram. The

calculation of the amount of each phase is identical. The only differences to keep in mind arise from the fact that the austenite phase is a solid, not a liquid. This means that the nucleation of the alpha and cementite phases generally starts at the grain boundaries (**heterogeneous** nucleation) in the austenite rather than at random (**homogeneous** nucleation), as in a liquid.

(Selected from *Essential of Material Science and Engineering*,
Donald R, Askeland, Pradeep P. Phule, 2005)

Questions

1. Describe purpose of thermal equilibrium diagram.
2. Describe procedure of drawing thermal equilibrium diagram.
3. List several applications of thermal equilibrium diagram.

New Words and Expressions

1. equilibrium *n.* 平衡，均衡
2. liquidus line 液相线
3. Lever Rule 杠杆原理
4. disperse *adj.* 分散的
5. solvus line 固相线
6. eutectic *n.* 共晶；*adj.* 共熔的
7. eutectoid *n.* 类低共熔体；*adj.* 共析的
8. cementite *n.* 渗碳体，碳化铁
9. stoichiometric *adj.* 化学当量的，化学计算的
10. pearlite *n.* 珠光体
11. hypereutectoid *adj.* 过共析的
12. hypoeutectoid *adj.* 亚共析的
13. ferrite *n.* 纯铁体，铁素体，铁氧体
14. heterogeneous *adj.* 非均质的，多相的
15. homogeneous *adj.* 同类的，均相的，均匀的，均质的，均一的

Notes

① If insufficient time is allowed for the stable or metastable phases to be produced throughout the material the phase diagram can be used to at least determine such things as the first solid to form and the last liquid to solidify.

这是一个典型的“if”引导的条件状语从句。

参考译文：如果时间短到不足以形成稳态或亚稳态相，至少可以用相图来作一些判定，比如：判定首先析出的固相和最后固化的液相。

② Once the alloy cools past this line, some tin will precipitate to form a new tin-rich phase. This may take the form of fine particles dispersed in the matrix, or in some cases, might be concen-

trated at the boundaries between grains.

"once" 也是引导状语从句的一个常用的引导词，译为 "一旦"。"this" 代词，指代上句所描述的内容。"might be concentrated..." 的前面省略了其主语 "fine particles"。

参考译文：一旦合金冷却越过固相线，就会有一些 Sn 析出形成新的富 Sn 相。这就会使得基体中弥散一些细小颗粒，或者，在大多数情况下，这些细小颗粒会在晶界上析出聚集。

Reading Material

Phase and Solubility

A phase is identified by its chemical composition and microstructure. A phase must be homogeneous in its crystal structure and atomic arrangement. A phase must have the same physical and chemical properties throughout. A phase must also have a definite interface between its surroundings and must be mechanically separable. Only if all these conditions are met does a single phase exist.

The definition does not mean that only pure elements can qualify as phases. Compounds can also have phases. Water (H_2O) is a classic example. When you fix a glass of ice water, there are two phases present: ice and water. These have the same chemical composition but different atom arrangements. Likewise, two solids may have the same atom arrangement but different compositions (many different metals have the FCC structure, and many ceramics have the NaCl structure).

Solid solutions are a very important part of materials science. By intentionally introducing solid substitutional atoms into an existing lattice, we can control the properties of the new alloy①. We will see that this includes not only mechanical properties (stiffness, strength, failure behavior) but also electrical, optical, magnetic, environmental, and other behavior. In a solid solution, some atoms of the solute replace those of the solvent in the solvent's normal lattice structure. They are randomly distributed among the lattice sites. If the alloy contains 10% A in B, then at each lattice site there is a 10% probability that we will find A. Ideally, this should not depend on what is at any other lattice site, but in reality, the distortion of the lattice around each A atom makes it either more or less likely to find other A atoms nearby.

For two substances to have unlimited solubility, any amount of either substance must be able to dissolve completely into any amount of the other substance. A common application of unlimited solubility is alcohol and water. In this example it is very important to remember that after the solution is thoroughly mixed, only one phase is produced.

Copper and nickel are good examples of metals that display unlimited solubility. A solid solution of Cu and Ni forms only one solid phase below the individual melting points of each metal. However, at temperatures between their melting points, both a solid and a liquid phase will coexist. The solid phase in this temperature range is still the same phase as the solid below the melting points.

For limited solubility, only a certain amount of one substance may completely dissolve into the other substance②. If this level of solubility is surpassed one of the original components will remain. At this time, two phases exist: the solution and the excess substance that was unable to mix. A simple example is sugar and water. Sugar will dissolve in water but only to a certain point (which de-

pends on temperature). After this point, the excess sugar will sink to the bottom of the container. Many materials behave this way. Copper and zinc are two metals that display limited solubility.

(Selected from *Essential of Material Science and Engineering*, Donald R, Askeland, Pradeep P. Phule, 2005)

Questions

1. What is the phase?
2. How did solid solutions affect the properties of the materials?

New Words and Expressions

1. compound *n.* 化合物，混合物；*adj.* 复合的；*v.* 混合，配合
2. stiffness *n.* 刚度，劲度
3. solvent *n.* 溶剂，基本成分
4. likewise *adv.* 同样地，照样地

Notes

① By intentionally introducing solid substitutional atoms into an existing lattice, we can control the properties of the new alloy.

参考译文：我们有意将置换原子引入到现有的晶格中来控制新合金的性能。

② For limited solubility, only a certain amount of one substance may completely dissolve into the other substance.

参考译文：有限固溶是指只有一定量的某种物质能完全溶解到另一种物质中。

2.3 Casting

The casting processes are used to produce the final form of some primary products. They may be further processed by machining or by welding, but these processes produce relatively minor modifications of the form of the part. Some castings may not be further processed at all; they are used as cast.

All the casting processes include the steps of melting the metal in the desired composition, preparing the pattern and using it to produce a mold, pouring the metal into the mold, letting it cool down and solidify, and conditioning the casting mechanically by removing the sprue, runners, gates, and other auxiliary parts[①], and otherwise improving the surface. If required, the casting is heat treated. There are several different casting processes that are classified according to the material and structure of the mold, which is mainly either expendable or permanent. The choice of the process depends on the size and material of the part, the accuracy and surface finish required, and very strongly on the quantity of parts to be made.

We will concentrate on the industrial casting processes in the production of machinery. A great

variety of metals are cast: gray iron, malleable and ductile iron, steel, aluminum alloys, zinc alloys, brasses, bronzes, and many others.

In pure metals and in eutectics a plane solidification front propagates away from the walls of the mold, which is where the heat is extracted (Fig. 2.3a). Close to the wall, where the cooling is fast, a layer of fine, equiaxial grains is produced. Further away from the wall long, columnar grains grow into the melt. Very little porosity is obtained and as a result of shrinkage of the material as it changes from liquid to solid and as the solid cools down, a rather deep depression called a pipe is generated at the top of material that has been poured into an open mold. In closed molds it is necessary to ensure a steady supply of molten metal from cavities additional to the functional mold, called risers, to ensure complete filling of the mold. Furthermore, the mold must be designed so as to ensure that freezing starts at walls and in cavities farthest from the inlet of the molten material, called the gate, and propagates towards the gate.

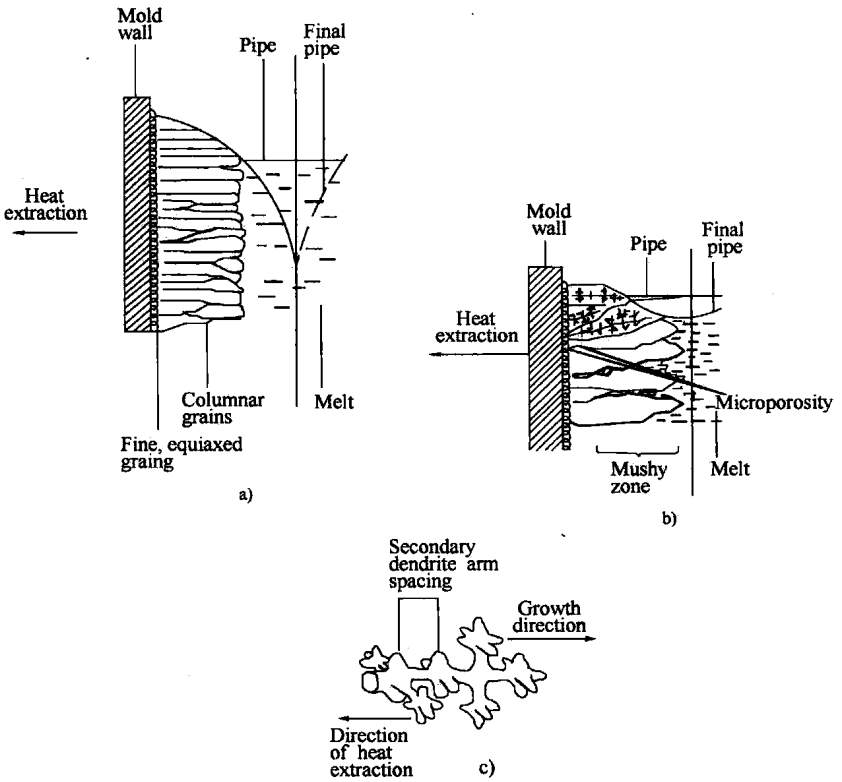


Fig. 2.3 Solid structures in a) columnar grains in eutectics, b) dendrites in non-eutectic solid solutions, c) shows the dendritic structure growing in crstallographically favorable directions.

In noneutectic solid solutions with their wide range of solidification temperatures and the variations of the composition in the crystals throughout the solidification process there is also a fine-grain layer at the wall of the mold (Fig. 2.3b), but farther away, the grains grow in the form of dendrites that resemble trees with branches[2] (Fig. 2.3c). These forms are initially weak, and they can be broken by agitation to result in fine grains. As the dendrites interweave, they lock in place and the

spaces between the arms may be starved of fluid due to local shrinkage. This results in microporosity, which is harmful to the toughness of the casting. The pipe in this case is much smaller due to the distributed shrinkage.

The properties of the cast, metal may also be improved by treatments applied after casting. One of them is called high-temperature isostatic pressing (HIP), in which a neutral gas such as argon is used to pressurize the casting. Pressures up to 200MPa and temperatures up to 2,000℃ are possible. The process is applied to superalloy and titanium castings. It eliminates porosity and improves toughness and fatigue strength. Other methods involve various kinds of heat treatment. Steel and iron castings may be quenched and tempered, and aluminum and titanium castings may be subjected to solid-solution or precipitation-hardening treatments. Annealing is often applied to various metals with the purpose of homogenizing the micro—and macro—segregation. Stress-relief heat treatment is also rather common.

Steel castings are used in a great variety of applications: in the transportation industries for parts of railway cars, highway trucks, and ships; in the mining industry for large excavators, shovels, ball mills, and crushers; in the construction industry as parts of road-building machinery; in agricultural machines; in power generation for the housings of turbines and for valve bodies; in steel plants for charging machines, rolls for rolling mills, and frames of rolling-mill stands. Some of the steel castings are very large. Several examples are shown here in impressive photographs. A railroad freight car contains steel castings as the coupler, the stricker, truck side frame, and bolster.

(Selected from *Manufacturing processes and equipment*, Jiri Tlusty, 2000)

Questions

1. Describe the solidification process during casting.
2. What advantage does steel castings show?
3. List several applications of steel casting.

New Words and Expressions

1. pattern *n.* 样本，样品，格式，形式；款式，图案，图形；模子，模具
2. mold *n.* 模子，模，模盘，印模
3. sprue *n.* 铸口，注料口，流道，直浇道
4. runner *n.* 流道，横浇道
5. gate *n.* 内浇道，浇口
6. auxiliary *adj.* 辅助的，次要的，从属的
7. malleable *adj.* 可锻的
8. equiaxial *adj.* 等轴的
9. riser *n.* 冒口，气口，气门，升降器
10. cavity *n.* 空洞，空腔，空穴，模槽
11. inlet *n.* 供料口，进料口，嵌入

12. isostatic pressing　等静压

Notes

① All the casting processes include the steps of melting the metal in the desired composition, preparing the pattern and using it to produce a mold, pouring the metal into the mold, letting it cool down and solidify, and conditioning the casting mechanically by removing the sprue, runners, gates, and other auxiliary parts,...

此长句是一个典型的动作连贯性句子，动作一律采用-ing形式，表明了铸造的基本全过程。“condition”本意是“条件”，在此作动词用，译为“处理”。

参考译文：所有的铸造都是由下面的步骤组成：以需要的成分熔化金属，准备图形，并利用其制作模子，将熔化金属倒入模子，让其冷却并凝固，然后利用机械方法除去浇道口及一些辅助部分，……

② In noneutectic solid solutions with their wide range of solidification temperatures and the variations of the composition in the crystals throughout the solidification process there is also a fine-grain layer at the wall of the mold, but farther away, the grains grow in the form of dendrites that resemble trees with branches.

“with”引导原因状语，也指发生的条件。“and”连接两个并列的原因。

参考译文：非共晶固溶体有宽的固化温度范围，且固化过程中晶体的成分在发生变化，所以在模壁上形成细晶层，但是离模壁远的地方，晶粒以枝状形式增长，形状与分叉的树很相像。

Reading Material

Welding

Welding is a metal joining process that involves local melting. The blacksmith heats the metal until the surface is just at the melting temperature, adds some borax to remove any oxide, and then hammers the pieces together. More localized melting methods use electrical current (spot or **arc welding**) or flames (oxy-acetylene or plasma welding) and may add additional metal that is melted and deposited in the joint (mixing to some degree with the base metal). When metal is added it can be much higher in alloy content than the base metal to achieve strength without subsequent heat treatment. Inert gases such as helium or argon are often used to prevent oxidation.

Problems in welding arise not in the weld metal, but typically in the base metal adjacent to the weld (the “heat affected zone”, as shown in Fig. 2.4) where the heat from the welding operation can cause any of several problems that produce undesirable microstructure and properties①. Excessive grain growth makes the material weak while formation of martensite may make it brittle. Careful control of the amount of heat energy used in welding is required to avoid catastrophic failures.

Arc welding is the most important of all the welding processes. It is used universally in all kinds of mechanical manufacturing from ship-building to car production, in the structures of machine tools, in agricultural and textile machinery, and so on. It is also important outside of machine

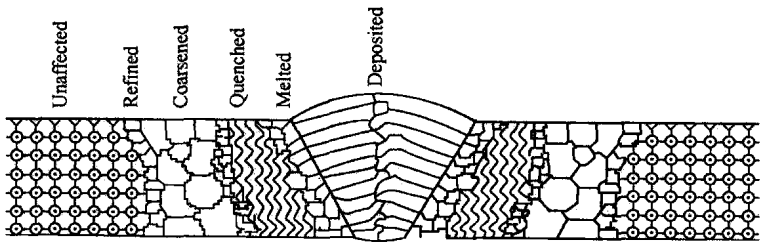


Fig. 2.4 Beat affected zone of the welding material

shops, in building construction and in pipeline construction, for example. We will discuss different arc welding processes mentioned in the introduction to this chapter. Each of them is best in particular applications, depending on the **base material**, the size and type of weld, the **accessibility** of the weld, and the requirements for mechanization and automation.

In all of them the source of the welding energy is the electric arc, which is produced between an electrode and the work (base). The arc is an electric discharge through a column of ionized gas, the plasma. The temperature in the arc is very high, between 5,000 and 30,000 K. The arc is maintained at voltages between the terminals of 15-40 V, and it carries currents commonly in the range of 50-500 A, although currents as low as 0.3 to 10 A are encountered in plasma arc welding of thin-gage metals, and currents as high as 1,600 A are used in submerged arc welding. The arc travels along the **weld seam**, melting the base metal and usually also the **filler metal**. The filler metal is provided either by melting the electrode, which has the form of a metallic rod or wire called a **consumable electrode**, or by being fed separately into the arc in processes using a nonconsumable electrode made of tungsten. In all the processes the arc and the **puddle** of the molten metal must be shielded against oxidation and against other kinds of contamination from the atmosphere.

The various processes differ in the way the shielding is provided. They further differ in the characteristics of the electric power supply. This may deliver DC, AC, or "pulsed" currents; it may have "constant-voltage" or "constant-current" characteristics and may be connected with the electrode negative (EN, also called "straight" polarity) or with the electrode positive (EP, also called "reversed" polarity). The type of material, type of shielding, and type of current influence the ways in which metal is **transferred** from the electrode to the base; therefore, a particular process may be more or less suitable for welding in the more difficult positions. The flat position is the easiest one, and any of the processes can be used. The overhead position is most difficult because the metal is transferred against gravity. Only some of the processes are suitable in this case, and even with these processes, much lower metal deposition rates are obtainable than in the flat, horizontal, and vertical positions, respectively.

The first process, illustrated in Fig. 2.5, is **shielded metal arc welding (SMAW)**. Metallic electrodes in the form of rods are used that are covered by a layer of **flux**. The arc is generated between the lower end of the electrode and the work. The consumable electrode melts away and is transferred to the weld. The heat of the arc converts the covering to gas and molten slag. The gas

shields the arc, and the slag shields the molten metal as it solidifies. The upper end of the electrode is bare and it is clamped in a holder through which runs the end of the cable from the power supply. The material of the core of the electrode is similar to the material of the base metal. The coverings exist in a variety of compositions which affect the chemistry of the weld and the stability of the arc.

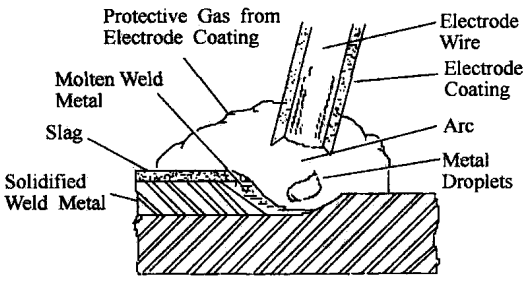


Fig. 2.5 Shielded metal arc welding. The coating of the metal stick electrode provides gas for shielding of the arc as well as protective slag over the molten metal poor.

In the **gas metal arc welding** (**GMAW**) process (Fig. 2.6), the electrode is in the form of wire that is continuously fed into the arc. Current is brought in through the contact tube in the wire guide in the torch. Shielding of both the arc and the molten metal is provided by an externally supplied gas. Depending on application, either the inert gases argon or helium are used, or carbon dioxide. The equipment is more complex than for SMAW because of the gas supply line and wire-supply components, but the process is **amenable** to mechanization and automation. The equipment then also includes machinery to guide the torch along the desired path. This may be a rail and carriage for simpler straight-line motions. For complex motions, it is common to use robots.

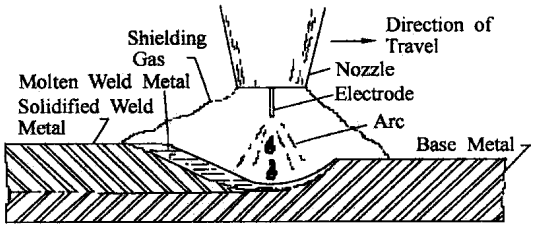


Fig. 2.6 Gas metal arc welding. Shielding of arc and weldpool is provided by the gas. The electrode is thin wire.

The GMAW process uses mostly a DC power source with EP polarity and the "constant-voltage" characteristic. As explained later, this is the basis for self-regulation of the process in which the burn-off rate adjusts itself automatically to any change in the wire feed rate. This aspect is very important for successful automation of the operation. The GMAW process is utilized in high-production welding operations. All commercially significant metals can be welded in all positions by choosing the appropriate parameters and conditions for the process.

The next process is **flux cored arc welding** (**FCAW**). It differs from the GMAW process in that the consumable, continuously fed electrode is **tubular** and contains a flux core that provides the shielding medium. This may or not be assisted by an additional gas shield. The FCAW process is used for welding carbon and low-alloy steels, stainless steels, and cast irons. Essentially, the FCAW process is a combination of the SMAW process, with the electrode wire and coating turned inside out, and the GMAW process.

The next two processes, **gas tungsten arc welding** (**GTAW**) and **plasma arc welding** (**PAW**), use nonconsumable electrodes, which may thus be used in situations where no filler metal is required. However, in most instances filler metal is added from a rod or wire fed into the arc. This permits better control of the ratio of added metal to melted base metal than with the processes u-

sing consumable electrodes. The weld quality is high because there is no slag, as in SMAW, which might be entrapped in the weld, and no filler metal is transferred across the arc as in GMAW, which could cause spatter. In the GTAW process the arc is generated between a tungsten electrode and the base, and inert gas is supplied through the torch to shield the arc and the molten metal②. This process can be used to weld almost any metal, but it is the preferred process in the aerospace industry for welding stainless steel, titanium alloys, nickel alloys, and aluminum alloys. It can be used in all positions. However, it is rather slow and not good for thick sections, because deposition rates are low. In the PAW process the intensity of the heat input is effectively increased by constricting the arc in a water-cooled copper orifice. Shielding is obtained primarily from the hot ionized gas issuing from the orifice. There is also an outer shielding gas supply to protect the weld. This arrangement, in which the nonconsumable tungsten electrode is recessed inside the orifice, leads to a very high directional stability of the arc and its insensitivity to variations in the tool standoff distance. The applications are of two kinds. The first one is low-current PAW, which is suitable for welding very thin sheet metal or welding small components. The second one is high-current PAW, which offers better penetration due to the higher heat intensity, and permits higher welding speeds than GTAW. However, the equipment is more expensive because of the need of a cooling water supply for the orifice and also because of the double inert gas supply lines. Because of the high heat intensity, this process is also used for thermal cutting.

The last process considered is **submerged arc welding (SAW)**. A **bare wire** electrode is mechanically fed into the arc, as in GMAW, but shielding is provided from granular flux that covers the welding arc. This flux is supplied through a feeding tube located in front of the arc. The unmelted flux acts as an air shield, a heat insulator, and a radiation shield. The molten flux provides slag covering the molten metal, and the vaporized flux provides the plasma for the arc. Very high currents are possible, and they result in very high deposition rates. The process has to be mechanized because the arc is not visible; it has to include automatic control of the wire feed rate, and it is limited to flat and horizontal welding. It is used for carbon and alloy steels and for nickel alloys.

(Selected from ① *Manufacturing processes and equipment*, Jiri Tlusty, 2000; ② *Essential of Material Science and Engineering*, Donald R, Askeland, Pradeep P. Phule, 2005)

Questions

1. Describe the solidification process during casting.
2. What advantage does steel castings show?
3. List several applications of steel casting.

New Words and Expressions

1. arc welding 电弧焊，弧焊
2. base material 基体金属，母材，母体金属

3. accessibility *n.* 可及性，可达性，可接近性，可亲性，渗入性
4. weld seam 焊缝
5. filler metal 填充金属，填料金属
6. consumable electrode 熔化电极，自耗电极
7. puddle *n.* 熔池
8. transfer *v.* 过渡，传递，转换
9. shielded metal arc welding (SMAW) 焊条电弧焊
10. gas metal arc welding (GMAW) 气体保护电弧焊
11. flux *n.* 焊剂，熔剂
12. amenable *adj.* 顺从的，符合的
13. flux cored arc welding (FCAW) 药芯焊丝电弧焊
14. tubular *adj.* 管状的
15. gas tungsten arc welding (GTAW) 钨极惰性气体保护焊
16. plasma arc welding (PAW) 等离子弧焊
17. submerged arc welding (SAW) 埋弧焊
18. bare wire 光焊丝，裸焊丝，裸线

Notes

① Problems in welding arise not in the weld metal, but typically in the base metal adjacent to the weld where the heat from the welding operation can cause any of several problems that produce undesirable microstructure and properties.

参考译文：焊接中存在的问题一般不在焊接金属上，而在基体金属焊接衔接处，在此处，焊接产生的热能引起一些其他问题，出现不希望出现的结构和性能。

② In the GTAW process the arc is generated between a tungsten electrode and the base, and inert gas is supplied through the torch to shield the arc and the molten metal.

参考译文：在钨极惰性气体保护焊中，电弧在钨极和基体之间产生，惰性气体保护电弧和熔融金属。

2.4 Nonferrous Alloy

This chapter presents a very superficial summary of some of the kinds of metal alloys other than irons and steels that are available for engineering use. It is more of an indication of the range of properties available than a selection guide. For each alloy type, a brief listing of a few key points is given. Note that many of the characteristics of the alloys can be predicted from the crystal structure and that the various alloying elements produce results that can be predicted from the phase diagrams.

Non-ferrous alloys include relatively common materials like aluminum and titanium, copper alloys (such as brass and bronze), and lead-tin alloys (such as solder and pewter). There are also many less common ones based on metals with much higher costs and special properties such as beryl-

lium, magnesium, tungsten, uranium, etc[①]. Many of these special alloys are very lightweight, and hence, of interest in aircraft construction. Others have good corrosion resistance in particular environments. Some, such as gold, silver and platinum, have special value because of their scarcity and decorative properties.

Aluminum Alloys

- Refined by electrolytic reduction of aluminum oxide (requires large amounts of electricity), but relatively inexpensive. Widely used in technical and consumer applications. Easily recycled.
- Easily formed (e. g., beverage cans), good electrical conductivity (used in high-voltage transmission wires) and lightweight (2.7vs. 7.9g/cm^3 for steel).
- Typically strengthened by solid solution alloying, precipitation hardening, or cold working. Aluminum is FCC, and hence, it has good ductility and work-hardens well.
- Typical alloying elements are:
  - — Boron or titanium to control grain size
  - — Copper, zinc, or magnesium for precipitation hardening
  - — Silicon for solid solution strengthening or precipitation hardening Lithium to reduce density and for age hardening
- Oxidation produces an adherent coating that prevents further oxidation and protects the metal in many environments (unlike steels which rust because the iron oxide coating is porous and flakes off).

Magnesium Alloys

- Magnesium is electrolytically extracted from magnesium chloride in seawater.
- Very low density, but poorer corrosion resistance, strength, ductility (because it has an HCP structure with few slip planes), modulus of elasticity, and fatigue resistance as compared to aluminum. Also, magnesium can burn in air at high temperatures.
- Does not strain-harden well (because of the HCP structure), but precipitation hardening with Zr, Th, Ag, or Ce is possible.
- Magnesium-aluminum or magnesium-lithium alloys are used for light-weight structures.
- Dispersion strengthening with oxide particles or fibers introduced into the molten metal is also used (Metal Matrix Composite, MMC).

Copper Alloys

- Some native copper exists and was used by early humans, but now copper is refined from oxide and sulfide ores by a variety of methods.
- Good ductility (because of the FCC structure) and corrosion resistance, but generally poor strength. Copper work-hardens well (again, due to the FCC structure), as in drawing wire.
- Copper-zinc alloys (brass) and copper-tin alloys (bronze) are solid solution strengthened and among the earliest alloy metals used by humans.

- Zirconium, chromium, and beryllium produce precipitation hardening in Cu.
- Lead is added to copper alloys to produce tiny lead spheres (molten Pb and Cu are insoluble, forming a monotectic) that improve machinability.
- Copper-aluminum alloys (called aluminum bronzes) produce eutectoid structures and martensitic transformations with a rich variety of microstructures and properties.
- High purity copper has very good electrical conductivity (only silver and gold are better).

Nickel Alloys

- Good high-temperature strength (e. g., turbine blades).
- Good formability (FCC structure produces good ductility).
- Nickel-copper alloys (Monel) are corrosion resistant in salt water.
- Aluminum and titanium additions produce age hardening.
- Nickel-titanium alloys have a martensitic transformation that can cause dimensional changes.
- Nickel-iron-cobalt alloys have even better high-temperature creep resistance than straight nickel.
- Alloys can also be strengthened by the formation of many different types of metal carbide particles.

Titanium Alloys

- Excellent corrosion resistance (including salt water).
- High strength and moderate density.
- Used in airframe and jet engine components, and in submarines (titanium is non-magnetic and therefore harder to detect than steels).
- Poor ductility (HCP structure and few slip planes).
- Tin and zirconium additions produce solid solution strengthening.
- Alloying with manganese, chromium, and iron produces phase diagrams with eutectoid transformations (two-phase structures) and martensitic transformations from the high-temperature BCC structure.
- Rich possibilities for microstructure control through alloying and heat treatment.

(Selected from *Essential of Material Science and Engineering*,
D. R. Askeland and P. P. Phule, 2005)

Questions

1. Describe the performance of aluminum alloys.
2. Describe the performance of nickel alloys.
3. Describe the performance of copper alloys.

New Words and Expressions

1. nonferrous alloy 有色合金

2. brass *n.* 黄铜；黄铜色；铜器；铜管乐器
3. bronze *n.* 青铜（铜和锡的合金），青铜制品；青铜色；青铜色的颜料；青铜器
4. solder *n.* 锡，钎料
5. pewter *n.* 铅锡锑合金
6. scarcity *adj.* 稀缺
7. magnesium *n.* 镁
8. martensitic *adj.* 马氏体的

Notes

① There are also many less common ones based on metals with much higher costs and special properties such as beryllium, magnesium, tungsten, uranium, etc.

参考译文：还有一些不太常见的金属合金，其成本要高很多，且具有特殊的性能，这些金属如铍、镁、钨、铀等。

Reading Material

Corrosion

Electrochemical Corrosion

Electrochemical corrosion occurs when metal atoms lose electrons (oxidation reaction) in an aqueous medium. An electrical circuit is formed between two different metals in which corrosion occurs at the anode. Electrons travel to the cathode. In pure water they produce hydrogen bubbles. If the solution contains dissolved oxygen (O_2), this reacts with the electrons to produce OH ions that in turn, react with the metallic ions, for instance, to produce the familiar rusting of iron in water①. In a low-pH solution containing H + ions the cathode reaction simply produces more water molecules and the only visible evidence of corrosion is the loss of metal from the anode.

Microstructural Effects on Corrosion

Structure and microstructure both determine how electrochemical corrosion proceeds. At the microstructural level many metals contain several phases, such as the pearlite in lamellae in steels. These have different emf values, so one will be attacked (this is how microstructures are etched for microscopy). Many stainless steels form chromium carbides at grain boundaries which reduce the chromium concentration there relative to the interior of grains. This composition difference makes the boundary regions anodic. Grain boundaries are usually anodic anyway because of the higher dislocation density there. Etching of grain boundaries is also used for microscopic examination. Higher dislocation density can also be produced by deformation and the regions that are deformed will act as anodes.

Coatings

In any pair of metals the more anodic one will be the anode and suffer electrochemical corrosion. This is why a block of zinc attached to a boat hull protects the brass fittings from corrosion (by being sacrificed itself) and why galvanized (zinc) coating on steel guardrails and garbage cans pre-

vents rusting. Note, however, that tinplate (tin coating on steel) does not provide electrochemical protection, so a pinhole in the coating on a "tin" can allows the metal to be attacked (the coating's main purpose is to allow the metal to be joined by soldering rather than to prevent corrosion).

Oxidation

Oxidation of metals can be either a problem or a means of protection. Some metals oxidize more readily than others (e. g. , magnesium oxide has a much higher free energy of formation [more negative] than copper oxide, but it can be taken as a given that when exposed to a normal atmosphere all metals will form some surface oxide in a very short time. The key to the behavior of the metal is whether the oxide that does form creates a continuous, adherent, nonporous protective layer that prevents further oxidation or creates other corrosive attack on the metal[②].

Polymer Degradation

Many pólymer materials are quite resistant to corrosion and are used as protective coatings on metals. Different thermoplastics and thermosetting polymers behave differently in different environments. Elastomers are also degraded by different environments.

When polymers are exposed to liquids, they may swell (becoming softer and more ductile) or dissolve. This process is accelerated by temperature. Rupturing bonds (called scission) within the chains by chemical attack (e. g. , ozone), heat, or ultraviolet light reduces molecular weight and strength. Removal of side groups from chains also reduces strength and may produce undesired by-products (e. g. , removing the chlorine from PVC produces HCl). In some cases radiation (light or x-rays) can cause ionization leading to cross-linking, reducing ductility.

The intentional degradation of "biodegradable" plastics is often based on breaking down starch fillers rather than attacking the actual polymer molecules.

(Selected from *Essential of Material Science and Engineering*,
Donald R, Askeland, Pradeep P. Phule, 2005)

Questions

1. Describe the importance of corrosion.
2. List several types of local corrosion.
3. Describe mechanism of Polymer Degradation.

New Words and Expressions

1. electrochemical corrosion 电化学腐蚀
2. rust *n.* 铁锈，锈
3. pearlite *n.* 珠光体
4. lamella *n.* 薄层，薄片，薄片层
5. grain boundary 晶界，晶粒边界，晶粒间界
6. sacrifice *n.* & *v.* 牺牲
7. galvanized *adj.* 电镀的，镀锌的

8. guardrail *n.* 扶栏
9. garbage can 垃圾桶，垃圾箱
10. tinplate *n.* 白铁皮，镀锡铁皮
11. degradation *n.* 退化，裂化，降解，降解作用，剥蚀

Notes

① If the solution contains dissolved oxygen, this reacts with the electrons to produce OH ions that in turn, react with the metallic ions, for instance, to produce the familiar rusting of iron in water.

参考译文：如果溶液中有溶解氧，会与电子反应生成氢氧根离子，反过来，氢氧根离子又会和金属离子反应，比如，生成常见的铁锈。

② The key to the behavior of the metal is whether the oxide that does form creates a continuous, nonporous protective layer that prevents further oxidation or creates other corrosive attack on the metal.

参考译文：金属反应的关键是：氧化产生的一层连续的无孔的保护层，是能阻止进一步氧化，还是在金属上产生腐蚀裂纹。

科技英语翻译技巧（二）：数 词

英语科技文献中离不开数量。数量在科技论文中有多种表示方法，在翻译时要特别注意英汉两种语言表达方式的不同。

1. 数量相同

由“as + 形容词（或者副词）原级 + as”构成“相同程度”比较句，例如：

These methods will reduce machining cost, which can be as much as 50% of the total manufacturing cost.

这些方法能够使得机加工成本降低到总成本的 1/2。

Particle reinforced metals (PRMs) commonly contain below 25 vol. % ceramic reinforcement when used for structural applications, but can have as much as 80 vol. % ceramic when used for electronic packaging.

颗粒增强金属复合材料当用于结构件时含有的陶瓷增强体的体积低于 25%，当用于电子组装时，添加陶瓷的体积高达 80%。

Engineers designing a hypersonic-speed transport will have to develop new high-temperature advanced materials to be able to withstand temperatures as high as 1800℃

工程师设计超声速运输机时必须开发新型先进材料，这种材料需要能够承受的温度高达 1800℃。

2. 倍数的增加

（1）“n + times + as + 形容词（或者副词）原级 + as”（A 是 B 的 n 倍）。

This railway is three times as long as that one.

这条铁路的长度是那条铁路的 3 倍。

Most quenching is done in either water or oil. Water gives a quenching rate about three times as fast as that of oil.

大部分淬火在水中或油中进行。水淬的速率是油淬的 3 倍。

Argon is approximately one and one-third times as heavy as air and ten times as heavy as helium.

氩气的密度是空气的 4/3 倍，是氦气的 10 倍。

（2）“n + times + 形容词（或副词）比较级 + than”（A 比 B 大、长、重、……$n-1$ 倍，或 A 是 B 的 n 倍）。

Generally speaking, fibers are at least 100 times longer than they are wide.

通常来说，纤维的长度至少是宽度的 100 倍。

This machine is five times heavier than that one.

这台机器比那台机器重 4 倍。

（3）“n + times + 名词（尺寸、长度、重量、体积等）或者代词 that”（A 是 B 的 n 倍，或 A 比 B 大、长、重、……$n-1$ 倍）。

For soft materials, the thickness of the test piece should be at least 15 times the depth of the indentation, while for hard materials the thickens should be at least 7 times the depth of the indenta-

tion.

对软材料而言，样品的厚度至少是压痕深度的 15 倍；而对于硬材料而言，样品的厚度应该至少是压痕深度的 7 倍。

To get the same equivalent shielding effectiveness, the flow of helium will have to be two to three times that of argon.

为了得到相同的保护效果，需要的氦气的流量是氩气的 2 ~ 3 倍。

(4) "n + fold increase" 或者 "increase 类动词 + 倍数" (增加 $n-1$ 倍，或者增加到 n 倍)。

Magnetic nanocomposites with 5-10 fold increases in magnetocaloric effects should be used to develop magnetic refrigerators that operate at room temperature.

磁性纳米复合材料的磁致热效应能增加 5 ~ 10 倍，可以用来开发在室温下运转的磁性电冰箱。

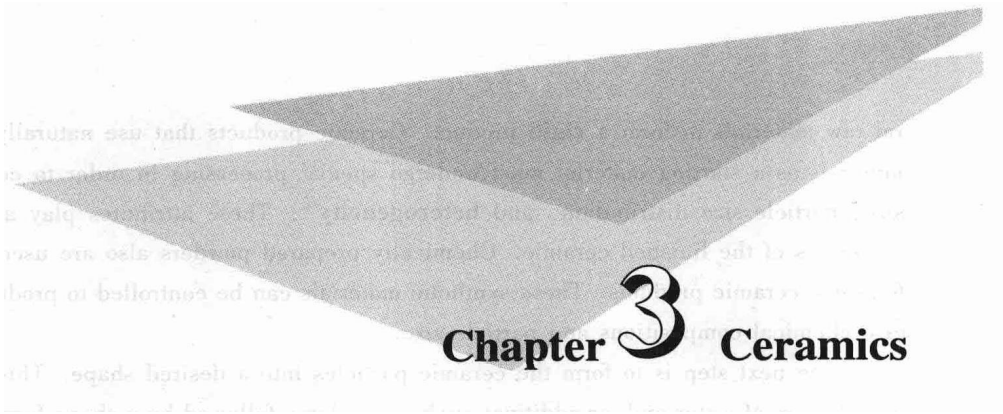
As a result of the newly adopted process, our output has increased by 50%.

由于采用新的生产方法，我们的产量已经增长了 50%。

3. 倍数的减少

Surprisingly, the density of packing is only reduced to 68% so that the BCC structure is nearly as densely packed as the FCC and HCP structure.

奇怪的是，堆积的密度只降低了 32%，就可以使得 BCC 的结构排列像 FCC 和 HCP 一样紧密。



Chapter 3 Ceramics

3.1 Introduction to Ceramics (I)

What Is a Ceramic?

Ceramics are classified as inorganic and nonmetallic materials that are essential to our daily lifestyle. Ceramic and materials engineers are the people who design the processes in which these products can be made, create new types of ceramic products, and find different uses for ceramic products in everyday life.

Ceramics are all around us. This category of materials includes things like tile, bricks, plates, glass, and toilets. Ceramics can be found in products like watches (**quartz tuning forks**—the time keeping devices in watches), **snow skies** (**piezoelectric**—ceramics that stress when a voltage is applied to them), automobiles (**sparkplugs** and ceramic engine parts found in racecars), and phone lines. They can also be found on **space shuttles**, **appliances** (**enamel coatings**), and airplanes (nose **cones**). Depending on their method of formation, ceramics can be dense or lightweight. Typically, they will demonstrate excellent strength and hardness properties; however, they are often **brittle** in nature. Ceramics can also be formed to serve as electrically conductive materials, objects allowing electricity to pass through their mass, or **insulators**, materials preventing the flow of electricity. Some ceramics, like **superconductors**, also display magnetic properties.

Ceramics are generally made by taking mixtures of **clay**, **earthen elements**, powders, and water and shaping them into desired forms. Once the ceramic has been shaped, it is fired in a high temperature oven known as a **kiln**. Often, ceramics are covered in **decorative**, **waterproof**, paint-like substances known as **glazes**.

Ceramic Processing

Ceramic processing is used to produce commercial products that are very **diverse** in size, shape, detail, complexity, and material composition, structure, and cost. The purpose of ceramics processing to an applied science is the natural result of an increasing ability to **refine**, develop, and characterize ceramic materials.

Ceramics are typically produced by the application of heat upon processed clays and other natu-

ral raw materials to form a **rigid** product. Ceramic products that use naturally occurring rocks and minerals as a starting material must undergo special processing in order to control purity, particle size, particle size distribution, and **heterogeneity**①. These attributes play a big role in the final properties of the finished ceramic. Chemically prepared powders also are used as starting materials for some ceramic products. These synthetic materials can be controlled to produce powders with precise chemical compositions and particle size.

The next step is to form the ceramic particles into a desired shape. This is **accomplished** by the addition of water and/or additives such as binders, followed by a shape forming process. Some of the most common forming methods for ceramics include **extrusion**, **slip casting**, **pressing**, **tape casting** and **injection molding**. After the particles are formed, these "green" ceramics undergo a heat-treatment (called firing or sintering) to produce a rigid, finished product. Some ceramic products such as electrical insulators, **dinnerware** and tile may then undergo a glazing process. Some ceramics for advanced applications may undergo a machining and/or polishing step in order meet specific engineering design criteria.

Ceramic Properties

The properties of ceramic materials, like all materials, are **dictated** by the types of atoms present, the types of bonding between the atoms, and the way the atoms are packed together. This is known as the atomic scale structure. Most ceramics are made up of two or more elements. This is called a compound. For example, alumina (Al_2O_3), is a **compound** made up of aluminum atoms and oxygen atoms.

The atoms in ceramic materials are held together by a chemical bond. The two most common **chemical bonds** for ceramic materials are covalent and ionic. For metals, the chemical bond is called the **metallic bond**. The bonding of atoms together is much stronger in **covalent** and **ionic** bonding than in metallic. That is why, generally speaking, metals are **ductile** and ceramics are brittle. Due to ceramic materials wide range of properties, they are used for a **multitude** of applications. In general, most ceramics are:

- hard,
- **wear-resistant**,
- brittle,
- **refractory**,
- thermal insulators,
- electrical insulators,
- **nonmagnetic**,
- oxidation resistant,
- **prone** to thermal shock, and
- chemically stable.

Ceramic History

Archeologists have uncovered human-made ceramics that date back to at least 24,000 BC.

These ceramics were found in **Czechoslovakia** and were in the form of animal and human figurines, **slabs**, and balls. These ceramics were made of animal fat and bone mixed with bone ash and a fine claylike material. After forming, the ceramics were fired at temperatures between 500-800℃ in **domed** and horseshoe shaped kilns partially dug into the ground with **loess** walls. While it is not clear what these ceramics were used for, it is not thought to have been a **utilitarian** one. The first use of **functional** pottery vessels is thought to be in 9,000 BC. These **vessels** were most likely used to hold and **store** grain and other foods.

It is thought that ancient glass manufacture is closely related to **pottery** making, which **flourished** in Upper Egypt about 8,000 BC. While firing pottery, the presence of calcium oxide (CaO) containing sand combined with soda and the overheating of the pottery kiln may have resulted in a colored glaze on the ceramic pot[②]. Experts believe that it was not until 1,500 BC that glass was produced independently of ceramics and fashioned into separate items.

Since these ancient times, the technology and applications of ceramics (including glass) has steadily increased. We often take for granted the major role that ceramics have played in the progress of humankind.

(Selected from *Ceramics in the Classroom*, Robyn L. Johnson, 2003)

Questions

1. What is a ceramic?
2. List several properties of ceramic materials.
3. Why metals are ductile and ceramics are brittle?
4. Describe the ceramic processing.

New Words and Expressions

1. quartz tuning fork 石英音叉
2. snow sky 雪照云光
3. space shuttle (往返于地球和太空站之间运载人和物资的) 航天飞机
4. appliance *n.* 器具，器械，装置
5. enamel coating 搪瓷涂层
6. brittle *adj.* 易碎的，易损坏的
7. insulator *n.* 绝缘、隔热或隔音等的物质或装置
8. superconductor *n.* 超导体
9. clay *n.* 黏土，泥土
10. earthen element 土元素
11. kiln *n.* 窑
12. decorative *adj.* (物体或建筑) 装饰性的，作装饰用的
13. waterproof *adj.* 不透水的，防水的；*vt.* 使防水，使不透水
14. glaze *n.* 上釉的表面，釉面；*vt.* 给……上釉

15. diverse *adj.* 不同的，多种多样的
16. rigid *adj.* 刚硬的，不弯曲的
17. heterogeneity *n.* 异种，异质，不同成分
18. accomplish *vt.* 完成，实现，做成功
19. extrusion *n.* 挤压，挤压成型；热［模］压；挤出
20. slip casting 浇铸成型
21. pressing *n.* 压制成型
22. tape casting 流延成型
23. injection molding 喷射成型
24. dinnerware *n.* 整套的餐具
25. dictate *vt.* 指示，指定，指令
26. compound *n.* 复合物，化合物
27. chemical bond 化学键
28. metallic bond 金属键
29. covalent *adj.* 共有原子价的，共价的
30. ionic *adj.* 离子的
31. ductile *adj.* 可延展的，有韧性的
32. multitude *n.* 大量，许多
33. wear-resistant *adj.* 耐磨的，抗磨的
34. refractory *adj.* 耐熔的，难熔炼的
35. nonmagnetic *adj.* 无磁性的
36. prone *adj.* 有……倾向的，易于……的
37. slab *n.* 厚板，平板，厚片
38. dome *n.* 拱顶
39. loess *n.* 黄土
40. utilitarian *adj.* 有效用的，实用的
41. functional *adj.* 有用的，实用的
42. vessel *n.* 器皿，容器
43. store *vt.* & *vi.* 储藏，存放
44. pottery *n.* 陶器，陶器器皿
45. flourish *vi.* 繁荣，兴旺发达
46. inorganic *adj.* 无机的；无机物的
47. nonmetallic *adj.* 非金属的；*n.* 非金属物质
48. piezoelectric *adj.* 压电的
49. spark plug *n.* 火花塞
50. cone *n.* 圆锥形，锥形物，尖圆体
51. refine *vt.* 精炼，提炼，提纯，提去（杂质等）
52. archeologist *n.* 考古学家
53. Czechoslovakia *n.* （原）捷克斯洛伐克

Notes

① Ceramic products that use naturally occurring rocks and minerals as a starting material must undergo special processing in order to control purity, particle size, particle size distribution, and heterogeneity.

参考译文：以天然岩石和矿物作为原料的陶瓷产品，必须经过特殊的处理过程，以控制其纯度、粒径大小、粒度分布和杂质。

② While firing pottery, the presence of calcium oxide(CaO) containing sand combined with soda and the overheating of the pottery kiln may have resulted in a colored glaze on the ceramic pot.

参考译文：当烧制陶器时，由于含砂的氧化钙（CaO）结合了钠碱，以及窑炉的过热，都可能形成一个带彩釉的陶瓷壶。

Reading Material

Introduction to Ceramics (Ⅱ)

Main

Ceramic materials that are derived from common, naturally occurring raw materials such as clay minerals and quartz sand. Through industrial processes that have been practiced in some form for centuries, these materials are made into such familiar products as china tableware, clay brick and tile, industrial abrasives and refractory linings, and **Portland cement**. This article describes the basic characteristics of the raw materials commonly used in traditional ceramics, and it surveys the general processes that are followed in the fabrication of most traditional ceramic objects. From this survey the reader can proceed to more detailed articles on the individual types of ceramic products, links to which are provided at the end of this article.

Traditional ceramic objects are almost as old as the human race. Naturally occurring **abrasives** were undoubtedly used to sharpen **primitive** wood and stone tools, and **fragments** of useful clay vessels have been found dating from the **Neolithic Period**, some 10,000 years ago. Not long after the first crude clay vessels were made, people learned how to make them stronger, harder, and less **permeable** to fluids by burning. These advances were followed by structural clay products, including brick and tile. Clay-based bricks, strengthened and **toughened** with fibres such as **straw**, were among the earliest composite materials. Artistic uses of pottery also achieved a high degree of **sophistication**, especially in China, the Middle East, and the Americas.

With the **advent** of the Metal Age some 5,000 years ago, early smiths capitalized on the **refractory** nature of common quartz sand to make **molds** for the casting of metals—a practice still employed in modern **foundries**. The Greeks and Romans developed **lime-mortar** cements, and the Romans in particular used the material to construct remarkable civil engineering works, some of which remain standing to this day. The Industrial Revolution of the 18th and 19th centuries saw rapid improvements in the processing of ceramics, and the 20th century saw a growth in the scientific

understanding of these materials. Even in the age of modern advanced ceramics, traditional ceramic products, made in large quantities by efficient, inexpensive manufacturing methods, still make up the bulk of ceramics sales worldwide[①]. The scale of plant operations can rival those found in the metallurgical and **petrochemical** industries.

Raw Materials

Because of the large volumes of product involved, traditional ceramics tend to be manufactured from naturally occurring **raw materials**. In most cases these materials are **silicates**—that is, compounds based on **silica** (SiO_2), an oxide form of the element silicon. In fact, so common is the use of silicate **minerals** that traditional ceramics are often referred to as silicate ceramics, and their manufacture is often called the silicate industry[②]. Many of the silicate materials are actually unmodified or chemically modified **aluminosilicates** (alumina [Al_2O_3] plus silica), although silica is also used in its pure form. Altogether, the raw materials employed in traditional ceramics fall into three commonly recognized groups: clay, silica, and **feldspar**. These groups are described below.

1. Clay

Clay minerals such as kaolinite ($Al_2[Si_2O_5][OH]_4$) are secondary **geologic** deposits, having been formed by the **weathering** of **igneous rocks** under the influence of water, dissolved carbon dioxide, and organic acids. The largest deposits are believed to have formed when feldspar ($KAlSi_3O_8$) was eroded from rocks such as **granite** and was deposited in lake beds, where it was subsequently transformed into clay.

The importance of clay minerals to traditional ceramic development and processing cannot be **overemphasized**. In addition to being the primary source of aluminosilicates, these minerals have layered crystal structures that result in plate-shaped particles of extremely small micrometre size[③]. When these particles are **suspended** in or mixed with water, the mixture exhibits unusual **rheology**, or flow under pressure. This behaviour allows for such diverse processing methods as slip casting and plastic forming, which are described below. Clay minerals are therefore considered to be formers, allowing the mixed ingredients to be formed into the desired shape.

2. Silica and feldspar

Other constituents of traditional ceramics are silica and feldspar. Silica is a major ingredient in refractories and whitewares. It is usually added as quartz sand, **sandstone**, or **flint pebbles**. The role of silica is that of a filler, used to **impart** "green" (that is, unfired) strength to the shaped object and to maintain that shape during firing. It also improves final properties. Feldspars are aluminosilicates that contain sodium (Na), potassium (K), or calcium (Ca). They range in composition from $NaAlSi_3O_8$ and $KAlSi_3O_8$ to $CaAl_2Si_2O_8$. Feldspars act as **fluxing agents** to reduce the melting temperatures of the aluminosilicate phases.

(Selected from *Traditional Ceramics*, Encyclopedia Britannica, 2009)

Questions

1. List several products of ceramic materials.

2. Describe the raw materials employed in traditional ceramics.
3. For traditional ceramics, what advantages do clay minerals have?
4. List several roles of feldspar.

New Words and Expressions

1. Portland cement 波特兰水泥，普通水泥，硅酸盐水泥
2. abrasive *adj.* 有磨蚀作用的；*n.* 磨料，金刚砂；研磨剂
3. refractory lining 耐火炉衬，耐火（材料）衬里
4. primitive *adj.* 原始的，初期的；简单的；粗糙的
5. fragment *n.* 碎片；片断
6. Neolithic Period 新石器时代
7. permeable *adj.* 可渗透的，具渗透性的
8. toughen *vt.* 使［变］强韧
9. straw *n.* 稻草，麦秆
10. sophistication *n.* 复杂的，先进的，久经世故的
11. advent *n.* 出现，到来
12. mold *n.* 模子，模型；*vt.* 浇铸，塑造
13. foundry *n.* 铸造，翻砂，玻璃厂，铸造厂
14. lime-mortar 石灰砂浆
15. petrochemical *adj.* 石化的，石化制品的，岩石化学的；*n.* 石化产品
16. raw materials 原材料
17. silicate *n.* 硅酸盐
18. silica *n.* 硅石，二氧化硅
19. mineral *n.* 矿物，矿石，矿物质
20. aluminosilicate *n.* 铝硅酸盐
21. feldspar *n.* 长石
22. kaolinite *n.* 高岭石
23. geologic *adj.* 地质（学）的，地质（学）上的
24. weathering *n.* 侵蚀，风化
25. igneous *adj.* 火的，（尤指岩石）火成的
26. igneous rock 火成岩
27. granite *n.* 花岗岩，花岗石
28. overemphasize *v.* 过分强调
29. suspend *v.* 悬，吊，使悬浮
30. rheology *n.* 流变学，流变能力
31. sandstone *n.* 砂岩
32. flint pebble 燧石
33. impart *v.* 给予，传授
34. flux *v.* 熔化，使熔解；用助熔剂处理；*vi.* 熔化

35. fluxing agent 助熔剂

Notes

① Even in the age of modern advanced ceramics, traditional ceramic products, made in large quantities by efficient, inexpensive manufacturing methods. still make up the bulk of ceramics sales worldwide.

参考译文：即使在现代的先进陶瓷时代，大量的由高效、低廉的生产方法制备的传统陶瓷产品，仍然占世界陶瓷销量的大部分。

② In fact, so common is the use of silicate minerals that traditional ceramics are often referred to as silicate ceramics, and their manufacture is often called the silicate industry.

参考译文：事实上，硅酸盐矿物的使用很常见，以至于传统陶瓷通常被称为硅酸盐陶瓷，其生产通常被称为硅酸盐工业。

③ In addition to being the primary source of aluminosilicates, these minerals have layered crystal structures that result in plate-shaped particles of extremely small micrometre size.

参考译文：除了作为硅铝酸盐的主要来源，由于这类矿物具有层状晶体结构，因此会形成尺寸极其微细的板状颗粒。

3.2 Novel Ceramic Processing Routes (I)

Conventional Ceramic Processing

Conventional ceramic processing of **polycrystalline** ceramic **components** requires a number of stages, including manufacture of the powder, its **calcination**, **milling**, **grading** and mixing, **incorporating** additives, shape forming, drying and densification, and finally **heat treatment** and machining. Since each of these steps affects the final ceramic properties they must all be understood, and a more **holistic** approach is required when processing ceramics compared to metals and polymers, for example. While current knowledge of conventional ceramic processing is by no means complete, it is at a reasonable level and much research and development work is aimed at 'novel' processing. In this article, recent developments in the fabrication of powders, polycrystalline ceramics, single-crystal fibres and ceramic matrix composites (CMC) are outlined, along with novel uses of fine powders in refractories, the creation of a new formulation which could significantly alter the whitewares industry, and the application of rapid **prototyping** to ceramics.

Novel Powder Processing

Most ceramics are produced by the controlled sintering of shaped powder preforms. Powders are becoming finer and purer, enabling more control over the resulting ceramic properties. Finer (**colloidal**) powders have larger surface areas and sintering, driven by surface area reduction, occurs at lower temperature or requires shorter times.

The use of finer powders also means that thinner polycrystalline layers can be made, useful in

capacitor and thin film technology in microelectronic applications. Techniques being used in a novel fashion for the production of ceramic powders include **sol-gel** processing, **combustion** synthesis, **fusion** and **Dimox** (directed metal oxidation).

Refractory Aluminosilicates

Sol-gel processing was developed in the 1950s for the production of **radioactive** powders of UO_2 and ThO_2 for nuclear fuels, without generation of large quantities of **dust**. It achieves this by producing gels from liquids and then **calcining** to form the product, which can be crystalline or **amorphous**, dense or **porous**, bulk solids, fibres, thin films or powders[①]. Sols are simply **dispersions** of solid particles with at least one dimension between 1nm and 1nm in a continuous liquid. Gels consist of a continuous solid **skeleton** enclosing a continuous liquid so that producing a gel from a sol requires linking the solid phase in the system.

The term sol-gel includes products made from both inorganic colloidal particles suspended in **aqueous** solutions (particulate systems) and via **alkoxides** (metal-organic liquids) which can be partially **hydrolysed** and then polymerised into a gel (polymeric systems). Research at the University of Sheffield has focused on the production of refractory aluminosilicate glass ceramics such as **cordierite** ($Mg_2Al_4Si_5O_{18}$), **celsian** ($Ba_2Al_2Si_2O_8$), and barium **osumilite** ($BaMg_2Al_6Si_9O_{30}$). Glass powders of these compositions have been fabricated by both melt and sol-gel routes and the evolution of the microstructures examined using electron microscopy.

The crystallisation **initiates** both at the original powder particle 'surface' and at the fibre/matrix interface. An alternative route to fabrication of such highly refractory powders is under development in a joint project between the University of Sheffield and British Glass using plasma melting. Temperatures in excess of 2,000℃ are generated in the **plasma** zone, which can be concentrated to avoid melt-container reaction. British Glass is operating an experimental plasma melter of 50kg per hour capacity in Sheffield.

Applications

These materials are being considered for uses in gas turbines for power generation and aerospace industries, in particular when reinforced with silicon carbide fibres. Hot pressed or hot **isostatically** pressed CMCs are strong, lightweight, heat resistant and damage tolerant, and are expected to form the thermal protection system on the next generation of space shuttles (the Skylon).

Core-Shell Zirconia

Tioxide Specialities has developed a novel **coating** method for ZrO_2 powders which produces a dense ceramic, resistant to **hydrothermal** degradation. **Tetragonal zirconia** polycrystals (TZPs) exhibit **disastrous** loss of strength and toughness when subjected to a **moist** environment in the temperature range 100℃ to 600℃. However, by processing the ceramic to give **nanoscale** zoning of the **yttria** stabiliser, the ceramic retains high toughness and excellent resistance to hydrothermal degradation. The resulting microstructure of the material reveals a **monoclinic**, yttria **depleted**, grain

core while the tetragonal grain shell is yttria rich.

Single Crystal Fibres

Single crystal fibres offer **distinct** advantages for high-temperature applications, since **degradation** by grain growth or **creep** of grain boundary phases is impossible. In the EFG (edge defined film-fed growth) process, a fibre is grown from an induction heated melt through a small diameter molybdenum crucible and wound continuously onto **spools**[②].

Single crystal alumina fibres are produced by this process (and marketed as Saphikon) as well as a variety of shaped **sapphire** components such as **substrates** for silicon-on-sapphire **wafers** for **integrated circuits**, **arc tubes** for lighting, **hollow** fibres as optical waveguides for medical uses of lasers, and (one of the most familiar commercial applications) as abrasion resistant windows for supermarket laser scanners.

(Selected from *Materials World*, by William Lee, 1996)

Questions

1. What is novel powder processing?
2. Explain sol-gel processing.
3. What advantages do single crystal fibres have?
4. List properties of hot pressed or hot isostatically pressed CMCs.

New Words and Expressions

1. conventional *adj.* 依照惯例的，约定俗成的；常规的
2. polycrystalline *adj.* 多晶的，复晶的
3. component *n.* 成分，组成部分，部件，元件
4. calcination *n.* 煅烧，焙烧，煅烧产物
5. milling *n.* 混炼；研磨
6. grading *n.* 筛分
7. incorporate *vt.* 把……合并，使并入
8. heat treatment 热处理
9. holistic *adj.* 整体的，全盘的
10. prototype *n.* 原型；样板
11. colloidal *adj.* 胶状的，胶质的
12. sol-gel *adj.* （尤指原生质）溶胶与凝胶状态相互转换的
13. combustion *n.* 燃烧，（有机体内营养料的）氧化
14. fusion *n.* 熔合，聚变，核合成
15. Dimox (=directed metal oxidation) 直接金属氧化法
16. radioactive *adj.* 放射性的
17. calcine *v.* 烧成石灰，煅烧，焙烧

18. dust *n.* 粉尘
19. crystalline *adj.* 结晶质的；*n.* 结晶质，结晶体；晶态
20. amorphous *adj.* 无定形的，非结晶的
21. porous *adj.* 多孔的，有气孔的，疏松的
22. dispersion *n.* 分散（体，相，体系，作用，系统）
23. skeleton *n.* 骨干，框架，骨架
24. aqueous *adj.* 水的，含水的
25. alkoxide *n.* 醇盐
26. hydrolyse *vi.* 水解
27. cordierite *n.* 堇青石
28. celsian *n.* 钡长石
29. osumilite *n.* 大隅石
30. initiate *vt.* 开始，着手
31. plasma *n.* 等离子体，浆
32. isostatically *adv.* 均衡地
33. coating *n.* 涂层，覆盖层
34. hydrothermal *adj.* 热液的，热水（作用）的
35. tetragonal *adj.* 四方晶系的，四角形的，四边形的
36. zirconia *n.* 氧化锆，锆土
37. disastrous *adj.* 灾难性的；极坏的，很糟的
38. moist *adj.* 潮湿的，润湿的
39. nanoscale *n.* 纳米尺度
40. yttria *n.* 氧化钇，三氧化二钇
41. monoclinic *adj.* 单斜晶［系］的
42. deplete *vt.* 使大大减少；损耗
43. distinct *adj.* 截然不同的，完全分开的；清晰的，明显的
44. degradation *n.* 降级，降解，退化
45. creep *vi.* 蠕变
46. spool *n.* 管，筒，线轴
47. sapphire *n.* 蓝宝石，刚玉
48. substrate *n.* 衬［基］底；基片；垫托物
49. wafer *n.* 薄片，晶片，基片
50. integrated circuit 集成电路
51. arc *n.* 弧，弧线；弧形物
52. tube *n.* 管，软管
53. hollow *adj.* 空的，空心的

Notes

① It achieves this by producing gels from liquids and then calcining to form the product, which

can be crystalline or amorphous, dense or porous, bulk solids, fibres, thin films or powders.

参考译文：实现这样的生产，是通过从液体中形成凝胶，然后焙烧，从而得到各种产品，这些产品可能是晶体或无定形体、致密体或多孔材料、散装固体、纤维、薄膜或粉末。

② In the EFG(edge defined film-fed growth) process, a fibre is grown from an induction heated melt through a small diameter molybdenum crucible and wound continuously onto spools.

参考译文：在 EFG（定边喂膜生长）过程中，纤维通过小直径钼坩埚从感应加热融化中生长，不断绕在线轴上。

wound 是 wind 的过去式。

Reading Material

Novel Ceramic Processing Routes (Ⅱ)

Combustion Synthesis

Combustion synthesis, also termed self **sustaining** high temperature synthesis (SHS), uses high temperature reactions to form powders or dense components, with large potential energy savings in a similar manner to the **thermit** process once used for welding iron and in **incendiary bombs**. The heat evolved during self-sustaining (once initiated) exothermic reactions can be used to form single phase or composite ceramics. The reaction is typically initiated at the top of a pellet and proceeds as a reaction **wavefront** down the sample to form the products①. For example, a **pellet** of fine silicon metal and **carbon black**, inductively heated in **graphite to** 1,200℃, will ignite **exothermically** to give temperatures of 2,250℃ at the pellet centre, leading to formation of SiC.

Other ceramics prepared by this route include borides, carbonitrides, **nitrides** and $YBa_2Cu_3O_{7-x}$ superconductors. A similar exothermic reaction mechanism is believed to occur in the formation of $MoSi_2$ powder by mechanicochemical synthesis of silicon and molybdenum powders. In this technique, the powders are milled in a high energy **ball mill** for several hours until the particles are fine enough that the surface and strain energy available will sustain the reaction. Composites of Saphikon fibres in a $MoSi_2$ matrix are currently being examined for various applications in the hot sections of **jet combustion chambers**, heat exchangers and high temperature **filters**.

Fine Powder Additives to Refractories

The addition of fine powders to refractories to improve their properties is an increasing trend. Metal powders (aluminium, silicon, and magnesium, and mixtures such as Al-Mg) have been added to MgO-graphite bricks for lining basic oxygen **steelmaking** furnaces since the 1970s, to improve oxidation resistance by **gettering** oxygen, and aid hot strength by forming ceramic bond phases such as $MgAl_2O_4$ and Mg_2SiO_4 at high temperature.

More recently, boron-containing ceramic powders including ZrB_2, B_2O_3, and B_4C have been used. B_4C functions by gettering oxygen leading to formation of boric acid, H_3BO_3, which then reacts with MgO to form a **viscous** glass that reduces the refractories' permeability, effectively acting

as an internal glaze. CA (calcium aluminate) bonded monolithic (unshaped) refractories are used for an increasing number of heat retention linings in reheat furnaces, **ladle** and **tundish** backing, **blast furnace** runners and repair of blast furnace throat, cone and **stack** sections, as well as the water-cooled delta sections of electric arc furnaces. Fine, colloidal SiO_2 (a by-product of silicon or ferrosilicon production) and reactive calcined Al_2O_3 added to CA **castable** refractories react to form **elongated mullite** grains in the bond phase which strengthens the structure and improves hot strength.

A New Look at Whitewares

A major problem with conventional whitewares is that the clay particles become aligned **macroscopically** in plastically-formed and slip-cast wares, and microscopically in those that are pressed from powder. The anisotropic firing **shrinkage** caused by clay alignment on the macroscale results in shape distortion, whereas on the microscale enlarged pores are formed, which reduce strength.

New body formulations have been developed by researchers at the University of Sheffield (UK) that have low clay contents, about one third of those used conventionally to reduce **anisotropic** shrinkage. The new **formulations** can be formed by pressing and casting. **Coupled** with newly developed binders that can be rapidly removed by a combination of water **leaching** and thermal debinding, injection moulding of certain shapes has become a practical possibility.

Glazing of whitewares is receiving much attention because of recent legislation in the USA concerning the use of PbO. However, PbO-containing glazes, and those recently developed to replace them containing Bi_2O_3, are easily **scratched** and abraded in service. The traditional glaze on hard porcelain is scratch resistant. Hard porcelain is glazed with a raw glaze, fired on at temperatures around 1,400℃. Recently, it has been shown to be possible to glaze at temperatures some 200℃ lower than is employed conventionally by using a sintering only approach using a fritted (powder) glaze with a tailored particle size[②].

One of the new low-clay **whitewares** has been formulated to have a thermal expansion coefficient to match that of the hard porcelain glaze, and it can be glazed at temperatures up to around 1,300℃. This whiteware is based on **anorthite** ($CaAl_2Si_2O_8$) and has a similar **appearence** to **bone china**. With a scratch resistant glaze it will be more serviceable than bone china, and as it has a high strength it should be more resistant to chipping than hard porcelain.

(Selected from *Materials World*, by William Lee, 1996)

Questions

1. What is combustion synthesis?
2. List several boron-containing ceramic powders.
3. What is the major problem of conventional whitewares?
4. Why glazing of whitewares is receiving much attention?

New Words and Expressions

1. sustaining *adj.* 持续的，支持的
2. thermit *n.* 铝热剂，灼热剂
3. incendiary bomb 燃烧弹
4. wavefront *n.* 波阵面；波前，波锋
5. pellet *n.* 球［条形，丸形］团矿
6. carbon black 黑烟末，炭黑
7. graphite *n.* 石墨，石墨粉，炭精，铅粉
8. exothermic *adj.* 发热的，放出热量的
9. boride *n.* 硼化物
10. carbonitride *n.* 碳氮化物
11. nitride *n.* 氮化物
12. ball mill 球磨机
13. jet *n.* 喷射，射流；喷注，气流
14. chamber *n.* 室，房间，枪膛；combustion chamber 燃烧室
15. filter *n.* 过滤，过滤器
16. steel making *n.* 炼钢
17. gettering *n.* 收气，吸气，吸附；吸气法（真空技术）
18. viscous *adj.* 黏性的；半流体的，黏滞流体的
19. ladle *n.* （铸，盛钢）桶，罐，铁［钢］液包
20. tundish *n.* 漏斗
21. blast furnace 鼓风炉，高炉
22. stack *n.* 烟道，（高炉）炉身烟囱
23. castable *adj.* 浇注的，铸块的，可浇铸材料的
24. elongate *vt.* 延长，加长；*adj.* 延长［伸］的
25. mullite *n.* 莫来石，高铝红柱石
26. macroscopical *adj.* 肉眼可见的，宏观的
27. shrinkage *n.* 收缩，皱缩，缩水
28. anisotropic *adj.* 各向异性的
29. formulate *v.* 用公式表示，明确地表达，作简洁陈述
30. couple *vt.* 连接，联结，联系
31. binde *n.* 粘合剂，粘合料
32. leaching *n.* 浸出［滤，提］；沥滤（法），淋溶（作用）
33. scratch *vt.* & *vi* 刮伤，刮痕
34. whiteware *n.* ［总称］白色陶瓷（器），卫生陶瓷（器）（如抽水马桶、餐具和绝缘陶瓷）
35. anorthite *n.* 钙长石
36. appearance *n.* 外观，外貌，外表

37. bone china 骨灰瓷（用瓷土与磷酸钙烧成的半透明瓷器）

Notes

① The reaction is typically initiated at the top of a pellet and proceeds as a reaction wavefront down the sample to form the products.

参考译文：这种反应通常是从一个颗粒的顶部开始，以一个反应波的形式继续传递，从而形成产品。

② Recently, it has been shown to be possible to glaze at temperatures some 200℃ lower than is employed conventionally by using a sintering only approach using a fritted (powder) glaze with a tailored particle size.

参考译文：近来，有研究表明，有可能在比通常使用的传统温度低约200℃时上釉，这种方法是用接近于特定粒径的熔块釉（粉末）进行烧结。

3.3 Advanced Ceramics (Ⅰ)

Background

The continuing evolution of the ceramics and materials world and the associated materials technologies is accelerating rapidly with each new technological development supplying more data to the knowledge bank. As new materials and even newer technologies are developed; methods of handling, forming and finishing are required to be devised to maintain pace with this rapid rate of development. One of the most **prominent** examples of this rapid and accelerating technological development is the electronic industry, more specifically the simple transistor. The **pace** of this development and the development of the associated materials and processing technology has been quite astounding. The push has been along **miniaturisation** and packing the maximum amount of performance into the smallest space. Recently noted, an e-mail quote stated that; "If the Automotive industry had advanced at the same pace as the Computer industry, we would be driving cars, which gave a thousand kilometres to the litre and cost $25". The concept of the simple transistor stands as one of the most significant electronic engineering achievements of the 20th century.

1. Advances in ceramic technology in the twentieth century

The 20th century has produced the greatest advancement in ceramics and materials technology since humans have been capable of conceptive thought. The extensive metallurgical developments in this period have now produced almost every **conceivable** combination of metal alloys and the capabilities of those alloys are fairly well known and exploited. The push for ever faster, more efficient, less costly production techniques continues today. As the limits of metal-based systems are surpassed, new materials capable of operating under higher temperatures, higher speeds, longer life factors and lower maintenance costs are required to maintain pace with technological advancements. Metals, **by virtue of** their unique properties: **ductility**, **tensile strength**, abundance, simple chemistry, relatively low cost of production, case of forming, case of joining, etc. have occupied

the **vanguard** position **in regard to** materials development. **By contrast** ceramics: brittle by nature, having a more complex chemistry and requiring advanced processing technology and equipment to produce, perform best when combined with other materials, such as metals and polymers which can be used as support structures. This combination enables large shapes to be made; the Space Shuttle is a typical example of the application of advanced materials and an excellent example of the capability of advanced materials.

2. Recent advances in ceramic technology

It is only during the last 30 years or so, with the advances of understanding in ceramic chemistry, **crystallography** and the more extensive knowledge gained in regard to the production of advanced and engineered ceramics that the potential for these materials has been realised. One of the major developments this century was the work by Ron Garvie et al at the **CSIRO, Melbourne** where PSZ (partially stabilised zirconia) and phase transformation toughening of this ceramic was developed. This advancement changed the way ceramic systems were viewed. Techniques previously applied to metals were now considered applicable to ceramic systems. Phase transformations, alloying, **quenching** and **tempering** techniques **were applied to** a range of ceramic systems. Significant improvements to the **fracture toughness**, ductility and **impact resistance** of ceramics were realised and thus the gap in physical properties between ceramics and metals began to close[①]. More recent developments in non-oxide and tougher ceramics (e.g., nitride ceramics) have closed the gap even further.

Properties of Ceramics

Ceramics for today's engineering applications can be considered to be non-traditional. Traditional ceramics are the older and more generally known types, such as: **porcelain**, brick, **earthenware**, etc. The new and emerging families of ceramics are referred to as advanced, new or fine, and utilise highly refined materials and new forming techniques. These "new" or "advanced" ceramics, when used as an engineering material, posses several properties which can be viewed as superior to metal-based systems. These properties place this new group of ceramics in a most attractive position, not only in the area of performance but also **cost effectiveness**. These properties include high resistance to **abrasion**, excellent hot strength, chemical inertness, high machining speeds (as tools) and dimensional stability.

1. Classifications of technical ceramics

Technical Ceramics can also be classified into three distinct material categories:

Oxides: **Alumina**, **zirconia**;

Non-oxides: **Carbides**, borides, nitrides, **silicides**;

Composites: Particulate reinforced, combinations of oxides and non-oxides.

Each one of these classes can develop **unique** material properties.

2. Oxide ceramics

Oxidation resistant, chemically **inert**, electrically **insulating**, generally low **thermal conductivity**, slightly complex manufacturing and low cost for alumina, more complex manufacturing and

higher cost for zirconia.

3. Non-oxide ceramics

Low oxidation resistance, **extreme** hardness, chemically inert, high thermal conductivity, and electrically conducting, difficult energy dependent manufacturing and high cost.

4. Ceramic-based composites

Toughness, low and high oxidation resistance (type related), variable thermal and electrical conductivity, complex manufacturing processes, high cost.

Production

Technical or Engineering ceramic production, **compared to** yesterday's traditional ceramic production, is a much more demanding and complex procedure. High purity materials and precise methods of production must be employed to ensure that the desired properties of these advanced materials are achieved in the final product.

1. Oxide ceramics

High purity starting materials (powders) are prepared using mineral processing techniques to produce a concentrate followed by further processing (typically wet chemistry) to remove unwanted impurities and to add other compounds to create the desired starting composition. This is a most important stage in the preparation of high performance oxide ceramics. As these are generally high purity systems minor impurities can have a **dynamic** effect, for example small amounts of MgO can have a marked effect upon the sintering behaviour of alumina. Various heat treatment procedures are utilised to create carefully controlled crystal structures. These powders are generally ground to an extremely fine or "**ultimate**" crystal size to assist ceramic reactivity. **Plasticisers** and **binders** are **blended with** these powders to suit the preferred method of forming (pressing, **extrusion**, **slip casting**, etc.) to produce the "raw" material. Both high and low-pressure forming techniques are used. The raw material is formed into the required "green" shape or **precursor** (machined or turned to shape if required) and fired to high temperatures in air or a slightly reducing atmosphere to produce a dense product.

2. Non-oxide ceramics

The production of non-oxide ceramics is usually a three stage process involving: first the preparation of precursors or starting powders, secondly the mixing of these precursors to create the desired compounds (Ti + 2B, Si + C, etc.) and thirdly the forming and sintering of the final component. The formation of starting materials and firing for this group, require carefully controlled furnace or kiln conditions to ensure the absence of oxygen during heating as these materials will readily oxidise during firing. This group of materials generally requires quite high temperatures to effect sintering. Similar to oxide ceramics, carefully controlled purities and crystalline characteristics are needed to achieve the desired final ceramic properties.

3. Ceramic-based composites

This group can **be composed of** a combination of: oxide ceramics-non-oxide ceramics (**granular**, **platy**, **whiskers**, etc.), oxide-oxide ceramics, non-oxide-non-oxide ceramics, and ceramics-

polymers, etc. an almost infinite number of combinations are possible. The object is to improve either the toughness or hardness to be more suited to a particular application. This is a somewhat new area of development and compositions can also include metals in particulate or matrix form[2].

(Selected from *Materials Australia*, by D. A. Taylor, 2001)

Questions

1. List several properties of ceramics.
2. Explain "new" or "advanced" ceramics.
3. What advantages do ceramic-based composites have?
4. Describe the process of non-oxide ceramics.

New Words and Expressions

1. prominent *adj.* 显著的，突出的
2. pace *v.* 踱步于，走动以步测量；步测，为……定步速
3. miniaturisation *n.* 小型化，微型化
4. conceivable *adj.* 可想到的，可相信的，可想象的
5. by virtue of 凭借……的力量；由于
6. ductility *n.* 延展性，塑性，粘性，可塑性，韧性
7. tensile strength 抗张强度
8. vanguard *n.* 先锋，先驱
9. in regard to 关于……，对于，就……而论
10. by contrast 对比起来，与之相比，相反地
11. crystallography *n.* 结晶学
12. CSIRO (Commonwealth Scientific and Industrial Research Organization) (澳大利亚) 联邦科学与工业研究组织
13. Melbourne *n.* 墨尔本（澳大利亚港市）
14. quenching *n.* 淬火
15. tempering *n.* 回火，退火
16. be applied to 适用于，应用于
17. fracture toughness 断裂韧度
18. impact resistance 冲击［撞击］阻力
19. porcelain *n.* 瓷，瓷器
20. earthenware *n.* 陶器
21. cost effectiveness 成本效率
22. abrasion *n.* 擦伤，磨损
23. technical ceramics 工业陶瓷，技术陶瓷
24. alumina *n.* 矾土，铝氧土；氧化铝
25. zirconia *n.* 氧化锆，锆土
26. carbide *n.* 碳化物，碳化钙，电石，硬质合金

27. silicide *n.* 硅化物
28. unique *adj.* 异常的，特有的，少见的；独一无二的，仅有的，惟一的
29. inert *adj.* 惰［惯］性的，不活泼的，钝的，不起化学作用的，中和（性）的
30. insulating *n.* & *adj.* 绝缘（的）；保温（的）；绝热（的）
31. thermal conductivity 导热性［系数］，热导率
32. extreme *adj.* 极度的，极端的；尽头的，末端的
33. toughness *n.* 韧性，韧度，刚性，黏稠性
34. compared to 与……相比
35. dynamic *adj.* 动力的，动力学的；力学（上）的；动态的，电动的，冲击的
36. ultimate *adj.* 最后的，终极的；基本的，首要的
37. plasticiser *n.* 增塑剂
38. binder *n.* 粘合剂，结合剂
39. blend with 混和
40. extrusion 挤压成型
41. slip casting 注浆成型
42. precursor *n.* 前驱物，初极粒子
43. be composed of 由……组成
44. granular *adj.* 粒的，含颗粒的；粒状的；粗面的
45. platy *n.* 板状的，扁平状的
46. whisker *n.* 须，须晶

Notes

① Significant improvements to the fracture toughness, ductility and impact resistance of ceramics were realised and thus the gap in physical properties between ceramics and metals began to close.

参考译文：陶瓷的断裂韧性、延展性和抗冲击性显著改善，从而使得陶瓷和金属之间物理性质的差距开始缩小。

② The object is to improve either the toughness or hardness to be more suited to a particular application. This is a somewhat new area of development and compositions can also include metals in particulate or matrix form.

参考译文：其目的是提高韧性或硬度，以更适合特定的应用。这是一个比较新的发展领域，其组分也可以包含颗粒或基体形式的金属。

Reading Material

Advanced Ceramics (Ⅱ)

Firing

Firing conditions for new tooling ceramics are somewhat diverse both in temperature range and

equipment. This subject is too lengthy to cover here. A wide range of publications is available on this subject for those interested. However, a brief **description** of some techniques and conditions is appropriate to provide an understanding of the basic technology of advanced ceramics firing. **In general** these materials are fired to temperatures well above metals, and typically in the range of 1,500℃ to 2,400℃ and even higher. These temperatures require much specialized **furnaces** and furnace **linings** to **attain** these high temperatures. Some materials require special gas environments such as **nitrogen** or controlled furnace conditions such as **vacuum**. Others require extremely high pressures (HPs) to achieve densification. Thus these furnaces are quite diverse both in design and concept. The typical methods of heating in these furnaces are gases (gas plus oxygen, gas plus heated air), **resistance heating** (metallic, carbon and ceramic heaters) or **inductance heating** (R. F., microwave).

1. Firing environments

Gas heating is generally **carried out** in normal to low pressures. Resistance heating is carried out in pressures ranging from vacuum to 200 MPa. Inductance heating can also be done over the same range as resistance. In both resistance and inductance heating the systems do not have to **contend with** high volumes of **ignition** products thus can be contained. The typical furnace types used in the foregoing methods are **box**, **tunnel**, **bell**, **HIP** (gas and resistance heated), sealed ("**autoclave**" sealed type for carbon element heated), sealed special design (water-cooled type for R. F. heated) or open design **microwave** heated (small items)[①].

2. The importance of the firing process

This brief listing serves to provide an indication of just how diverse the techniques employed to fire advanced ceramics are. Each ceramic type has its own special requirement in regard to firing rate, environmental condition and temperature. If these conditions are not met then the quality of the final product and even the formation of the final compounds and densities will not be achieved.

Finishing

One of the final stages in the production of advanced materials is the finishing to precise tolerances. These materials can be extremely hard, with hardness's **approaching** diamond, and thus finishing can be quite an expensive and slow process. Finishing techniques can include: laser, **water jet** and **diamond cutting**, diamond **grinding** and **drilling**, however if the ceramic is electrically conductive techniques such as EDM (electrical discharge machining) can be used. As the pursuit of hardness is one of the prime **developmental** objectives, and as each newly developed material increases in hardness, the problems **associated with** finishing will also increase[②]. The development of **CNC** grinding equipment has lessened the cost of final grinding by minimising the labour content, however large runs are generally required to offset the set up costs of this equipment. Small runs are usually not economically **viable**. One alternative to this problem is to "net form" or form to predictable or acceptable tolerances to minimise machining. This has been achieved at Taylor Ceramic Engineering by the introduction of a technique called "near to net shape forming". Complex components can be formed by this unique Australian development with **deviations** as low as ±0.3% resulting in

considerable savings in final machining costs.

In many applications today, the beneficial properties of some materials are combined to enhance and at times support other materials, thus creating a **hybrid composite**. **In the case** of hybrid composites, it is the availability and performance properties of each new material, which sets the capability of the new material. In-field evaluation testing has to be carried out in certain instances, to determine the long-term **durability** of the new composite before actually **committing** to service.

Design

The properties of advanced materials need to be considered when designing structures, components and devices. The final design and material selection must ultimately be cost effective, must function reliably and, ideally, should be an improvement upon existing technology. Prior performance knowledge is obviously an **asset**, however in many new applications prior knowledge may not be available thus careful observation and recording of performance characteristics of the experimental model, or in **plant trial**, is needed. **In this regard** the Materials Engineer works in close contact with the research team to cooperatively develop the new concept. As we are still working with relatively brittle materials this **aspect** has to be always kept in mind. New techniques such as **Finite Element Analysis** have **proven** beneficial in this regard. The use of **computer modelling** allows the structures to be created on screen without the need for costly prototypes.

Where to Next?

Advanced ceramic materials are now well established in many areas of every day use. The improvements in performance, service life, savings in **operational costs** and savings in maintenance are clear evidence of the benefits of advanced ceramic materials. Life expectancies, now in years instead of months with cost economics in the order of only double existing component costs, give advanced ceramics materials a major advantage. The production of these advanced materials is a complex and demanding process with high equipment costs and the requirement of highly specialised and trained people. The ceramic materials of tomorrow will **exploit** the properties of **polycrystalline phase** combinations and composite ceramic structures, i. e. the **co-precipitation** or **inclusion** of differing crystalline structures having beneficial properties working together in the final compound.

Tomorrow (even today) the quest will be to pack the highest amount of bond energy into the final ceramic compound and to impart a high degree of ductility or **elasticity** into those bonds. This energy level has to be exceeded to cause failure or **dislocation**. The changing pace of technology and materials also means that newer compounds precisely engineered to function will be developed. Just how this will be achieved and when the knowledge becomes public—who can tell! Ceramics, an old class of material, still present opportunities for new material developments.

It is a fascinating quest but this aspect of secrecy and the continued presence of "Black Art" in many ceramic production industries makes it even more fascinating.

(Selected from *Materials Australia*, by D. A. Taylor, 2001)

Questions

1. List several typical methods of firing.
2. What is EDM?
3. Explain HIP.
4. Where to next about advanced ceramic materials?

New Words and Expressions

1. firing *n.* 烧成，烧制
2. description *n.* 叙述，描写，说明；种类，类型
3. in general 一般而言，总的来说，大体上
4. furnace *n.* 炉子，熔炉，高炉；窑，燃烧室
5. lining *n.* 衬里，里子；衬料，内衬
6. attain *vt.* & *vi.* 实现，达到，得到
7. nitrogen *n.* 氮
8. vacuum *n.* 真空
9. densification *n.* 增浓作用，稠化（作用）；密封，封严；压实，夯实
10. HP (= Hot Pressing) 热压［烧结］
11. resistance heating 电阻炉
12. inductance *n.* 电感，感应，感应系数［现象］；（发动机）进气
13. inductance heating 感应加热
14. microwave *n.* 微波
15. carried out 完成，实现；进行；执行，贯彻
16. contend with 与（某事物）抗争，苦于应付；与（某人）竞争
17. ignition *n.* 点火，着火，引燃；灼热
18. box *n.* 匣钵，盒，箱；*vt.* 把……装入匣钵中
19. tunnel *n.* 隧道，坑道，地道；烟道，烟囱；风洞；管道
20. bell *n.* 钟，钟形物；bell kiln 钟罩式窑
21. HIP (= Hot Isostatic Pressing) 热等静压［烧结］
22. autoclave *n.* 高压釜，压热器
23. approach *vt.* & *vi.* 靠近，接近，临近
24. water jet 喷射，射流；喷注，气流
25. diamond cutting 金刚石切割法
26. grinding *adj.* 研磨的，磨光［碎］的
27. drilling *n.* 钻孔；钻井
28. developmental *adj.* 发展的；试验性的；开发的
29. associate with 与……交往，联系
30. CNC(= Computerized Numerical Control) 电脑数值控制，计算机数控
31. viable *adj.* 切实可行的，可实施的

32. deviation　*n.* 偏差，误差；偏斜
33. hybrid composite　复合材料
34. in the case of　至于……，就……来说
35. durability　*n.* 耐久性，耐用性；坚固
36. commit to　交付，把……投入
37. asset　*n.* 资产，财产；有价值的人或物；优点，长处
38. plant trial　工厂条件下试用；生产上试用
39. *in this regard*　关于此事，在这点上
40. aspect　*n.* 方面；方位，朝向；面貌，模样，神态
41. Finite Element Analysis　有限元分析
42. proven　*adj.* 经过验证或证实的
43. computer modelling　计算机模拟
44. operational cost　经营成本
45. exploit　*vt.* 开采，开发，剥削；*n.* 功绩[勋]，业绩，英勇的行为，辉煌的成就
46. polycrystalline phase　晶相
47. co-precipitation　共沉淀
48. inclusion　*n.* 包含，内含物；夹杂，夹杂物，夹渣
49. elasticity　*n.* 弹力，弹性
50. dislocation　*n.* 混乱，紊乱；位错

Notes

① The typical furnace types used in the foregoing methods are box, tunnel, bell, HIP (gas and resistance heated), sealed ("autoclave" sealed type for carbon element heated), sealed special design (water-cooled type for R. F. heated) or open design microwave heated (small items).

参考译文：在上述方法中，使用的典型窑炉类型有箱式窑、隧道窑、钟罩炉、热等静压设备（天然气和电阻加热）、密封炉（碳加热的密封式"高压釜"）、特殊设计的密封炉（水冷式射频加热型）或开放式设计的微波加热设备（小件物品）。

② As the pursuit of hardness is one of the prime developmental objectives, and as each newly developed material increases in hardness, the problems associated with finishing will also increase.

参考译文：由于硬度逐渐成为首要的目标之一，随着每一种新开发材料硬度的增加，与修整相关的问题也随之出现。

3.4 Clean Energy through Ceramics (Ⅰ)

Recent advances in low-power electronics have generated **tremendous** interest and provided new opportunities for the use of **piezoelectric** materials to power electronic devices without the need for batteries. Ceramic fiber **spinning** technology has been refined to produce inexpensive piezoelectric fiber composites, which have generated sufficient power to run **wireless sensor networks** and electronic devices from waste mechanical energy.

Piezoelectric ceramics generate electricity when **exposed to** a mechanical stress, and, **conversely**, they change shape when an electric field is applied. Piezoelectric fibers **take full advantage of** this phenomenon, and piezoelectric fiber composites are being produced for their maximum energy-harvesting efficiency. These ceramic fibers are **flexible** and, in composite form, very **robust**. Typical successes include powering wireless **sensors** from low-level environmental **vibrations** as the source of power, and recharging or eliminating batteries in remote locations. Fig. 3. 1 shows the energy generation capability of these devices under vibration. At the low acceleration level of 0. 1g, it takes just 5 minutes to charge sufficient energy to power a wireless sensor and **transmitter**. At about 1g, the charging time reduces to under 1 minute.

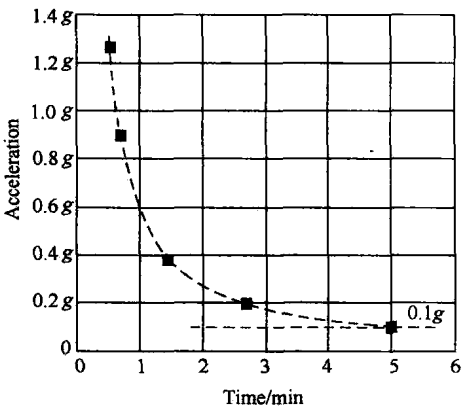


Fig. 3. 1 Acceleration input vs. the time to charge to 5V in a 200μF capacitor.

This green technology produces useful amounts of electricity from environmentally available sources of mechanical energy and **eliminates** the need for expensive wiring or the installation of heavy, expensive, difficult-to-replace and polluting batteries[①]. In addition, ceramic fiber-powered products are priced competitively with **rechargeable** batteries.

Energy Harvesting

Energy harvesting (EH), sometimes referred to as energy **scavenging**, has gained tremendous attention as a means to lessen or eliminate the need for battery power. Novel EH approaches are available to generate power by utilizing energy from human and environmental sources. Given battery limitations, wider **adoption** of EH is coming but requires a clever combination of design skills. A **multi-discipline** approach is required that **leverages** knowledge in several fields of engineering, including electrical, mechanical, material and process.

The concept of EH is not new. Consider hand-cranked radios, **flashlights** and watches powered by shaking, as well as **windmill** farms, **solar energy** and even sailboats. What is new is the application of EH for ultra-low-power **embedded** electronics that require no moving parts. The **convergence** of high-charge piezoelectric ceramics and ceramic fiber composite process technology has enabled the application of self-powered systems for an array of electronics. Added to the obvious advantages associated with utilizing free mechanical energy to power many types of systems, EH eliminates concerns regarding battery replacement and disposal.

Converging Technologies

The science of piezoelectric devices is fairly well understood in the engineering world, but their application remains a **nascent** field rich with possibilities. The emergence of piezoelectric ceramic fiber "**super transducers**" that offer significantly increased deliverable power, combined with elec-

tronic components that measure performance in **nano-watts**, is opening a range of new products and services.

The need for constant and/or long-term power for numerous electronic systems and devices is **fueling** extensive research, development and growth. Piezoelectric ceramic fibers, given their unique properties of **flexibility**, light weight and higher output per pound of material, offer the greatest potential for enabling the wide-scale deployment of self-powered piezoelectric ceramic systems[②].

Conventional piezoelectric ceramic materials are rigid, heavy and produced in block form. A new low-cost technology, termed the **viscous suspension spinning process** (VSSP), can produce fibers that range in diameter from 10 to 1,300 microns. When formed into user-defined (shaped) composites, the ceramic fibers possess all the desirable properties of ceramics (electrical, thermal, chemical) but eliminate the **detrimental** characteristics (brittleness, weight).

The VSSP generates fibers with 20% -30% more sensitivity (higher output voltage) than traditional bulk ceramics **due to** their small **cross-sectional** area. Mechanical-to-electrical **transduction efficiency** can reach 70%, compared to the 10% -15% common with solar energy harvesting. In addition, vibrations can be harvested 24 hours per day, almost anywhere.

Piezo Power Generation

Piezoelectric fiber composites (PFCs) open the door for an array of energy-harvesting applications. The fiber can recover (harvest) waste energy from mechanical forces such as motion, vibration, compression and/or tension. With simple, low-cost **analog** circuits, the piezo power can be converted, stored and regulated as an independent power source or a direct replacement for batteries. A typical PFC can generate voltages in the range of 80 Vp-p from vibration, while a typical PFCB (**bimorph**) can generate voltages in the range of 500 Vp-p, with some forms reaching outputs of 4,000 Vp-p. The converted energy can be stored in a **capacitor** to power electronic devices.

Fig. 3. 2a shows the frequency dependance of such power. The full width at half maximum (FEHM) is fairly wide (10Hz), and the frequency can be tuned as desired. Further, the FWHM

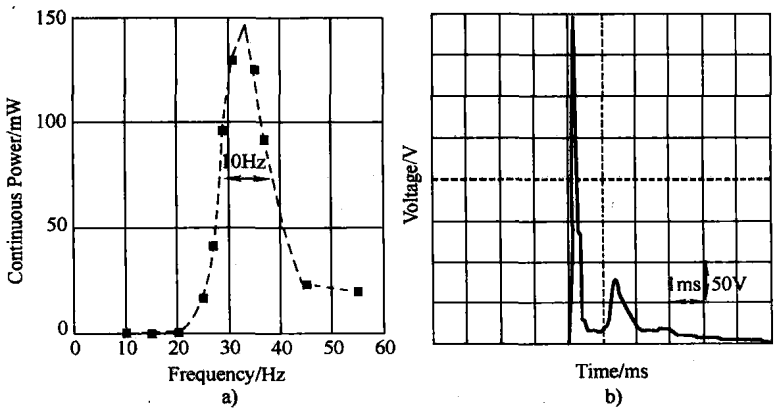


Fig. 3. 2 Output voltage signal of PFCB
a) when 4 N force was applied, and
b) peak voltage generation of a 1-3 fiber composite for an igniter.

increases significantly as the frequency increases. Piezoelectric multilayer composites (PMCs), however, are designed to withstand large impact forces and accelerations up to a few thousand g's. This type of transducer is a good sensor that can produce large voltages, even with the moderate force of 1 N impacting the **transducer** (Fig. 3.2b).

Using a constant vibration source with the frequency **matched to** the **resonance** of a standard PFCB at 30Hz, piezo-fibers have the proven ability to produce enough energy with maximum efficiency to run many electronics continuously[3]. Energy levels sufficient to power wireless systems for sensing, monitoring and control of security equipment, appliances, medical devices, buildings and other **infrastructure** elements are in development or have been **commercialized**.

Power output is **scalable** by combining two or more PFC elements **in series or parallel**, depending on the application. The composite fibers can be molded into unlimited **user-defined** shapes and are both flexible and motion-sensitive. The fibers are typically placed where there is a rich source of mechanical movement or waste energy. Fig. 3.3 shows the results of **real-time** road tests to power a **toll transponder** device using the piezoelectric fiber transducer. The charging time varied depending on the vibration level transferred from the road, but in all cases provided suitable power within the required time.

(Selected from *Advanced Cerametrics*,
by Richard Cass, Hyeoungwoo Kim, etc. ,2008)

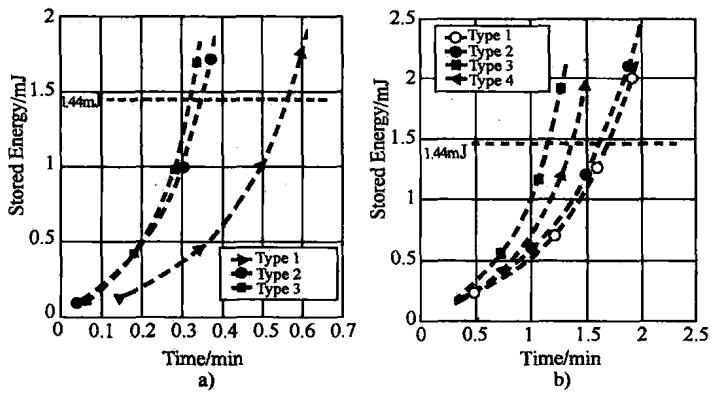


Fig. 3.3 Real-time road experiment results storing a threshold 1.44mJ of energy for a toll transponder device using the piezoelectric fiber transducers in a) a Dodge Truck and b) a Honda Civic.

Questions

1. List several applications of EH.
2. Describe the properties of conventional piezoelectric ceramic materials.
3. Explain VSSP.
4. What advantages do piezoelectric fiber composites have?

New Words and Expressions

1. tremendous *adj.* 极大的，巨大的，惊人的；绝妙的，极棒的
2. piezoelectric *adj.* 压电的
3. spinning *n.* 纺，精纺；旋转，自转，旋压；*adj.* 纺纱的，旋转的
4. sensor *n.* 传感器，灵敏元件
5. wireless sensor networks 无线传感器网络
6. expose to 暴露，面临
7. conversely *adv.* 相反地，颠倒地
8. take full advantage of 充分利用
9. flexible *adj.* 易弯的，挠性的，有弹性的；柔韧的；灵活的；可塑造的
10. robust *adj.* 健康的，要用力气的，坚定的，粗野的
11. vibration *n.* 震［颤、振］动；摆动；振荡
12. transmitter *n.* 变送［传感、发送、传递］器；发射［报、信、话］机
13. eliminate *vt.* 消除，排除；忽略；淘汰
14. rechargeable *adj.* 可再充电的
15. scavenging *n.* 除气，除气法；净化，清除
16. adoption *n.* 采纳，采用；收养
17. multi-discipline 多学科
18. leverage *n.* 杠杆机构；杠杆作用；扭转力矩；*vt.* 促使……改变
19. flashlight *n.* 手电筒
20. windmill *n.* 风车，风车房；风力发动机，螺旋桨
21. solar energy 太阳能
22. embedded *adj.* 装入的，压入的，嵌入的，内含的
23. convergence *n.* 集中，收敛
24. nascent *adj.* 开始形成的，发生中的，初期的；初生的，新生的
25. super transducer 超级传感器
26. nano-watts 毫微瓦（特），10^{-9}瓦特
27. fuel *vt.* & *vi.* （给……）加燃料；（给船等）上煤；（给……）加油；刺激，推动
28. flexibility *n.* 弹性，适应性，机动性，挠性
29. viscous suspension spinning process 粘性悬浮纺丝工艺
30. detrimental *adj.* 有害的，不利的
31. due to 由于；欠下债［账］，应给予
32. cross-sectional *adj.* 代表性的
33. transduction efficiency 换能效率
34. analog(= analogue) *n.* 相似物，类似物，类比
35. bimorph *n.* 双压电晶片，双晶
36. Vp-p(= Peak-to-peak voltage) 峰峰值
37. capacitor *n.* 电容器；电容

38. transducer *n.* 转换器，变流器，换频器，发送器；传感器；转录程序
39. matched to 使和……相等，匹配
40. resonance *n.* （波长的）调谐；共鸣，共振；回声，反响
41. infrastructure *n.* 基础；基础结构［设施］
42. commercialized *vt.* 使商业化，使商品化
43. scalable *adj.* 可（用磅称等）称的；可攀登的；可升级的
44. in series or parallel 串联或并联
45. user-defined 自定义
46. real-time 即时处理的；实时的
47. toll transponder 收费器

Notes

① This green technology produces useful amounts of electricity from environmentally available soures of mechanical energy and eliminates the need for expensive wiring or the installation of heavy, expensive, difficult-to-replace and polluting batteries.

参考译文：这项新技术可以从环境中的机械能有效地生产出大量的电力，并且无需使用昂贵的线路，或者可以省去电池的安装，这些电池沉重、昂贵、难以替代并有污染。

② Piezoelectric ceramic fibers, given their unique properties of flexibility, light weight and higher output per pound of material, offer the greatest potential for enabling the wide-scale deployment of self-powered piezoelectric ceramic systems.

参考译文：压电陶瓷纤维，由于其灵活、重量轻、每磅材料产量高等独特的性能，使其为自供电压电陶瓷系统的大规模推广应用，提供了最大的可能性。

③ Using a constant vibration source with the frequency matched to the resonance of a standard PFCB at 30Hz, piezo-fibers have the proven ability to produce enough energy with maximum efficiency to run many electronics continuously.

参考译文：经证实，使用在 30Hz 时与标准的双晶压电纤维复合材料产生共振的振动源，压电纤维能够产生足够的能量，以最大效率供大量电子设备持续运行。

Reading Material

Advanced Ceramics: Clean Energy Through Ceramics (Ⅱ)

Wireless Sensor Networks

Sensors that measure everything from process temperatures to system pressures and machine vibrations have been historically expensive to **deploy** in manufacturing, infrastructure and industrial environments. The sensors require expensive wiring or batteries and are expensive to service as well. With the emergence of the new **ZigBee standard**, based on **IEEE** 802.15.4 (and other low-power **RF protocols**), the availability of large, low-cost, low-power wireless sensor networks (WSNs) that are self-managed is becoming a reality.

Sensors, **signal conditioners**, controllers and RF **transceivers** continue to become smaller,

lower power and more highly integrated. The combination of wireless networking, **intelligent sensors** and **distributed computing** has created a new **paradigm** for **monitoring** the health of machines, buildings and environments.

A low-cost, **renewable energy source** is critical to **ubiquitous deployment** of WSNs. New piezoelectric ceramic fiber-based energy harvesters will, in some cases, **obviate** the need for batteries in WSNs. In other cases, the harvesting technology can be used to recharge batteries to enhance service life.

The power comes from the vibration of the system being monitored. Piezo fiber-based products require no maintenance, significantly reduce life cycle costs, improve the overall quality of industrial and machine control, and enhance security systems by responding to pressures as small as sound pressure.

Fig. 3.4 shows an example of the PZT fiber acting as an energy harvester to convert waste mechanical energy into a self-sustaining power source for a ZigBee wireless sensor **node**①. The piezoelectric fiber captures the energy generated by the structure's vibration, compression or **flexure**. The resulting energy (after conversion to current) is used to charge a storage circuit that then provides the necessary power level for the sensor node electronics.

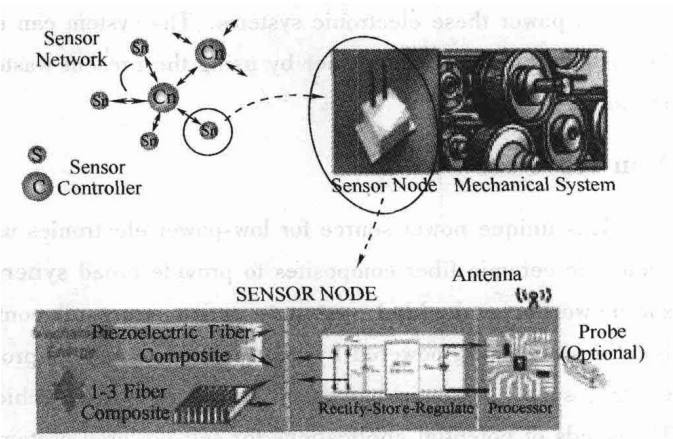


Fig. 3.4 Example of PZT fiber acting as an energy harvester to convert waste mechanical energy into a self-sustaining power source for a ZigBee wireless sensor node.

In this example, energy is harvested by the vibration of PZT fiber composites. The energy is converted and stored in a **low-leakage** charge circuit until a certain **threshold voltage** is reached. Once the threshold is reached, the **regulated power** is allowed to flow for a sufficient period to power the micro-controller and the RF data transmission.

Additional Applications

PFCs can convert mechanical energy directly into light energy with no intervening electronics. By harvesting energy from **ambient vibrations**, PFCs can provide **electroluminescent**, **LED** or **fluorescent** lighting on vehicles, **bridge decks**, **digital signage**, **buoys** and other low-power lighting loads using waste energy. Some of the frequencies of electroluminescent lights can be readily seen through smoke or fog and could serve as **signaling** devices that have no electromagnetic signature.

PFCs also offer solutions for **vibration damping** and structural **morphing**. To enable self-adjusting systems, a smart structure containing PFCs can sense a change in motion. The motion produces an electrical signal that can be sent to a control processor that measures the magnitude of the change in motion and returns an amplified signal that either **stiffens** or relaxes the active fiber **actua-**

tors/sensors[②]. Just a 2g PFC can create a 20lb **blocking** force.

For self-powered RFID tagging systems, incident evidence can be collected in a flash memory that is powered by the incident and then evaluated later, so that penetration, damage or other activities can be sensed and recorded without the need for external power sources. In addition, one version of the energy harvester can create a shoe-powered **GPS/homing beacon**. Identical devices can be easily installed on containers, **inventory** or other places where RFID is being considered for active **tracking**. Similar designs are being assembled for Homeland Security border control using tree or grass motion as the source of power for long-scale wireless sensor networks.

Unmanned aerial vehicles (UAVs) are finding wide use in many **surveillance** systems, and power sources for both guidance and **telemetry** have been a **nagging** problem. The batteries currently in use are heavy and fail frequently. One PFCB design uses vibrations from the engine and airframe to power these electronic systems. The system can either help keep the batteries charged longer or eliminate them altogether by using the present waste energy without **debiting** any ongoing operations.

You Have the Power

This unique power source for low-power electronics uses environmental energy and flexible piezoelectric ceramic fiber composites to provide broad **synergy** with many applications. Wireless sensor networks, **embedded systems**, active structural control and other mechanical and electronic functions are being powered by this technology and its products from ambient sources of mechanical energy, such as human movement, wind or water, vehicle passage, or unexpected occurrences. Thousands of potential applications for self-powered systems could take advantage of flexible piezoelectric fiber ceramic composites[③].

(Selected from *Advanced Cerametrics*,
by Richard Cass, Hyeoungwoo Kim, etc., 2008)

Questions

1. List several applications of PFCs.
2. What are UANs?
3. Describe the wireless sensor networks.

New Words and Expressions

1. deploy *vt.* & *vi.* (尤指军事行动) 使展开；施展；部署
2. ZigBee standard 紫蜂短距离无线传输标准
3. IEEE (=Institute for Electrical and Electronic Engineers) (美) 电气和电子工程师学会
4. RF(=Radio Frequency) 射频，无线电频率
5. protocol *n.* (条约等的) 草案；(外交的) 议定书；会谈记录；礼仪，礼节
6. signal conditioner 信号调节器

7. transceiver *n.* 无线电收发机，收发器
8. intelligent sensor 智能传感器
9. distributed computing 分布式计算（技术）
10. paradigm *n.* 典范，范例，示例；聚合体
11. monitoring *n.* 监视，控制，监测，追踪
12. renewable energy source 可再生能源
13. ubiquitous *adj.* 无所不在的，普遍存在的
14. deployment *n.* 展开，部署，调度
15. obviate *vt.* 消除；排除（障碍、危险等）；预防，避免
16. node *n.* 节，结，瘤；节点，波节（振动体的静止点）
17. flexure *n.* 屈曲，褶曲，弯曲（部）；曲线；曲率
18. low-leakage 低泄漏，低漏电
19. threshold *n.* 阈；阈值
20. threshold voltage 阈值电压
21. regulated power 稳压电源
22. ambient *adj.* 周围的，外界的
23. electroluminescent *adj.* 场致发光的，电致发光的
24. LED(= light-emitting diode) 发光二级管
25. fluorescent *adj.* 荧光性的，发荧光的
26. bridge deck 桥面
27. digital signage 数字标牌
28. buoy *n.* 浮标，航标，救生圈；*vt.* 使浮起，鼓励
29. signaling *n.* 打信号，发信号
30. vibration damping 减振
31. morphing *n.* 变形
32. stiffen *vt.* & *vi.* （使）变硬；变坚强，加强
33. actuator *n.* 致动器，传动装置［机构］；执行器；加载器
34. blocking *n.* 封闭，阻塞
35. GPS (= Global Position System) 全球定位系统
36. homing beacon 归航（无线电）信标
37. inventory *n.* 详细目录，存货清单
38. tracking *n.* 跟踪，探测
39. unmanned aerial vehicles 无人驾驶飞行器
40. surveillance *n.* 监视，监督，侦测
41. telemetry *n.* 遥测学；遥测技术［装置］，测距术
42. nagging *adj.* 唠叨不休的，责备的，挑剔的；恼人的
43. debit *n.* 借方，借；*vt.* 记入借方
44. synergy *n.* 协同，配合，企业合并后的协力优势或协合作用
45. embedded system 嵌入式系统

Notes

① Fig. 3.4 shows an example of the PZT fiber acting as an energy harvester to convert waste mechanical energy into a self-sustaining power source for a ZigBee wireless sensor node.

参考译文：图 3.4 示出了一个压电陶瓷纤维作为一种能源转换器，将浪费的机械能转换为 ZigBee 无线传感器节点的自续电源的例子。

② The motion produces an electrical signal that can be sent to a control processor that measures the magnitude of the change in motion and returns an amplified signal that either stiffens or relaxes the active fiber actuators/sensors.

参考译文：该运动能够产生一个电信号，可以发送到控制处理器，处理器测量运动变化的大小，并返回一个放大信号，该信号会加强或削弱纤维致动器/传感器的动作。

③ Thousands of potential applications for self-powered systems could take advantage of flexible piezoelectric fiber ceramic composites.

参考译文：对于成千上万的潜在的自供电系统的应用，可以采用灵活的压电陶瓷纤维复合材料。

科技英语翻译技巧（三）：常见多功能词 as 的用法

1. 肯定形式“as...as”译为“和……一样”“与……相同”“高达……”

These methods will reduce machining cost, which can be as much as 50% of the total manufacturing cost.

这些方法能够使得机加工成本降低到总成本的 1/2。

Surprisingly, the density of packing is only reduced to 68% so that the BCC structure is nearly as densely packed as the FCC and HCP structure.

奇怪的是，堆积的密度只降低了 32%，就可以使得 BCC 的结构排列像 FCC 和 HCP 一样紧密。

Rapid solidification technology can now produce metal alloy powders which have been rapidly cooled from the melt at rates as high as 1 million degrees Celsius per second.

快速的凝固技术能够制备金属粉末，这些粉末可以通过对熔融金属以高达 1×10^6℃/s 的速度冷却来获得。

2. 否定形式译为“和……不一样”“……不如……”“……不像……”

The Rockwell scale is therefore not as accurate as the Vickers scale in distinguishing small differences in hardness of hard materials.

因此，当硬材料的硬度值差别比较小的时候，洛氏硬度值就不像维氏硬度值那么准确。

However, the same type of notch does not give the same results on large section test pieces as are obtained on small sections.

但是，对于大工件和小工件而言，相同的切口并不能测出相同的结果。

3. “such as”译为“像……一样”或“比如”

Non-metallic elements such as carbon, nitrogen, and oxygen may also be contained in metallic materials.

在金属材料中也可能含有像碳、氮、氧一样的非金属元素。

Metals and alloys are commonly divided into two classes: ferrous metals and alloys that contain a large percentage of iron such as the steels and cast irons and nonferrous metals and alloys that do not contain iron or only a relatively small amount of iron.

金属和合金通常可分为两类：一种是黑色金属和合金，含有一定量的铁，比如：钢和铸铁；另一种是有色金属和合金，不含铁或者含非常少量的铁。

Microelectronic devices have made possible such new products as communication satellites, advanced computers, digital watches, and welding robots.

微电子设备可以使新的产品成为可能，比如：通信卫星、先进计算机、数字手表、焊接机器人。（同样译为“比如”，但为了句子结构的协调，避免头重脚轻，将 such as 放到了句子的最后，这与汉语的描述大相径庭。）

High energy radiation, such as neutrons produced in nuclear reactors, can affect the internal structure of all materials, producing a loss of strength, embrittlement, or critical alteration of physical properties.

高强度辐射，比如像核反应产生的中子，会对材料的内部结构产生影响，使材料强度降低、变脆，并改变物理性能的临界值。

4. as 引导让步状语从句，可译为“虽然……”“尽管……”

Complicated as the problem is, it can be worked out in a few minutes by a computer.

尽管那个问题很复杂，但计算机能在几分钟内将它解出。

5.“as soon as”译为“一旦……”

As soon as the current has reached a constant value, the induced e. m. f. disperses.

电流一旦到达恒值，感应电动势就消失。

In elastic behaviour, the strain produced in a stressed material is completely removed as soon as the stress is removed.

弹性行为中，一旦去掉应力，受力材料的应变会随之消失。

6.“as...”，as 引导定语从句，译为“正如……”

As might be expected, these additional requirement lead to more complex crystal structures.

正如期望的那样，这些附加的要求使得晶体结构更加复杂。

As stated previously, the Brinell hardness number is not reliable above 450 HBW.

如前面所讲，布氏硬度值超过 450HBW 结果就不可靠了。

7. as 表明的是一种状态，翻译的时候可以不译出来

The specimen is now ready for examination in the as-polished condition.

抛光的样品现在可以用来进行检测。

The as-cast ingot structure with its coarse grains is broken up.

具有粗糙晶粒结构的铸锭很容易断裂。

8.“... +as...”，as 作简单介词，译为“作为……”

These spaces then remain as micro-porosity with a characteristic shape.

然后，这些空间作为微孔保留下来成为一种特征形貌。

Hot working is the usual first stage of processing, while cold working processes are carried out as finishing operations on previously hot worked material.

热加工是加工过程常用的首要步骤，而冷加工则是作为热加工材料的最后成形步骤来进行。

In the Rockwell test the depth of the indentation is measured by the instrument and this is directly indicated on a dial as a hardness value.

在洛氏硬度测量中，压痕的深度是由仪器测量的，可以直接从表盘上读出来作为硬度值。

9.“……被动语态 + as + ……”，比如，“... defined as...”，“... known as...”等，译为“……定义为……”“……称之为……”

Stress is defined as the force divided by the cross sectional area on which the force acts.

应力就是施加在横截面上的力除以面积。

Solid substances can be classified as either amorphous or crystalline.

固体物质可以分为非晶体或晶体。

This relationship is known as Hooke's law.

我们称这种关系为胡克定律。

In crystalline substances, the atoms occur in a regular three dimensional pattern known as a space lattice.

在晶体结构中，原子呈现三维有序排列，我们称之为空间点阵。

When the metal first makes contact with the mould, the mould is cold and this has a chilling effect on the molten metal, which results in the formation of very small crystals, known as chill crystals, at the surface of the ingot.

当熔融金属与铸模开始接触后，冷铸模会对金属产生激冷作用，从而在铸锭表面形成非常小的晶体，我们称之为激冷晶体。

Chapter 4 Polymer Materials

4.1 Polymers

Conventional macromolecules (or polymers) **consist of a minimum of** several hundred covalently linked atoms and have molar masses clearly above 10^3 g/mol. **The degree of polymerization** P, and **the molecular weight** M, are the most important characteristics of macromolecular substances because nearly all properties in solution and in bulk depend on them. The degree of polymerization indicates how many monomer units are linked to form the polymer chain. The molecular weight of a **homopolymer** is given by the following equation.

$$M = PM_{ru}$$

where M_{ru} stands for the molar mass of the monomer **repeating unit**. While pure low-molecular-weight substances consist of molecules of identical structure and size, this is generally not the case for macromolecular substances. They, instead, consist of mixtures of macromolecules of **similar** structure but different degrees of polymerizations and molecular weights[①]. Therefore, they are called polydisperse. As a result of this polydispersity, the values of P and M are only mean values.

High molar masses and chain-like architectures result in properties quite different from those of low-molecular-weight substances. This maybe demonstrated for the case of polyethylene:

$$—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—$$

While chains having molecular weights of a few thousands only form **brittle waxes**, polyethylenes having molar masses of above hundred thousand show much better mechanical properties. They can be processed into films, pipes, and other **performance products**. When molar mass is further increased up to several millions, even higher **impact strengths** and **abrasion resistances** are achieved which enable these materials to be used in heavy-duty applications like skating floors and **artificial hips**.

Macromolecules may be classified according to different criteria. One criterion is whether the material is natural or synthetic in origin. **Cellulose**, **lignin**, **starch**, silk, wool, **chitin**, natural rubber, polypeptides (proteins), **polyesters** (polyhydroxybutyrate), and **nucleic acids** (DNA, RNA) are examples of naturally occurring polymers while **polyethylene**, **polystyrene**, **polyurethanes**, or **polyamides** are representatives of their synthetic counterparts. When natural polymers are modified by chemical conversions (cellulose→**cellulose acetate**, for example), the products are

called **modified natural polymers** (Fig. 4.1).

Another criterion is the chemical composition of the macromolecules: when containing only carbon, hydrogen, oxygen, nitrogen, halogens, and phosphorus, they are called **organic**. If they additionally contain metal atoms, or if they have a carbon-free main chain but organic lateral substituents —such as **polysiloxanes**, **polysilanes**, and **polyphosphazenes**—they are called organometallic or hybridic. Finally, if they do not contain carbon atoms at all—such as polymeric sulfur—they are called inorganic (Fig. 4.2).

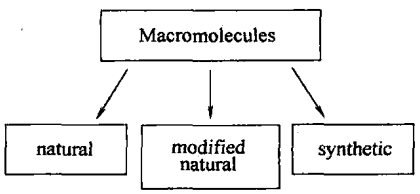


Fig. 4.1 Classification of macromolecules (Ⅰ)

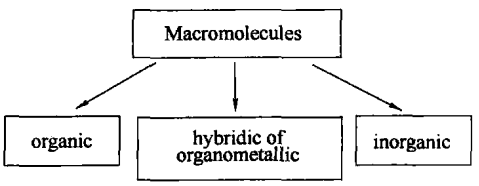


Fig. 4.2 Classification of macromolecules (Ⅱ)

At the same time, the macromolecules might be classified according to whether their chains have only one kind of atoms—like carbon—in the **backbone** (isochains) or different elements (heterochains). Concerning their chain architecture, polymers are subdivided into linear, branched, **comb-like**, crosslinked, **dendritic**, or **star-like** systems (Fig. 4.3)[②].

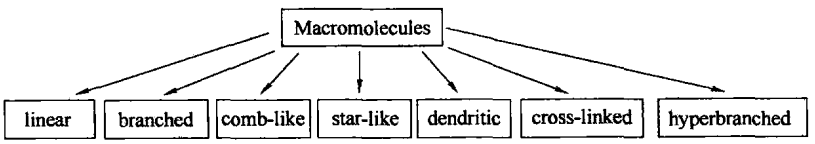


Fig. 4.3 Classification of macromolecules (Ⅲ)

Moreover, polymers are quite often classified according to the number of different types of monomers they are prepared from (Fig. 4.4). When produced from one single type of monomer, they are called a) homopolymers. If a second or third type of monomer is involved in the polymer synthesis, the resulting materials are called binary and ternary copolymers. In addition, a distinction is also made on how the different monomers are arranged in the resulting copolymer chains, distinguishing among others: b) **alternating-**, c) **statistic-**, d) **block-**, and e) **graft-copolymers**.

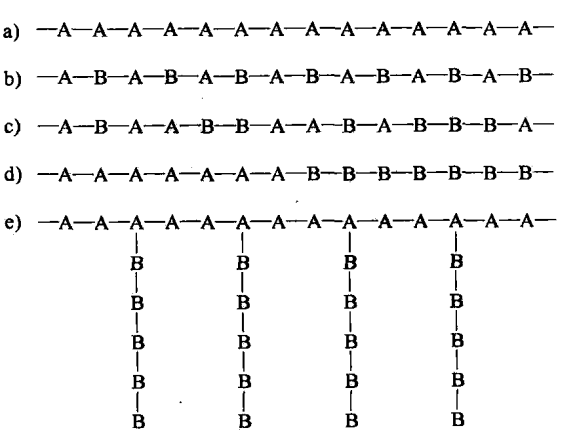


Fig. 4.4 Copolymer architectures

Finally, for practical reasons it is useful to classify polymeric materials according to where and how they are employed. A common subdivision is that into structural polymers and functional poly-

mers. Structural polymers are characterized by—and are used because of—their good mechanical, thermal, and chemical properties. Hence, they are primarily used as construction materials in addition to or in place of metals, ceramics, or wood in applications like plastics, fibers, films, elastomers, foams, paints, and adhesives. Functional polymers, in contrast, have completely different property profiles, for example, special electrical, optical, or biological properties. They can assume specific chemical or physical functions in devices for **microelectronic**, **biomedical applications**, analytics, synthesis, **cosmetics**, or **hygiene**.

(Selected from *Polymer Synthesis: Theory and Practice*, by Dietrich Braun, 2005)

Questions

1. What is a polymer?
2. What is the degree of polymerization, P?
3. Why can the polyethylene present different mechanical properties?
4. How are the polymers classified?
5. List several functional polymers.

New Words and Expressions

1. consist of 组成，由……构成
2. the degree of polymerization 聚合度
3. the molecular weight 分子量[⊖]
4. homopolymer 均聚物
5. repeating unit 重复单元
6. similar *adj.* 相像的，相仿的，类似的
7. brittle waxes 脆性蜡
8. performance product 高性能产品
9. impact strength 冲击强度
10. abrasion resistance 耐磨性
11. artificial hip 人工髋关节
12. cellulose *n.* 纤维素
13. lignin *n.* 木质素
14. starch *n.* 淀粉
15. chitin *n.* 甲壳素
16. polyester *n.* 聚酯，涤纶
17. nucleic acid 核酸
18. polyethylene *n.* 聚乙烯
19. polyurethane *n.* 聚氨酯

⊖书中分子量均指相对分子质量，不再一一注出。

20. polystyrene *n.* 聚苯乙烯
21. polyamide *n.* 聚酰胺
22. cellulose acetate 醋酸纤维素
23. organic *adj.* 有机体的，生物的
24. polysiloxane *n.* 聚硅氧烷
25. polysilane *n.* 聚硅烷
26. polyphosphazene *n.* 聚磷腈
27. backbone *n.* 主架
28. comb-like 梳状
29. dendritic *adj.* 树枝状的；树状的
30. star-like 星形
31. alternating-copolymer 交替共聚物
32. statistic-copolymer 无规共聚物
33. block-copolymer 嵌段共聚物
34. graft-copolymer 接枝共聚物
35. a minimum of 最低
36. microelectronic 微电子
37. biomedical application 生物医学应用
38. cosmetic *n.* 化妆品；装饰品
39. hygiene *n.* 卫生，保健

Notes

① They, instead, consist of mixtures of macromolecules of similar structure but different degrees of polymerizations and molecular weights.

参考译文：然而，这些物质是聚合度和分子量不同的高分子同系物的混合物。

② Concerning their chain architecture, polymers are subdivided into linear, branched, comb-like, crosslinked, dendritic, or star-like systems.

参考译文：根据链结构，聚合物分为线型、枝状、梳状、交联、树枝状或星形等类型。

③ In addition, a distinction is also made on how the different monomers are arranged in the resulting copolymer chains, distinguishing among others: b) alternating-, c) statistic-, d) block-, and e) graft-copolymers.

参考译文：此外，按照单体单元在共聚物大分子链中的排列顺序不同，还可以分为（b）交替、（c）无规、（d）嵌段以及（e）接枝共聚物。

Reading Material

Characterization of Macromolecules

For the unequivocal characterization of a low-molecular-weight compound, it is sufficient to specify a few physical or chemical properties, for example, boiling point, melting point, angle of

optical rotation, refractive index, elemental analysis, IR and NMR spectra. If two low-molecular-weight samples have the same characteristic properties, they may be considered as identical.

The characterization of macromolecular substances is considerably more difficult. Owing to the high intermolecular forces, macromolecules are not volatile without decomposition and so, no boiling point can be determined. The melting points of partially crystalline polymers are generally not sharp. Amorphous polymers frequently show only sintering or softening, often accompanied by decomposition. In addition to elemental analysis, other data must be determined, for example, solubility, viscosity of the solution, mean molecular weight, molecular weight distribution, and degree of crystallinity.

The fundamental difficulty is that polymeric substances cannot be obtained in a structurally and molecularly uniform state, unlike low-molecular-weight compounds①. Thus, macromolecular materials of the same analytical composition may differ not only in their structure and configuration but also in molecular size and molecular weight distribution; they are polydisperse, i. e., they consist of mixtures of molecules of different size②. Hence, it is understandable that the expression "identical" is not, in practice, applicable to macromolecules. Up to the present time, there is no possibility of preparing macromolecules of absolutely uniform structure and size. It follows, therefore, that physical measurements on polymers can only yield average values. The aforementioned peculiarities of macromolecular substances mean that the methods of characterization suitable for low-molecular-weight compounds are frequently not applicable or only applicable in a substantially modified form; often completely new methods of investigation must be employed③.

Since the properties of a polymer can be noticeably influenced by small variations in the molecular structure, and these in turn depend on the preparation conditions, it is necessary when reporting data to indicate not only the type of measurement (e. g., molecular weight by end group analysis; crystallinity by infrared measurement or by X-ray diffraction; etc.), but also the type of preparation (e. g., radical polymerization in bulk at 80 ℃; polymerization with a particular organometallic catalyst at 20 ℃).

(Selected from *Polymer Synthesis: Theory and Practice*, by Dietrich Braun, 2005)

Questions

1. Why is the characterization of macromolecular substances considerably more difficult?
2. What are polydisperse of polymer?
3. List several methods of characterization of macromolecular.

New Words and Expressions

1. boiling point 沸点
2. melting point 熔点
3. optical rotation 旋光度
4. refractive index 折射率

5. elemental analysis 元素分析
6. identical *adj.* 同一的，完全相同的
7. volatile *adj.* 易挥发的
8. amorphous polymer 非晶态聚合物
9. crystalline polymer 晶态聚合物
10. solubility *n.* 溶解度
11. viscosity *n.* 粘度
12. degree of crystallinity 结晶度
13. uniform state 统一状态
14. average value 平均值
15. end group analysis 端基分析法
16. infrared measurement 红外测量
17. X-ray diffraction X 射线衍射
18. organometallic catalyst 有机金属催化剂

Notes

① The fundamental difficulty is that polymeric substances cannot be obtained in a structurally and molecularly uniform state, unlike low-molecular-weight compounds.

参考译文：最根本的困难在于，和低分子量化合物不同，很难制得分子结构均一的聚合物。

② Thus, macromolecular materials of the same analytical composition may differ not only in their structure and configuration but also in molecular size and molecular weight distribution; they are polydisperse, i. e. , they consist of mixtures of molecules of different size.

参考译文：因此，相同分析成分的高分子材料不仅可能在结构和构形上不同，分子大小和分子量分布也会不同；它们多是分散的，即聚合物是不同大小分子的同系物的混合物。

③ The aforementioned peculiarities of macromolecular substances mean that the methods of characterization suitable for low-molecular-weight compounds are frequently not applicable or only applicable in a substantially modified form; often completely new methods of investigation must be employed.

参考译文：大分子物质的上述特性意味着，适用于低分子量化合物的表征方法对于大分子往往不能适用或只有经过重大修改后才适用；经常要采用全新的研究方法。

4.2 Methods for Synthesis of Polymers

Chain Polymerization

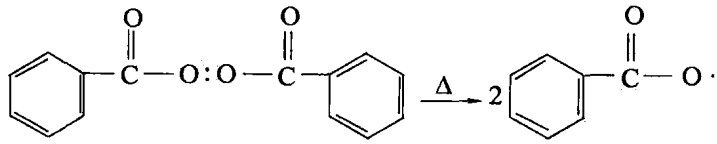
Polymers may be synthesized by two major **kinetic** schemes, chain and stepwise polymerization. The most important of the chain polymerization methods is called **free radical polymerization.**

1. Free Radical Polymerization

The synthesis of **poly(ethyl acrylate)** will be used as an example of free radical polymerization. **Benzoyl peroxide** is a common **initiator**. Free radical polymerization has three major kinetic steps—initiation, **propagation**, and **termination**①.

2. Initiation

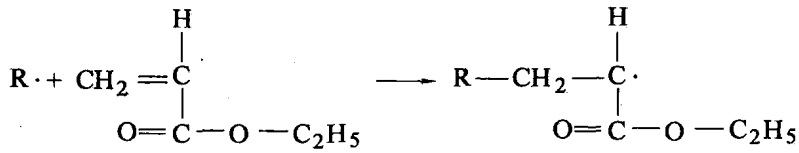
On heating, benzoyl peroxide **decomposes** to give two free radicals:



Benzoyl peroxide　　Free radical, R.

In this reaction the electrons in the oxygen-oxygen bond are **unpaired** and become the **active site**. With R representing a generalized organic chemical group, the free radical can be written R · . (It should be pointed out that hydrogen peroxide undergoes the same reaction on a wound, giving a burning sensation as the free radicals "kill the germs.")②

The initiation step usually includes the addition of the first monomer molecule:

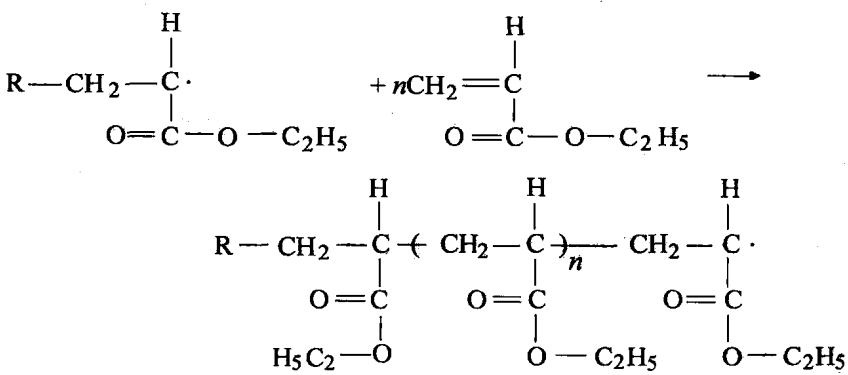


Free radical　　Ethyl acrylate　　Growing chain

In this reaction the free radical **attacks** the monomer and adds to it. The double bond is broken open, and the free radical reappears at the far end.

3. Propagation

After initiation **reactions**, many **monomer** molecules are added rapidly, perhaps in a fraction of a second:

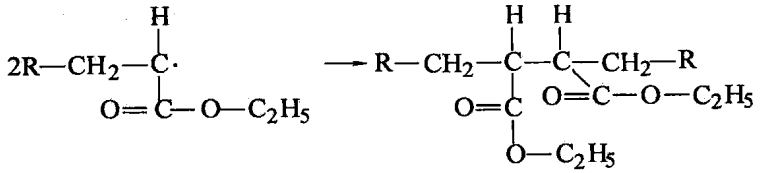


On the addition of each monomer, the free radical moves to the end of the chain.

4. Termination

In the termination reaction, two free radicals react with each other. Termination is either by

combination,

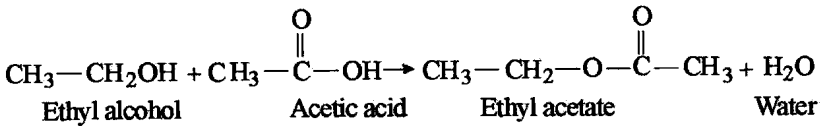


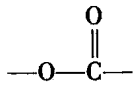
where R now represents a long-chain portion, or by **disproportionation**, where a hydrogen is transferred from one chain to the other. This latter result produces in two final chains. While the normal mode of addition is a head-totail reaction, this termination step is normally head-to-head.

As a **homopolymer**, poly(ethyl acrylate) is widely used as an **elastomer** or adhesive, being a polymer with a low T_g, −22℃. As a **copolymer** with other acrylics, it is used as a **latex paint**.

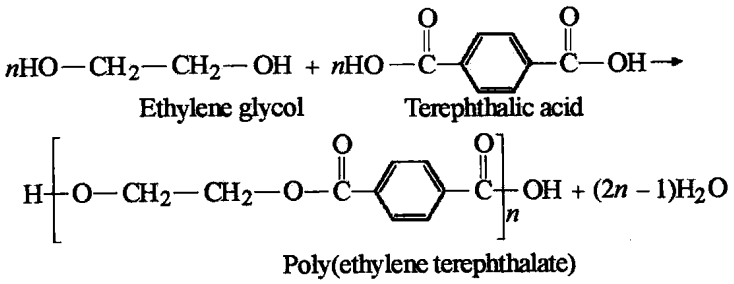
Step Polymerization

The second important kinetic scheme is step polymerization. As an example of a step polymerization, the synthesis of a **polyester** is given. The general reaction to form esters starts with an acid and an alcohol:

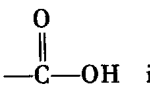
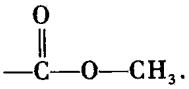


where the ester group is  , and water is eliminated.

The chemicals above cannot form a polyester because they have only one **functional group** each. When the two **reactants** each have **bifunctionality**, a **linear polymer** is formed:



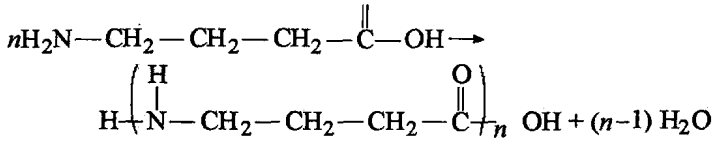
In the stepwise reaction scheme, monomers, **dimers**, **trimers**, and so on, may all react together. All that is required is that the appropriate functional groups meet in space[3]. Thus the molecular weight slowly climbs as the small molecule water is eliminated. Industrially,

 is replaced by  . Then, the reaction is an ester interchange, releasing **methanol**.

Poly(ethylene terephthalate) is widely known as the fiber Dacron®. It is highly **crystalline**,

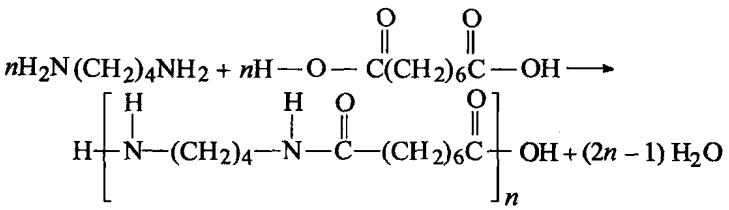
with a melting temperature of about +265℃.

Another well-known series of polymers made by step polymerization reactions is the **polyamides**, known widely as the nylons. In fact there are two series of nylons. In the first series, the monomer has an amine at one end of the molecule and a carboxyl at the other. For example,



which is known as **nylon-4**. The number 4 indicates the number of carbon atoms in the mer.

In the second series, a **dicarboxylic acid** is reacted with a **diamine**:



which is named nylon 48. Note that the **amine** carbon number is written first, and the acid carbon number second. For reaction purposes, **acyl chlorides** are frequently substituted for the **carboxyl** groups.

(Selected from *Introduction to Physical Polymer Science*, by L. H. Sperling, 2006)

Questions

1. What is the chain polymerization?
2. What is the step polymerization?
3. List several free radical initiators.
4. Distinguish the combination termination and the disproportion termination.
5. Describe the synthesis of polyamide 610 from the monomers.

New Words and Expressions

1. kinetic *adj.* 动力学的
2. free radical polymerization 自由基聚合
3. poly (ethyl acrylate) 聚(丙烯酸乙酯)
4. benzoyl peroxide 过氧化苯甲酰
5. initiator *n.* 引发剂
6. propagation *n.* 增长
7. termination *n.* 终止
8. decompose *n.* 分解

9. unpaired *adj.* 未配对的
10. active site 活性点，活性中心
11. attack *v.* 攻击
12. react *v.* 反应
13. monomer *n.* 单体
14. combination *n.* 结合，联合
15. disproportionation *n.* 歧化（终止），不均匀
16. homopolymer *n.* 均聚物
17. T_g（= glass transition temperature） 玻璃化转变温度
18. copolymer *n.* 共聚物
19. latex paint 乳胶漆
20. polyester *n.* 聚酯；涤纶
21. functional group 官能团
22. reactant *n.* 反应物
23. bifunctionality 双官能度
24. linear polymer 线性聚合物
25. *dimmers* *n.* 二聚体
26. trimers *n.* 三聚体
27. methanol *n.* 甲醇
28. poly（ethylene terephthalate） 聚（对苯二甲酸乙二醇酯）
29. crystalline *adj.* 结晶的
30. polyamides *n.* 聚酰胺
31. nylon *n.* 尼龙
32. dicarboxylic acid 二羧酸
33. diamine *n.* 二胺
34. amine *n.* 胺（类）
35. acyl chloride 酰氯
36. carboxyl *n.* 羧基
37. elastomer *n.* 弹性体

Notes

① Free radical polymerization has three major kinetic steps—initiation, propagation, and termination.

参考译文：自由基聚合主要有三大动力学步骤——链引发、链增长和链终止。

② It should be pointed out that hydrogen peroxide undergoes the same reaction on a wound, giving a burning sensation as the free radicals "kill the germs."

参考译文：应该指出，过氧化氢在处理伤口时会发生相同反应，当自由基"杀灭细菌"时产生灼热感。

③ In the stepwise reaction scheme, monomers, dimers, trimers, and so on, may all react to-

gether. All that is required is that the appropriate functional groups meet in space.

参考译文：逐步反应中，单体、二聚体、三聚体等，都可能相互发生反应，条件是体系中存在适当的官能团。

Reading Material

Natural Product Polymers

Living organisms make many polymers, nature's best. Most such **natural** polymers strongly **resemble** step polymerized materials①. However, living **organisms** make their polymers enzymatically, the structure ultimately being controlled by DNA, itself a polymer.

Some of the more important commercial natural polymers are shown in Table 4.1. People sometimes refer to these polymers as natural products or **renewable resources**.

Table 4.1 Some natural product polymers

Name	Source	Application
Cellulose	Wood, cotton	Paper, clothing, rayon, cellophane
Starch	Potatoes, corn	Food, thickener
Wool	Sheep	Clothing
Silk	Silkworm	Clothing
Natural rubber	Rubber tree	Tires
Pitch	Oil deposits	Coating, roads

Wool and silk are both proteins. All **proteins** are actually copolymers of polyamide-2 (or nylon-2, old terminology). As made by plants and animals, however, the copolymers are highly ordered, and they have **monodisperse** molecular weights, meaning that all the chains have the same molecular weights.

Cellulose and starch are both **polysaccharides**, being composed of chains of **glucose**-based rings but bonded differently.

Natural rubber, the **hydrocarbon polyisoprene**, more closely resembles chain polymerized materials. In fact synthetic polyisoprene can be made either by free radical polymerization or **anionic polymerization**②. The natural and synthetic products compete commercially with each other.

Pitch, a **decomposition** product, usually contains a variety of **aliphatic** and **aromatic hydrocarbons**, some of very high molecular weight.

(Selected from *Introduction to Physical Polymer Science*, by L. H. Sperling, 2006)

Questions

1. What are natural product polymers?
2. List several natural product polymers.
3. What is DNA?
4. Show the structure of the natural rubber.

New Words and Expressions

1. natural *adj.* 天然的
2. resemble *vt.* 像，类似
3. organism *n.* 生物，有机体
4. cellulose *n.* 纤维素
5. starch *n.* 淀粉
6. pitch *n.* 沥青
7. renewable resource 可再生资源
8. protein *n.* 蛋白质
9. monodisperse *adj.* 单分散的
10. polysaccharide *n.* 多糖
11. glucose *n.* 葡萄糖
12. hydrocarbon *n.* 碳氢化合物
13. polyisoprene *n.* 聚异戊二烯
14. anionic polymerization 阴离子聚合
15. decomposition 分解
16. aliphatic *adj.* 脂肪族的
17. aromatic *adj.* 芳香族的

Notes

① Most such natural polymers strongly resemble step polymerized materials.

参考译文：大多数这样的天然聚合物很像逐步聚合材料。

② In fact synthetic polyisoprene can be made either by free radical polymerization or anionic polymerization.

参考译文：事实上，既可通过自由基聚合的方法，也可通过阴离子聚合的方法来合成聚异戊二烯。

4.3 Processing of Polymers

Processing of a polymer can be performed with the polymer in various states of aggregation: in solution, in dispersion, and in the melt. The method chosen will depend on whether the polymer melts without **decomposition** and whether it is soluble. However, the nature of the application is also decisive. In practice a **molded object** can be prepared from a **thermoplastic** only via the melt, while for **textile coatings** the only feasible method is to process from solution or dispersion[①]. But processing of polymers is not only of industrial interest. A previous processing step is also necessary for many physical and chemical investigations, which only can be done with a well-defined test **specimen**. Although suitable equipment is available for injection molding and extrusion on the laboratory scale which require amounts of substances in the range of 5 to 1,000 g, the following simpler meth-

ods suffice for preliminary investigations.

Melt Processing of Polymers

The processing of polymers in the melt is the method most extensively used in technology. It is an essential requirement that the product does not undergo any significant degradation at the high processing temperature and under **shear**. The processing temperature must generally be considerably higher than the softening or melting temperature in order to reduce the high viscosity of the polymer melt. In this processing technique the polymer is heated above its melting or softening point, the viscous melt is brought into the desired form by mechanical forces and the formed object is finally cooled. This procedure is very widely applicable and allows the preparation of objects in practically any size or shape, for example, of molded bodies (by **pressing**, **injection molding**, or **extrusion**), of films and sheets (by extrusion and **calendering**), and of fibers (by extrusion).

Polymers that are difficult to process in the melt, either because the **melt viscosity** is too high or because they decompose, can often be processed at low temperatures through the addition of a **plasticizer**, leading to improved flow properties and lower processing temperature.

Processing of Polymers from Solution

If suitable equipment for processing the polymer melt is not available, or if the polymer will not melt, or melts only with decomposition, the processing may be carried out from solution. This technique, however, is limited to the fabrication of films, **membranes**, **fibers**, **coatings**, and **adhesives**.

(Selected from *Polymer Synthesis: Theory and Practice*, by Dietrich Braun, 2005)

Questions

1. How many methods of processing of a polymer are mentioned in the text?
2. Why is the conventional grinding in a mortar usually ineffective to a polymer?
3. What is a plasticizer?
4. Describe the processing of polymers from solution.

New Words and Expressions

1. decompose *n.* 分解
2. molded object 模塑对象
3. thermoplastic 热塑性塑料
4. textile coating 纺织涂层
5. specimen *n.* 样品，样本
6. shear *n.* 切变
7. pressing molding 模压成型
8. injection molding 注射成型

9. extrusion molding 挤压成型
10. calendaring *n.* 压延
11. melt viscosity 熔体粘度
12. plasticizer *n.* 增塑剂
13. membrane *n.* 薄膜，膜状物
14. fiber *n.* 纤维
15. coating *n.* 涂料
16. adhesive *n.* 胶粘剂

Notes

① In practice a molded object can be prepared from a thermoplastic only via the melt, while for textile coatings the only feasible method is to process from solution or dispersion.

参考译文：实践中可以由一种热塑性塑料通过熔融来制备模塑品，而纺织涂层只能通过溶液或分散状态来生产。

Reading Material

Thermoplastic Elastomers

These new materials contain physical cross-links rather than chemical cross-links. A physical cross-link can be defined as a **non-covalent bond** that is **stable** under one condition but not under another. **Thermal stability** is the most important case. These materials behave like cross-linked elastomers at **ambient temperatures** but as linear polymers at **elevated temperatures**, having **reversible properties** as the temperature is raised or lowered①.

The most important method of introducing physical cross-links is through **block copolymer** formation②. At least three blocks are required. The simplest structure contains two hard blocks (with a T_g or T_f above ambient temperature) and a soft block (with a low T_g) in the middle. The soft block is amorphous and above T_g under **application temperatures**, and the hard block is glassy or crystalline.

The thermoplastic elastomers depend on **phase separation** of one block from the other, which **in turn** depends on the very low **entropy** gained on mixing the blocks. The elastomeric phase must form the **continuous phase** to produce rubbery properties; thus the center block has a higher molecular weight than the two end blocks combined.

Examples of the thermoplastic elastomers include polystyrene-*block*-**polybutadiene**-*block*-polystyrene (SBS) or the **saturated** center block counterpart (SEBS). In the latter, the EB stands for **ethylene-butylene**, where a combination of 1,2 and 1,4 copolymerization of butadiene on hydrogenation presents the appearance of a **random copolymer** of ethylene and butylene.

Important applications of the triblock and its cousins, the starblock copolymer thermoplastic elastomers, include the rubber soles of running shoes and sneakers and **hot melt adhesives**. In the former application, **sliding friction** generated heat momentarily turns the elastomer into an adhe-

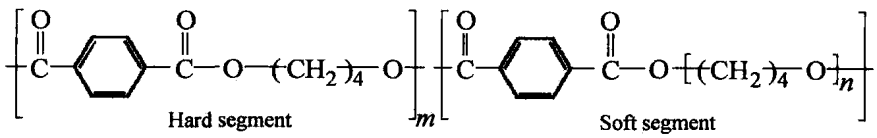
sive, reducing slips and falls. When sliding stops, the sole surface cools again, regenerating the rubber.

The so-called segmented **polyurethanes** form thermoplastic elastomers of the $-(AB)_n$ type, where A is usually a **polyether** such as **poly(ethylene oxide)** and B contains aromatic urethane groups (142,143). These polyurethanes make excellent **elastic fibers** that stretch about 30% and are widely used in undergarments under the trade names **Spandex®** and **Lycra®**.

The literature distinguishes various kinds of polyurethanes. There are those that are not thermoplastic elastomers, often densely **cross-linked**. These need not be elastomeric at all.

The **thermoplastic elastomer** polyurethanes, TPU, may be of two general types: partly crystalline elastic fibers (see preceding paragraph) or softer elastomers, depending on the relative length of the soft segment. Those polyurethanes based on polyester soft segments tend to **be more resistant to hydrocarbons**, while the polyether types are more resistant to **hydrolysis** but tend to **swell** more **in aqueous environments.**

A newer type of $(AB)_n$ block copolymer, known as the poly(ether-ester) elastomers and sold as Hytrel®, contains alternating blocks of poly(butylene oxide) and **butylene terephthalate** as the soft and hard blocks, respectively:



Usually $m = 1$ or 2, and $n = 40 \sim 60$; thus the soft segment is much longer than the hard segment. The hard blocks crystallize in this case.

(Selected from *Introduction to Physical Polymer Science*, by L. H. Sperling, 2006)

Questions

1. What are thermoplastic elastomers?
2. List some methods of introducing physical cross-links.
3. Do you know Spandex® and Lycra®? Describe their structures and advantages.

New Words and Expressions

1. non-covalent bond 非共价键
2. stable *adj.* 稳定的，牢固的；平稳的
3. thermal stability 热稳定性
4. ambient temperature 常温
5. elevated temperature 高温
6. reversible properties 可逆性质
7. block copolymer 嵌段共聚物
8. application temperature 适用温度

9. phase separation 相分离
10. in turn 反过来
11. entropy 熵（热力学函数）
12. continuous phase 连续相
13. polybutadiene *n.* 聚丁二烯
14. saturated *adj.* 饱和的
15. ethylene-butylene 乙烯-丁烯
16. random copolymer 无规共聚物
17. hot melt adhesive 热熔胶
18. sliding friction 滑动摩擦
19. polyurethane *n.* 聚氨酯
20. polyether *n.* 聚醚
21. poly（ethylene oxide） 聚（环氧乙烷）
22. elastic fiber 弹性纤维
23. Spandex *n.* 氨纶
24. Lycra *n.* 莱卡
25. cross-linked 交联的
26. thermoplastic elastomers 热塑性弹性体
27. be resistant to 能抗，耐
28. hydrocarbon 碳氢化合物
29. swell *v.* 膨胀
30. in aqueous environments 水环境
31. butylene terephthalate 对苯二甲酸丁二醇酯

Notes

① These materials behave like cross-linked elastomers at ambient temperatures but as linear polymers at elevated temperatures, having reversible properties as the temperature is raised or lowered.

参考译文：这些材料在常温下像交联弹性体，但在高温下像线性聚合物，随着温度升高或降低，具有可逆性。

② The most important method of introducing physical cross-links is through block copolymer formation.

参考译文：引入物理交联最重要的方法是通过嵌段共聚物的制备。

科技英语翻译技巧（四）：常见多功能词 it 的用法

1. it 作人称代词时，译成“它”或者译出所指代的名词

When a force (or load) is applied to material, it produces a stress in the material.

当对材料施加载荷时，它会产生应力。（译为“它”，指代载荷）

We are always interested in how the material behaves when it is exposed to sudden intense blow (impact).

我们常常对材料突然承受强烈的冲击时显示怎样的性能有兴趣。（译出所指代的名词）

The dislocation can move through the crystal until it emerges at one edge to produce a step.

位错沿着晶体移动直到它在一边产生台阶。（译为“它”，指代位错）

The rate at which a molten metal is cooling when it reaches its freezing point affects the size of the crystals which form.

熔融金属达到凝固点时冷却的速率会影响到形成的晶粒的尺寸。（译出所指代的名词）

2. 作指示代词时，译成“这”“那”“这件事”，译出所指代的内容

Plastic deformation can occur by twinning. It is most easily achieved in c. p. h. metals.

孪晶能产生塑性变形。这种现象最容易出现在密排六方晶体中。（it 指代这种现象）

It can be seen that when a metal is stressed beyond its elastic limit, plastic deformation occurs.

我们能看到，当金属承受应力超出它的弹性极限时，就会发生塑性变形。

3. 作无人称代词时，如表示自然现象、时间、距离等，可省略不译出

It is far to the school.

到学校很远。（不译）

It is raining.

下雨了。（不译）

It is time to school.

上学的时间到了。

4. it 作形式主语，译出实际主语代替

It is usual in such illustrations to represent atoms as solid spheres and to ignore the atomic structure.

像这样用实心球代表原子而忽视原子结构的图是很常见的。

In order to completely define the structure of a particular metal it is necessary to state the type of crystal structure and the dimensions of the unit cell.

为了完全确定金属结构，必须确定出晶体结构类型和单胞的尺寸。

5. it 作形式宾语时，it 无实际意义，不必译出

The invention of radio has made it possible for mankind to communicate with each other over along distance.

无线电的发明使人类有可能进行远距离通信联络。

6. it 在强调句中，通常译为“正是”“就是”“只是”等词

It is to reduce accidents that safety valves are designed.

正是为了减少事故，才设计了安全阀。

It was this engineer who improved the molding technology.

就是这个工程师改进了成型工艺。

7. 在 it is（was）not until... 强调时间状语的句型中，通常译为“直到……才……”

It was not until 1，500 BC that glass was produced independently of ceramics and fashioned into separate items.

直到公元前 1500 年，玻璃才开始独立于陶瓷，形成独立的项目。

It was not until the industrial revolution that the modern polymer industry began to develop.

直到工业革命，现代高分子工业才开始发展。

8. 强调一个状语从句时，翻译中应表现出状语从句

It is only when the engineers recognize the type of loading to which the material is exposed that they can choose the materials correctly.

工程师只有很清楚材料承受载荷的类型，才能正确选择材料。（强调条件状语）

It is because the carbon content of the core（0. 15%）and the case（0. 8%）are different that two treatment temperatures are necessary.

正是因为心部和表面的含碳量不同，才需要两个热处理温度。（强调原因状语）

Chapter 5 Composites

5.1 Composite Basics—Material System

Modern structural composites, frequently referred to as "Advanced Composites", are a blend of two or more components, one of which is made up of **stiff**, long fibers, and the other, a **binder** or "matrix" which holds the **fibers** in place. The fibers are strong and stiff relative to the **matrix** and are generally **orthotropic** (having different properties in two different directions). The fiber, for advanced structural composites, is long, with length to diameter ratios of over 100. The fiber's strength and stiffness are usually much greater, perhaps several times more, than the matrix material. The matrix material can be **polymeric** (e.g., **polyester resins**, epoxies), metallic, ceramic or carbon. When the fiber and the matrix are joined to form a composite they retain their individual identities and both directly influence the composite's final properties. The resulting composite will generally be composed of layers (laminate) of the fibers and matrix stacked to achieve the desired properties in one or more directions.

The high strength or stiffness to weight ratios of advanced composites are well known, but there are other advantages also (Table 5.1).

Table 5.1 Advantages/disadvantages of advanced composites

Advantages	Disadvantages
Weight reduction	Cost of raw materials and **fabrication**
High strength or stiffness to weight ratio	
Tailorable properties	Transverse properties may be weak
Can tailor strength or stiffness to be in the load direction	
Redundant load paths (fiber to fiber)	Matrix is weak, low toughness
Longer life (no corrosion)	Reuse and disposal may be difficult
Lower manufacturing costs because of less part count	Difficult to attach
Inherent damping	Analysis is difficult
Increased (or decreased) thermal or electrical conductivity	Matrix subject to environmental

These advantages translate not only into aircraft, but into everyday activities, such as longer drives with a graphite-shafted golf club (because more of the mass is concentrated at the clubhead) or less fatigue and pain because a graphite composite tennis racquet has inherent damping[①]. Generally, the advantages **accrue** for any fiber/composite combination and disadvantages are more obvious with some. These advantages have now resulted in many more reasons for composite use. Proper design and material selection can **circumvent** many of the disadvantages.

An advanced composite **laminate** can be tailored so that the directional dependence of strength and stiffness matches that of the loading environment. To do that, layers of unidirectional material called laminae are oriented to satisfy the loading requirements. These laminae contain fibers and a matrix. Because of the use of directional laminae, the tensile, flexural and torsional shear properties of a structure can be disassociated from one another to some extent and a golf shaft, for example, can be changed in torsional stiffness without changing the flexural or tensile stiffness.

Fibers can be of the same material within a lamina or several fibers mixed (hybrid). The common commercially available fibers are as follows:

- **fiberglass**;
- graphite;
- **aramid**;
- polyethylene;
- **boron**;
- **silicon** carbide;
- silicon nitride, silica, alumina, **alumina silica**.

The advantages of fiberglass are its high tensile strength and strain to failure, but heat and fire resistance, chemical resistance, moisture resistance and thermal and electrical properties are also cited as reasons for its use. It is by far the most widely used fiber, primarily because of its low cost; but its mechanical properties are not comparable with other structural fibers.

Carbon/graphite fibers have demonstrated the widest variety of strengths and modulii and have the greatest number of suppliers. The fibers begin as an organic fiber, **rayon**, **polyacrylonitrile** or **pitch** which is called the **precursor**[②]. The precursor is then stretched, oxidized, carbonized and graphitized. There are many ways to produce these fibers, but the relative amount of exposure at temperatures from 2,500 to 3,000℃ results in greater or less graphitization of the fiber. Higher degrees of graphitization usually result in a stiffer fiber (higher **modulus**) with greater electrical and thermal conductivities and usually higher cost.

The organic fiber Kevlar 49, also called aramid, essentially revolutionized pressure vessel technology because of its great tensile strength and consistency coupled with low density, resulting in much more weight effective designs for rocket motors. Aramid composites are still widely used for pressure vessels but have been largely supplanted by the very high strength graphite fibers. Aramid composites have relatively poor shear and compression properties; careful design is requires for their use in structural applications that involve bending or compression.

The polyethylene fibers have the same property drawbacks as aramids, but also suffer from low

melting temperature which limits their use to composites that cure or operate below 149℃ (300℉) and a **susceptibility** to degradation by ultraviolet light exposure. Both of these types of fibers have wide usage in personal protective armor. In spite of the drawbacks, production of both of these fibers is enjoying strong worldwide growth.

Boron fibers, the first advanced composite fibers to be used on production aircraft, are produced as individual **monofilaments** upon a **tungsten** or carbon **substrate** by **pyrolytic** reduction of boron trichloride (BCL_3) in a sealed glass chamber. The relatively large cross section fiber is used today primarily in metal matrix composites which are processed at temperatures which would attack carbon/graphite fibers.

The functions and requirements of the matrix are to:

- keep the fibers in place in the structure;
- help to distribute or transfer loads;
- protect the **filaments**, both in the structure and before and during fabrication;
- control the electrical and chemical properties of the composite;
- carry interlaminar shear.

The needs or desired properties of the matrix, that depend on the purpose of the structure are:

- minimize moisture absorption;
- have low shrinkage;
- must wet and bond to fiber;
- low coefficient of thermal expansion;
- must flow to **penetrate** the fiber bundles completely and eliminate voids during the **compacting/curing** process;
- have reasonable strength, modulus and elongation (elongation should be greater than fiber);
- must be elastic to transfer load to fibers;
- have strength at elevated temperature (depending on application);
- have low temperature capability (depending on application);
- have excellent chemical resistance (depending on application);
- be easily processable into the final composite shape;
- have dimensional stability (maintain its shape).

There are many matrix choices available; each type has impact on the processing technique, physical and mechanical properties and environmental resistance of the finished composite. The common **thermoset** matrices for composites include the following:

- polyester and **vinylesters**;
- epoxy;
- **bismaleimide** (BMI);
- **polyimide**;
- **cyanate ester** and **phenolic** triazine.

Each of the resin systems has some drawbacks, which must be accounted for in design and

manufacturing plans.

Polyester matrices have been in use for the longest period, and are used in the widest range and greatest number of structures. The usable polymers may contain up to 50% by weight of **unsaturated monomers** and **solvents** such as **styrene**. Polyesters cure via a **catalyst** (usually a **peroxide**) resulting in an **exothermic** reaction, which can be **initiated** at room temperature.

The most widely used matrices for advanced composites have been the epoxy resins. These **resins** cost more than polyesters and do not have the high temperature capability of the bismaleimides or polyimides, but because of the advantages they are widely used.

(Selected from *Handbooks of Composites*, by S. T. Peters, 1998)

Questions

1. Describe the functions and requirements of the matrix.
2. List several common thermoset matrices for composites.
3. What are Modern structural composites?
4. List several advantages of fiberglass.

New Words and Expressions

1. composite *n.* 复合材料
2. stiff *adj.* 刚性的
3. binder *n.* 粘结剂
4. fiber *n.* 纤维
5. matrix *n.* 基体
6. orthotropic *adj.* 各向异性的
7. polymeric *adj.* 聚合的，聚合体的
8. polyester *n.* 聚脂
9. fabrication *n.* 制作，构成
10. tailorable *adj.* （衣料等）可裁制的
11. redundant *adj.* 多余的，过剩的
12. inherent *adj.* 固有的，内在的
13. accrue *v.* 增加，增长
14. circumvent *v.* 设法克服或避免（某事物）；回避
15. damping *n.* 阻尼，减幅，衰减
16. laminate *n.* 层压材料，层压板
17. fiberglass *n.* 玻璃纤维，玻璃丝
18. aramid *n.* 芳族聚酰胺，芳纶
19. boron *n.* 〈化〉硼
20. silicon *n.* 〈化〉硅
21. alumina *n.* 氧化铝，矾土

22. alumina silica 硅铝矾土硅石
23. rayon *n.* （美）人造丝，人造纤维，人造丝织物，人造纤维织物
24. polyacrylonitrile *n.* 聚丙烯腈（纤维）
25. pitch *n.* 沥青
26. precursor *n.* 先驱，先行者；先兆，前驱体
27. modul *n.* 模量
28. susceptibility *n.* 易受影响或损害的状态
29. monofilament *n.* 单（根长）丝，单纤（维）丝
30. tungsten *n.* <化>钨
31. substrate *n.* （供绘画、印刷等的）底面，基底
32. pyrolytic *adj.* 热解的
33. filament *n.* 长丝，单丝，长纤维
34. penetrate *v.* 渗透，渗入
35. compacting *n.* 压实，压制，（加）压（模）塑
36. cure *v.* 硬化，固化
37. thermoset *n.* 热固性树脂，热固性塑料；*adj.* 热固性的
38. vinylester *n.* 乙烯酯树脂
39. bismaleimide *n.* 双马来酰亚胺
40. polyimide *n.* 聚酰亚胺
41. cyanate *n.* 氰酸盐
42. cyanate ester 氰酸酯
43. phenolic *adj.* 酚的，石碳酸的
44. unsaturated *adj.* 没有饱和的，不饱和的
45. monomer *n.* 单体
46. solvent *n.* 〈化〉溶剂
47. styrene *n.* 苯乙烯
48. catalyst *n.* 〈化〉催化剂，触媒
49. peroxide *n.* 过氧化氢，过氧化物
50. exothermic *adj.* 发热的，放出热量的
51. initiate *v.* 引发
52. resin *n.* 树脂

Notes

① These advantages translate not only into aircraft, but into everyday activities, such as longer drives with a graphite-shafted golf club (because more of the mass is concentrated at the clubhead) or less fatigue and pain because a graphite composite tennis racquet has inherent damping.

参考译文：复合材料的优异性能使之不仅应用于飞行器，而且应用于日常生活，譬如：用石墨复合材料制造的高尔夫球杆击球更远（因为更多的质量集中在杆头），因石墨复合材料制造的网球拍存在固有阻尼，可以减轻球手的疲劳。

② . . . , rayon, polyacrylonitrile or pitch which is called the precursor.

参考译文：……、粘胶纤维、聚丙烯腈纤维或沥青纤维等都是碳纤维的前驱体。

Reading Material

Polymer-matrix Composites

Polymer-matrix composites are much easier to fabricate than metal-matrix, carbon-matrix, and ceramic-matrix composites, whether the polymer is a thermoset or a thermoplast. This is because of the relatively low processing temperatures required for fabricating polymer-matrix composites. For thermosets, such as epoxy, phenolic, and **furfuryl** resin, the processing temperature typically ranges from room temperature to about 200℃; for **thermoplasts**, such as polyimide (PI), **polyethersulfone** (PES), **polyetheretherketone** (PEEK), **polyetherimide** (PEI), and **polyphenyl sulfide** (PPS), the processing temperature typically ranges from 300 to 400℃.

Thermosets (especially epoxy) have long been used as polymer **matrices** for carbon fiber composites. During curing, usually performed in the presence of heat and pressure, a thermoset resin hardens gradually due to the completion of **polymerization** and the **cross-linking** of the **polymer** molecules. Thermoplasts have recently become important because of their greater **ductility** and processing speed compared to thermosets, and the recent **availability** of thermoplasts that can withstand high temperatures. The higher processing speed of thermoplasts is due to the fact that thermoplasts soften immediately upon heating above the glass transition temperature (T_g) and the softened material can be shaped easily. Subsequent cooling completes the processing. In contrast, the curing of a thermoset resin is a reaction which occurs gradually.

Epoxy is by far the most widely used polymer matrix for carbon fibers. Epoxy has an excellent combination of mechanical properties and corrosion resistance, is dimensionally stable, exhibits good adhesion, and is relatively inexpensive. Moreover, the low molecular weight of uncured epoxide resins in the liquid state results in exceptionally high molecular mobility during processing. This mobility enables the resin to quickly wet the surface of carbon fiber.

The curing of an epoxy resin requires a cross-linking agent and/or a catalyst. The epoxy and **hydroxyl** groups (-OH) are the reaction sites for cross-linking. Cross-linking agents include **amines**, **anhydrides**, and **aldehyde** condensation products. In the curing reaction, the epoxide ring is opened (called ring **scission**) and a donor **hydrogen** from, say, an amine or hydroxyl group bonds with the **oxygen** atom of the **epoxide** group①. **Ethylene diamine** is an amine which serves as a cross-linking agent.

Semicrystalline thermoplasts (e. g., PEEK) are more efficiently reinforced than are **amorphous** thermoplasts (e. g., PES). This is because the fibers act as nucleation sites for crystallization; the fiber becomes surrounded by a microcrystalline structure, which binds the fiber more firmly to the polymer and improves the modulus. Furthermore, the degree of reinforcement increases with the degree of crystallinity.

The addition of fibers increases the softening temperature of a thermoplast and the effect is grea-

ter with semicrystalline polymers than with amorphous polymers, where the gain is typically 10-20℃. This is because softening is governed by Tg for an amorphous polymer, but is governed by the melting point (T_m) and the degree of crystallinity for a semicrystalline polymer.

The addition of fibers increases the **creep** resistance because it impedes the molecular mobility. The effect is greater with amorphous thermoplasts than with semicrystalline thermoplasts, as crystalline polymers themselves inhibit creep.

The use of fibers produces higher melt **viscosities** at a given shear rate, so higher processing temperatures and/or higher injection pressures are necessary. On the other hand, the addition of fibers reduces shrinkage during processing.

Surface treatments of carbon fibers are essential for improving the bonding between the fibers and the polymer matrix. They involve **oxidation** treatments and the use of **coupling agents**, wetting agents, and/or **sizings** (coatings). Carbon fibers need treatment both for thermosets and thermoplasts. As the processing temperature is usually higher for thermoplasts than thermosets, the treatment must be stable to a higher temperature (300-400℃) when a thermoplast is used.

Oxidation treatments can be applied by gaseous, **solution**, electrochemical, and **plasma** methods. They serve mainly to remove a weak surface layer from the fibers. More severe oxidation treatments also serve to roughen the fiber surface, thereby enhancing the mechanical interlocking between the fibers and the matrix. Chemical modification occurs, but contributes little to the fiber-matrix adhesion. The oxidation treatments essentially do not improve the fiber wetting. However, the effect of the treatments varies with the polymer species.

The treatments degrade the fiber properties but improve the composite properties. Epoxy embedded single fiber tensile testing showed that **anodic** oxidation of pitch-based carbon fibers in ammonium sulfate solutions increased the interfacial shear strength by 300%. As the modulus of the fiber increases, progressively longer treatment times are required to attain the same improvement in ILSS (composite interlaminar shear strength). Although the treatment increases ILSS, it decreases the impact strength (i. e., impact energy), so the treatment time must be carefully controlled in order to achieve a balance in properties. The choice of treatment time also depends on the particular fiber-resin combination used. For a particular treatment, as the modulus of the fiber increases, the treatment's positive effect on the ILSS and its negative effect on the impact strength both become more severe[②].

Commercial carbon fibers are surface treated to enhance the bonding with epoxy, though the surface treatment is proprietary. The interfacial shear strength was determined from the critical shear transfer length, i. e., the length of the fiber fragments after fracture of a single fiber pulled in tension while being encapsulated in epoxy.

Although surface treatments of carbon fibers result in some degree of oxidation, which places oxygen on the surface in an acidic form, the treatments themselves produce little acidity. Surface acidification is not desirable because it is accompanied by surface degradation.

In addition to oxidation treatments, carbon fibers require the use of coupling agents, wetting agents, and/or sizings (coatings) in order to improve the wetting of the fibers by the polymer, the

adhesion between the fibers and the matrix, and the handle ability of the fibers. As one agent often serves more than one function, the distinction among coupling agents, wetting agents, and sizings is often **vague.**

Coupling agents are mostly short-chain **hydrocarbon** molecules, one end of which is **compatible** or interacts with the polymer while the other end interacts with the fiber. A coupling agent molecule has the form X-R, where X interacts with the fiber and R is compatible or interacts with the polymer.

Wetting agents are polar molecules with one end attracted to the fiber and the other end to the polymer. The agent forms a protective layer around the fiber, thereby improving **dispersion.** It also promotes adhesion by allowing more efficient wetting of the polymer on the fiber. The main difference between a wetting agent and a coupling agent is that a coupling agent forms a chemical bond with the fiber but a wetting agent does not.

Carbon fiber polymer-matrix composites can be classified according to whether the matrix is a thermoset or a thermoplast. Thermoset-matrix composites are by tradition far more common, but thermoplast-matrix composites are under rapid development. The advantages of thermoplast-matrix composites compared to thermoset-matrix composites include the following:

Lower manufacturing cost:

- no cure;
- unlimited shelf-life;
- reprocessing possible (for repair and recycling);
- less health risks due to chemicals during processing;
- low moisture content;
- thermal shaping possible;
- weldability (fusion bonding possible).

Better performance:

- high toughness (damage tolerance);
- good hot/wet properties;
- high environmental tolerance.

The disadvantages of thermoplast-matrix composites include the following:

- limitations in processing methods;
- high processing temperatures;
- high viscosities;
- **stiff** and dry **prepregs** when a solvent is not used;
- fiber surface treatments less developed.

Carbon fiber polymer-matrix composites can be classified according to whether the fibers are short or continuous. Continuous fibers have much more effect than short fibers on the composite's mechanical properties, electrical resistivity, thermal conductivity, and on other properties, too. However, they give rise to composites that are more **anisotropic.** Continuous fibers can be in unidirectionally **aligned** tape or woven fabric form.

Carbon fiber polymer-matrix composites are predominantly used for the aerospace industry, but the decreasing price of carbon fibers is widening the applications of these composites to include the automobile, marine, sports, biomedical, construction, and other industries.

One area of aerospace applications is space vehicles. Satellite structures and solar panels also use carbon fiber polymer-matrix composites. Most space applications utilize standard aerospace grade carbon fibers combined with a 177℃ cure multifunctional epoxy resin matrix. Thermoplast matrices such as PEEK and PES are gaining attention for space applications.

A second area is military aircraft. Examples include French Rafale, and U. S. B 2, which use the 177℃ cure toughened thermoset matrix resins along with intermediate-modulus, or high-strength, intermediate-modulus carbon fibers. The U. S. Advanced Tactical Fighter is planned to use thermoplastics or toughened **bismaleimide** as a primary structural material. Older military aircraft are being modified with epoxy-matrix composite wings.

Helicopters are a third area, both for military and commercial use. For example, the all-composite MBB BK117 helicopter is two-thirds carbon fiber epoxy-matrix composite, one-third aramid fiber and glass fiber epoxy-matrix composite.

A fourth area is concerned with primary and secondary structures in commercial aircraft. Examples of primary structural applications include the Airbus A310/A320 vertical tail fin boxes, the A320 horizontal tail fin and the ATR 72 external wing box.

A fifth area of aerospace applications is commercial aircraft engines. Outer and front sections of the engine are subjected to lower temperatures and can utilize an epoxy matrix. Thermoplasts such as PEEK are being considered for engine applications.

Aluminum is a lightweight metal that competes with carbon fiber polymer-matrix composites for aerospace applications. In addition to their much higher strength and modulus, the carbon fiber composites are produced using much less energy and costly pollution control compared to aluminum.

Carbon fiber polymer-matrix composites have started to be used in automobiles mainly for saving weight. The so-called graphite car employs carbon fiber epoxy-matrix composites for body panels, structural members, **bumpers**, wheels, drive shaft, engine components, and suspension systems. Thermoplastic composites with PEEK and **polycarbonate** (PC) matrices are finding use as spring elements for car suspension systems.

The electrically conductive characteristic of carbon fiber polymer-matrix composites makes them suitable for **static dissipation**, functional elements in **high-impedance** circuits, and shielding from radio frequency interference. The electrically conductive characteristic also makes carbon fiber polymer-matrix composites useful as **electrodes**.

The high thermal conductivity and low thermal expansion of continuous carbon fiber polymer-matrix composites make them suitable for **heat sinks** in electronics. Since a heat sink is in contact with a ceramic chip carrier or a printed circuit board, a low thermal expansion is preferred. The low **density** of the composites (compared to copper) makes them even more attractive for aerospace electronics.

Thermoplasts filled with short or continuous carbon fibers are useful as bone plates for fracture

fixation. Metal bone plates suffer from metallic ion **leaching**, which may cause adverse local tissue reactions and even local tumor formation, and from stress protection **atrophy**. **Polylactic acid** (PLA) is an absorbable thermoplast used for this application, but its mechanical properties are not sufficient for long bone fixation, so continuous carbon fibers are added to produce a semiabsorbable composite.

(Selected from *Carbon Fiber Composites*, by Deborah D. L. Chung, 1994)

Questions

1. What are polymer-matrix composites?
2. Why polymer-matrix composites are much easier to fabricate than others?
3. List several advantages of thermoplast-matrix composites compared to thermoset-matrix composites.
4. Describe the curing of a thermoset resin.
5. According to the passage, what are coupling agents?

New Words and Expressions

1. furfuryl *n.* 糠基
2. thermoplast *n.* 热塑（性）塑料；热塑性
3. polyethersulfone *n.* 聚醚砜
4. polyetheretherketone *n.* 聚醚醚酮
5. polyetherimide *n.* 聚醚酰亚胺
6. polyphenylene sulfide *n.* 聚苯硫醚
7. matrices *n.* 母体，基体（matrix 的复数形式）
8. polymerization *n.* 聚合
9. cross-linking 交联
10. polymer *n.* 聚合物（体）
11. ductility *n.* 展延性，柔软性
12. availability *n.* 可用性，有效性，实用性
13. hydroxyl *n.* 羟（基），氢氧基
14. amine *n.* 胺
15. anhydride *n.* 酐
16. aldehyde *n.* 醛，乙醛
17. epoxide *n.* 环氧化物
18. scission *n.* 切断，分开，分离，分裂
19. hydrogen *n.* 〈化〉氢
20. oxygen *n.* 〈化〉氧，氧气
21. ethylene diamine 乙二胺
22. semicrystalline *adj.* 半晶质的

23. amorphous *adj.* 无固定形状的，模糊的，非结晶的
24. creep *v.* 蠕变
25. viscosity *n.* 粘度，粘性
26. oxidation *n.* 氧化
27. coupling agent 耦联剂
28. sizing *n.* 胶料
29. solution *n.* 溶液
30. plasma *n.* 〈物〉等离子体
31. anodic *adj.* 阳极的
32. vague *adj.* 模糊的
33. hydrocarbon *n.* 碳氢化合物，烃
34. compatible *adj.* 可以并存的，相容的，协调的
35. dispersion *n.* 散布，驱散
36. stiff *adj.* 不易弯曲的，硬的；稠的
37. prepreg *n.* （塑料或其他合成材料在模塑之前用树脂浸饱的）预浸料坯
38. anisotropic *adj.* 各向异性的
39. align *v.* 使成一线
40. bismaleimide *n.* 双马来酰亚胺
41. aluminum *n.* 铝
42. bumper *n.* （汽车上的）保险杠，缓冲器
43. polycarbonate *n.* 聚碳酸酯
44. static *adj.* 不变化的，不发展的，静止的，静态的
45. dissipation *n.* 消散，消耗
46. impedance *n.* 阻抗，全电阻
47. electrode *n.* 电极
48. heat sink 吸热设备，冷源；散热片；（半导体）热沉
49. density *n.* 〈化〉密度
50. leach *v.* （将化学品、矿物质等）过滤，（液体）过滤；滤去
51. atrophy *n.* 萎缩，衰退；*v.* 萎缩，引起萎缩
52. polylactic acid 聚乳酸

Notes

① In the curing reaction, the epoxide ring is opened (called ring scission) and a donor hydrogen from, say, an amine or hydroxyl group bonds with the oxygen atom of the epoxide group.

参考译文：固化反应过程中，环氧环打开，胺或羟基的氢原子与环氧集团的氧原子键合。

② For a particular treatment, as the modulus of the fiber increases, the treatment's positive effect on the ILSS and its negative effect on the impact strength both become more severe.

参考译文：对某种特定的表面处理，被处理纤维的模量越高，提高层间抗剪强度的积极作用与降低冲击强度的负面效果越明显。

5.2 Introduction to Carbon Fiber Composites

Composite materials refer to materials containing more than one phase such that the different phases are artificially blended together. They are not multiphase materials in which the different phases are formed naturally by reactions, phase transformations, or other phenomena.

A composite material typically consists of one or more fillers in a certain matrix. A carbon fiber composite refers to a composite in which at least one of the fillers is carbon fibers, either short or continuous, unidirectional or multidirectional, woven or nonwoven. The matrix is usually a polymer, a metal, a carbon, a ceramic, or a combination of different materials. Except for sandwich composites, the matrix is three-dimensionally continuous, whereas the filler can be three-dimensionally discontinuous or continuous[①]. Carbon fiber fillers are usually three-dimensionally discontinuous, unless the fibers are three-dimensionally **interconnected** by weaving or by the use of a binder such as carbon.

The high strength and modulus of carbon fibers makes them useful as a **reinforcement** for polymers, metals, carbons, and ceramics, even though they are brittle. Effective reinforcement requires good bonding between the fibers and the matrix, especially for short fibers. For a **unidirectional** composite (e. g., one containing continuous fibers all in the same direction), the **longitudinal** tensile strength is quite independent of the fiber-matrix bonding, but the transverse **tensile strength** and the **flexural** strength (for bending in longitudinal or transverse directions) increase with increasing fiber-matrix **bonding**. On the other hand, excessive fiber-matrix bonding can cause a composite with a brittle matrix (e. g., carbon and ceramics) to become more brittle, as the strong fiber-matrix bonding causes cracks to **propagate** straightly, in the direction **perpendicular** to the fiber-matrix **interface** without being **deflected** to propagate along this interface. In the case of a composite with a **ductile** matrix (e. g., metals and polymers), a crack initiating in the brittle fiber tends to be **blunted** when it reaches the ductile matrix, even when the fiber-matrix bonding is strong[②]. Therefore, an optimum degree of fiber-matrix bonding **is** needed for brittle-matrix composites, whereas a high degree of fiber-matrix bonding is preferred for ductile-matrix composites.

The mechanisms of fiber-matrix bonding include chemical bonding, **Van der Waals** bonding, and mechanical **interlocking**. Chemical bonding gives the largest bonding force, provided that the density of chemical bonds across the fiber-matrix interface is sufficiently high. This density can be increased by chemical treatments of the fibers or by **sizings** on the fibers. Mechanical interlocking between the fibers and the matrix is an important contribution to the bonding if the fibers form a three-dimensional network. Otherwise, the fibers should have a rough surface in order for a small degree of mechanical interlocking to take place.

Both chemical bonding and Van der Waals bonding require the fibers to be in **intimate** contact with the matrix. For intimate contact to take place, the matrix or matrix precursor must be able to wet the surfaces of the carbon fibers during **infiltration** of the matrix or matrix precursor into the carbon fiber **preform**. Chemical treatments and **coatings** can be applied to the fibers to **enhance** wetting. The choice of treatment or coating depends on the matrix. Another way to enhance wetting is

the use of a high pressure during infiltration. A third method is to add a wetting agent to the matrix or matrix precursor before infiltration. As the **wettability** may vary with temperature, the infiltration temperature can be chosen to enhance wetting.

The occurrence of a reaction between the fibers and the matrix helps the wetting and bonding between the fibers and the matrix. However, an excessive reaction degrades the fibers, and the reaction product(s) may be undesirable for the mechanical, thermal, or **moisture resistance** properties of the composite. Therefore, an optimum amount of reaction is preferred.

Carbon fibers are electrically and thermally conductive, in contrast to the nonconducting nature of polymer and ceramic matrices. Therefore, carbon fibers can serve not only as a reinforcement, but also as an additive for enhancing the electrical or thermal conductivity. Furthermore, carbon fibers have nearly zero **coefficient of thermal expansion**, so they can also serve as an **additive** for lowering the thermal expansion. The combination of high thermal conductivity and low thermal expansion makes carbon fiber composites useful for **heat sinks** in electronics and for space structures that require dimensional stability. As the thermal conductivity of carbon fibers increases with the degree of **graphitization**, applications requiring a high thermal conductivity should use the graphitic fibers, such as the high-modulus pitch-based fibers and the **vapor grown carbon fibers**. Carbon fibers are more **cathodic** than practically any metal, so in a metal matrix, a **galvanic couple** is formed with the metal as the **anode**. This causes corrosion of the metal. The corrosion product tends to be unstable in moisture and causes **pitting**, which **aggravates corrosion**. To alleviate this problem, carbon fiber metal-matrix composites are often coated.

Carbon is the matrix that is most **compatible** to carbon fibers. The carbon fibers in a carbon-matrix composite (called carbon-carbon composite) serve to strengthen the composite, as the carbon fibers are much stronger than the carbon matrix due to the **crystallographic texture** in each fiber. Moreover, the carbon fibers serve to toughen the composite, as the debonding between the fibers and the matrix provides a mechanism for energy absorption during mechanical deformation. In addition to having attractive mechanical properties, carbon-carbon composites are more thermally conductive than carbon fiber polymer-matrix composites. However, at elevated temperatures (above 320℃), carbon-carbon composites degrade due to the **oxidation** of carbon (especially the carbon matrix), which forms CO_2 gas. To alleviate this problem, carbon-carbon composites are coated.

Carbon fiber ceramic-matrix composites are more oxidation resistant than carbon-carbon composites. The most common form of such composites is carbon fiber reinforced **concrete**. Although the oxidation of carbon is catalyzed by an **alkaline** environment and concrete is alkaline, the chemical stability of carbon fibers in concrete is superior to that of competitive fibers, such as polypropylene, glass, and steel. Composites containing carbon fibers in more advanced ceramic matrices (such as SiC) are rapidly being developed.

Carbon fiber composites are most commonly fabricated by the **impregnation** (or infiltration) of the matrix or matrix precursor in the liquid state into the fiber preform, which is most commonly in the form of a woven **fabric**. In the case of composites in the shape of tubes, the fibers may be impregnated in the form of a continuous bundle from a **spool** and subsequently the bundles may be

wound on a **mandrel**. Instead of impregnation, the fibers and matrix material may be **intermixed** in the solid state by **commingling** carbon fibers and matrix fibers, by coating the carbon fibers with the matrix material, by **sandwiching** carbon fibers with foils of the matrix material, and in other ways. After impregnation or intermixing, **consolidation** is carried out, often under heat and pressure.

Due to the decreasing price of carbon fibers, the applications of carbon fiber composites are rapidly widening to include the aerospace, automobile, marine, construction, biomedical, and other industries. This situation poses an unusual demand on research and development in the field of carbon fiber composites.

(Selected from *Carbon Fiber Composites*, by Deborah D. L. Chung, 1994)

Questions

1. What is carbon fiber composite?
2. Why an optimum degree of fiber-matrix bonding is needed for brittle-matrix composites, whereas a high degree of fiber-matrix bonding is preferred for ductile-matrix composites?
3. Explain the mechanisms of fiber-matrix bonding.
4. According to text, how to fabricate Carbon fiber composites?

New Words and Expressions

1. interconnect *v.* 互相连接；互相联系
2. reinforcement *n.* 增强
3. unidirectional *adj.* 单向的，单向性的
4. longitudinal *adj.* 经度的，纵向的
5. tensile *adj.* 拉力的，张力的，可拉长的
6. tensile strength 抗张强度，抗拉强度
7. flexural *adj.* 曲折的，弯曲的
8. bonding *n.* 黏结；连［搭，焊，胶，粘］接，结［耦，焊，接］合，键合
9. propagate *v.* 传播，增殖
10. perpendicular *adj.* 垂直的，成直角的
11. interface *n.* 界面，分界面
12. deflect *v.* （使）偏斜，（使）偏离，（使）转向
13. ductile *adj.* 可延展的，有韧性的
14. blunt *adj.* 率直的，直言不讳的，钝的；*vt.* 把……弄钝，减弱
15. Van der Waals 范德华
16. interlock *n.* 连锁，互锁
17. sizing *n.* 胶料
18. intimate *adj.* 密切的
19. infiltration *n.* 渗透
20. preform *v.* 预先形成；*n.* 粗加工的成品，预成型坯

21. coating *n.* 涂层，覆盖层
22. enhance *v.* 提高，增加，加强
23. wettability *n.* 润湿性
24. moisture resistance 防潮性；抗湿性
25. coefficient of the thermal expansion 温度膨胀系数，热膨胀系数
26. additive *n.* 添加剂
27. heat sink 吸热设备，冷源；散热片；（半导体）热沉
28. graphitization *n.* 石墨化
29. vapor grown carbon fibers 气相生长碳纤维
30. cathodic *adj.* 阴极的，负极的
31. galvanic *adj.* 电流的，由电流引起的
32. galvanic couple 电耦合
33. anode *n.* 阳极
34. pitting *n.* 蚀损斑，氢气泡
35. aggravate *vt.* 使恶化，使更严重
36. corrosion *n.* 腐蚀；受腐蚀的部位
37. compatible *adj.* 可以并存的，相容的，协调的
38. crystallographic *adj.* 晶体的；晶体学的
39. texture *n.* 手感，质感，质地
40. oxidation *n.* 氧化
41. concrete *adj.* 实体的，有形的；*n.* 凝结物，混凝土
42. alkaline *adj.* 碱的，碱性的
43. impregnation *n.* 注入，浸渍
44. fabric *n.* 织物，布
45. spool *n.* （绕线、铁线、照相软片等的）管、筒、线轴
46. mandrel *n.* 心轴
47. intermix *v.* （使）混和，（使）混杂
48. commingle *v.* 混合，掺和，合并
49. sandwich *v.* 夹入
50. consolidation *n.* 固化

Notes

① Except for sandwich composites, the matrix is three-dimensionally continuous, whereas the filler can be three-dimensionally discontinuous or continuous.

参考译文：除夹层复合材料之外，基体材料三维连续，而增强体可以三维连续或不连续。

② In the case of a composite with a ductile matrix (e. g. , metals and polymers), a crack initiating in the brittle fiber tends to be blunted when it reaches the ductile matrix, even when the fiber-matrix bonding is strong.

参考译文：如果基体是韧性材料（如金属和聚合物等），即使纤维与基体间的键接很

强，脆性纤维引发的裂纹到达基体时也会钝化。

Reading Material

Carbon Fibers

Carbon fibers refer to fibers which are at least 92 wt. % carbon in composition. They can be short or continuous; their structure can be crystalline, amorphous, or partly crystalline.

Carbon fibers exhibit truly outstanding properties. Their strength, σ, competes with the strongest steels; they can have stiffness, E, greater than any metal, ceramic or polymer; and they can exhibit thermal and electrical conductivities that greatly exceed those of competing materials. If the strength or stiffness values are divided by the low density ($\rho = 1,800 \sim 2,200 kg/m^3$), then their huge specific properties (σ/ρ, E/ρ) make this class of materials quite unique.

All carbon fibers sold commercially are fabricated from **polyacrylonitrile** (PAN) or from a coal, **petroleum** or **synthetic pitch**. PAN-based fibers are produced from a solubilized mixture that is wet or dry **spun** to produce a fiber, **ostensibly** for use in the textile industry[①]. This fiber is stabilized and **carbonized** to produce a carbon fiber. Aerospace grade material can be obtained in tows that contain between 3,000 and 12,000 fibers. Lower performance materials are usually formed using larger tows that contain up to 320,000 fibers. PAN-based carbon fibers are cheaper when produced from larger tows.

Pitch fibers are melt spun products obtained in small tow sizes varying from 2,000 to 4,000 fibers. They are usually of larger diameter (10 ~ 15μm) than fibers formed from PAN.

The spinning process is controlled by the pitch-based carbon fiber producer; thus, microstructural features developed in the spinning process that also influence the stiffness, strength and the thermal and electrical properties of pitch can be optimized[②]. Nevertheless, the tensile strength of PAN-based fibers has always been superior to pitch-based fibers; since PAN fibers were developed before pitch fibers, most structural materials and components use PAN-based fibers.

The most important mechanical and physical properties exhibited by carbon fibers are the elastic modulus, tensile strength and the electrical and thermal conductivities. These properties are sensitive to the crystallite size and **perfection** of the **graphene** layers developed within the carbon fiber and depend for the most part on the degree of molecular alignment with respect to the fiber axis. Growth and **alignment** of such layers occur within the **precursor** and within the solid carbon fiber when it is heated to high temperature. However, it can be argued that the most extensive structural rearrangement occurs when the basic structural units (BSUs) present in the original precursor are large and plate-like so that the shear stresses generated during spinning can align these large areas more easily. Heating the fiber to high temperature after spinning relaxes the spinning stresses and allows the oriented regions to grow. Compared to PAN, the basic structural units in an original **mesophasic** pitch are much larger in area and length and are not **twisted** to the same degree. The resulting ease of graphitization and alignment of the graphene layers and the development of large **crystallites**, produces a large elastic modulus and electrical and thermal conductivity parallel to the fiber

axes. Unfortunately, large **graphitized** regions tend to produce high local stress concentrations, especially if they are misaligned. Thus, pitch-based fibers tend to exhibit high modulus and high electrical and thermal conductivities, but low strength. PAN-based fibers tend to be of intermediate modulus and relatively high strength.

The mechanical properties of structural metals generally vary in direct proportion to density. Thus, the specific properties (σ/ρ, E/ρ) tend to remain relatively constant; structures designed to resist a given set of loads tend to weigh the same **irrespective** of whether they are made from aluminum, **titanium** or steel. These mechanical property/density relationships are not followed by carbon fibers; so, compared with metals, similar structures made from carbon fiber reinforced composites will be lighter.

The most successful use of carbon fiber reinforced materials has been for military purposes, especially aeronautical structures. Composite use in civilian **aviation** has been more limited, largely because of cost. However, in 1985 the European Airbus **consortia** used carbon/epoxy vertical stabilizers on their A310 and, since 1993, delivered their A340 and A330 models equipped with composite tail sections, floor panels, landing gear doors and carbon-carbon brakes. The new Boeing 777 and the projected McDonnell-Douglas MD-12 contains similar composite structures.

The methods used to fabricate carbon fibers from PAN or from pitch seem to be almost identical, for example, both methods involve the preparation, spinning and subsequent thermal degradation of organic precursors. Essentially a precursor material is prepared, spun into a fibrous shape, stabilized to change it from a thermoplastic to a thermoset, then heated until all unwanted elements are **expelled**. Depending on the final heat treatment temperature, a fiber is produced that is primarily carbon. A strikingly similar production technique is used to produce either type of fiber; however, the initial pretreatment and the chemical reactions that occur within either PAN or pitch during stabilization and carbonization are markedly different. These differences determine the ultimate properties and the cost of the carbon fibers that are produced.

The chemical composition of PAN-based precursors tends to be **proprietary**; however, in general it consists of small diameter linear molecules that are made up from **nitrogen**, **hydrogen** and carbon. Spinning tends to orient these molecules parallel to the fiber axis, but they continue to be randomly oriented transverse to that direction. Thus, a fiber with a twisted **fibrillar** structure is produced. This fiber is supplied by the textile industry to the carbon fiber fabricator who stabilizes it under tension before converting it into a carbon fiber using a controlled heat treatment process. Apart from the obvious generation of the fibrous shape, the importance of the spinning process to the fabrication of carbon fibers from PAN is relatively minor; more important is the chemical makeup of the PAN and the presence of small amounts of other constituents that influence the complex chemical reactions that occur during stabilization and carbonization. Stabilization involves **cyclization** of the oriented molecules and results in the release of most of the hydrogen and part of the nitrogen as NH_3, and other nitrogen compounds. The role of the retained nitrogen is very important to both the crosslinking process and to the development of optimum properties during carbonization.

A pitch precursor taken from a petroleum or coal tar **feedstock** initially contains individual mol-

ecules that exhibit appreciably different molecular weights. These untreated precursors have been used to produce fibers; however, they are **isotropic** and exhibit relatively poor mechanical and physical properties. Conversely, the carbon fiber producer can **pretreat** the pitch to develop a continuous **anisotropic** phase (similar to a mesophasic liquid crystal) or a two phase mixture that becomes highly oriented during the subsequent spinning process. In contrast to the chemical changes occurring in PAN, physical changes are responsible for the final properties of pitch-based carbon fibers. Essentially, the precursor isotropic pitch is pretreated to produce a two phase mixture that is predominantly anisotropic. During spinning and **drawdown**, this mixture is very strongly oriented both parallel and transverse to the fiber axis. Oxygen added during stabilization tends to crosslink these large molecules in a simple way before being released on carbonization as CO, CO_2, and H_2O. More recent interest has centered on producing fibers from synthetic pitches. These require no extensive pretreatment and they stabilize faster at a given temperature. Fibers made from these pitches should cost less to produce.

Precursor materials that have been used to produce carbon fibers include: polyamides, polyesters, polyvinyl alcohol, **alkylbenzenes**, rayon, polyacrylonitrile (PAN) and various petroleum, coal tar and synthetic pitches.

The carbonization of stabilized PAN and pitch involves controlled heating to a temperature of about 1,500℃. The majority of gases emitted from either the PAN or the pitch are emitted before a temperature of 1,000℃ is reached and the emission is primarily from unstabilized regions. Indeed, the quantity of gases emitted from an unstabilized central core of either PAN or pitch can be so large that the fiber can **disintegrate**. Great care should therefore be taken to determine the optimum heating rate for stabilized or under-stabilized fibers. In some cases, hold times should be incorporated into the heating cycle. Both materials emit a variety of gas molecules containing oxygen, hydrogen and carbon; however, a major difference between PAN and pitch involves nitrogen containing compounds which are only emitted from PAN. The temperature and rate of emittance are important control parameters since they affect the strength of the resultant carbon fibers.

A stabilized polyacrylonitrile fiber which contains about 11% oxygen by weight can be thermally degraded by heating at a slow heating rate in an inert atmosphere such as nitrogen or a reactive environment where nitrogen gas is bubbled through acid or water. As the temperature increases, many complex reactions take place resulting in the evolution of **volatile** products.

Results obtained from experiments involving slow pyrolysis at 4℃/min indicate that optimum mechanical and physical properties are unobtainable unless high nitrogen contents are retained within the precursor until the later stages of carbonization. Therefore, a large nitrogen content (large N/C ratio) should be present when local molecular ordering (LMO) begins and the carbon skeleton is being formed. Since the N/C atomic ratio depends inversely upon the H/C ratio, LMO should occur at large N/C and small H/C ratios. Essentially, small amounts of **aromatic** hydrogen and a relatively large amount of nitrogen present during the LMO stage allow the carbon skeleton to remain flexible enough at high temperatures that molecular rearrangement is easy. Within this overall fibrous texture, the **nanotextural** features of the carbonized fibers are the consequence of the variations in cy-

clization, stabilization, carbonization and graphitization conditions[③]. If the original precursor is CH- and NH-rich but oxygen-poor, the corresponding carbonized fibers will have low porosity, high **compactibility** and **stacking** order and a relatively high strength. Likewise, if two nitrogen atoms are present in two aromatic rings contained within **adjacent** sheets, they are able to promote bonding of contacting BSUs together with a N_2 release. The ultimate strength value of the fibers increases as the compactibility and the availability of "efficient" nitrogen increases. Bright and Singer (1979) agreed with others when they found that the tensile strength of most heat treated fibers tends to decrease with higher temperature exposures and release of nitrogen. The same authors argue that if adequate nitrogen exists within the fiber after LMO occurs, then a greater potential for bonding exists and an improved rather than a diminished strength will result. This conclusion is based on the observation that, in contrast to other fibers, the strength of (nitrogen containing) commercially available Toray T-300 fibers increased from 2.2 to 3.2GPa after heat treatment to 2,800℃. Tension also increases cyclization and nitrogen elimination which increases the tensile strength of the final carbon fiber. Exactly what influence nitrogen has on the development of high tensile strength is still being debated. However, the texture of the graphitic layers, the amount of nitrogen present in the original precursor and the temperature at which **misshapen** layers touch and hence are available to bond and emit nitrogen are obviously important.

Up to 1,000℃, carbonization leads to an **effluent** loss and increasing **aromatization**. As a result, the solid residue transforms from a **viscoelastic** into a brittle solid material. The stabilized PAN normally carbonizes into a statistically isotropic but nanoporous carbon material which, because of the small dimensions of the initial LMOs, is inherently non-graphitizable. Continuing **pyrolysis** up to 1,500℃ eliminates most of the residual nitrogen and completes the conversion of the PAN molecules into sheets of carbon that are appreciably anisotropic. Continued heating eliminates the remaining nitrogen and, since the material is then only made of pure carbon, further modifications are only structural[④].

Graphitization is the name of the process that involves heating the carbonized fiber to approximately 2,500℃ in times as short as a minute. Graphitized pitch fibers exhibit a larger, more graphitic and better oriented crystal structure than PAN-based carbon fibers which are inherently non-graphitizable. Parallel to the fiber axes, pitch fibers have higher stiffness and thermal conductivity values and a reduced thermal expansion coefficient. These changes due to graphitization do not produce any significant increase in relative strength values. As a result of the extreme temperatures required to process them, graphitized pitch-based carbon fibers are more expensive and are fabricated for specialized applications.

(Selected from *Carbon Fiber Composites*, by Deborah D. L. Chung, 1994)

Questions

1. Describe the outstanding properties of carbon fibers.
2. How to produce PAN-based carbon fibers?

3. What is the main point of the last paragraph?
4. What differences are there between stabilization and carbonization of fibers?
5. Which kinds of precursors are usually used in carbon fiber producing?

New Words and Expressions

1. polyacrylonitrile *n.* 聚丙烯腈
2. petroleum *n.* 石油
3. synthetic *adj.* 合成的，人造的
4. pitch *n.* 球场，沥青
5. spun spin 的过去式和过去分词；*adj.* 纺成的
6. ostensible *adj.* （指理由等）假装的，表面的
7. carbonize *vt.* 使成碳，碳化，使与碳化合
8. perfection *n.* 完美；完善
9. graphene *n.* 石墨的单原子层
10. alignment *n.* 排成直线
11. precursor *n.* 先驱体；先行者
12. mesophase *n.* 中间期，中间相
13. twist *v.* 扭，搓，缠绕
14. crystallite *n.* 微晶
15. graphitization *n.* 石墨化
16. irrespective *adj.* 不考虑的，不问的，不顾的
17. titanium *n.* 钛
18. aviation *n.* 航空，航空工业
19. consortium *n.* （数家公司或银行联合组成的）财团，联营企业
20. expel *v.* 驱逐，赶走，放逐
21. proprietary *adj.* 私有的
22. nitrogen *n.* 〈化〉氮
23. hydrogen *n.* 〈化〉氢
24. fibrillar *adj.* 纤丝状的，纤维状的
25. cyclization *n.* 环化（作用）
26. feedstock *n.* 给料（指供送入机器或加工厂的原料）
27. isotropic *adj.* 各向同性的
28. pretreat *v.* 预先处理，预处理
29. anisotropic *adj.* 各向异性的
30. drawdown *n.* 牵伸
31. alkylbenzene *n.* 烷基苯
32. disintegrate *v.* （使）破裂［分裂，粉碎］；（使）崩溃
33. volatile *adj.* （液体或油）易挥发的
34. aromatic *adj.* 芳香的；有香味的

35. nanotextural *adj.* 纳米组织上的
36. compactibility *n.* 压塑性，成型性，紧密性
37. stack *v.* 堆积
38. adjacent *adj.* 邻近的
39. misshapen *adj.* 奇形怪状的，畸形的
40. effluent *adj.* 发出的，流出的
41. aromatization *n.* 芳构化
42. viscoelastic *adj.* 粘弹性的
43. pyrolysis *n.* 高温热解

Notes

① PAN-based fibers are produced from a solubilized mixture that is wet or dry spun to produce a fiber, ostensibly for use in the textile industry.

参考译文：聚丙烯腈纤维是由可溶性混合物经过湿法或干法纺丝工艺纺制而成的，一般用于纺织行业。

② The spinning process is controlled by the pitch-based carbon fiber producer; thus, microstructural features developed in the spinning process that also influence the stiffness, strength and the thermal and electrical properties of pitch can be optimized.

参考译文：纺丝工艺由沥青基碳纤维制造者控制，因此，影响沥青的刚度、强度、热性能、电性能的微观结构特征通过纺丝过程形成，其可以得到优化。

③ Within this overall fibrous texture, the nanotextural features of the carbonized fibers are the consequence of the variations in cyclization, stabilization, carbonization and graphitization conditions.

参考译文：整体纤维结构中，碳化纤维的纳米结构特征是由环化、稳定化、碳化、石墨化条件的变化引起的。

④ Continued heating eliminates the remaining nitrogen and, since the material is then only made of pure carbon, further modifications are only structural.

参考译文：连续加热消除剩余的氮，因为此时的材料仅由纯碳构成，进一步的改性只是结构上的变化。

5.3 Three-Dimensionally Reinforced Preforms and Composites

Conventional fiber-reinforced polymer (FRP) laminates have a layered two-dimensional construction. The lack of reinforcement in the through-thickness or z-direction results in the laminates having low **interlaminar** strength and fracture resistance.

Laminated two-dimensional composites are not suitable for applications where through-thickness stresses may exceed the (low) tensile strength of the **matrix** (or matrix/fiber bond) and in addition, to provide sufficient residual strength after anticipated impact events, two-dimensional laminates must be made thicker than required for meeting strength requirements. The resulting penalties

of increased cost and structural weight provide impetus for the development of more damage-resistant and tolerant composite materials and structures.

Considerable improvements in damage resistance can be achieved by using tougher thermoset or thermoplastic matrices together with optimized fiber/matrix bond strength. However, this approach can involve significant costs, and the improvements that can be obtained are limited. There are also limits to the acceptable fiber/matrix bond strength because high bond strength can lead to increased **notch-sensitivity**①.

An alternative and potentially more effective means of increasing damage resistance and through-thickness strength is to develop a fiber **architecture** in which a proportion of fibers in the composite are oriented in the z-direction. This fiber architecture can be obtained, for example, by three-dimensional weaving or three-dimensional braiding. A much simpler approach is to apply z-direction **reinforcement** to a conventional two-dimensional fiber **configuration** by **stitching**; however, this does not provide all of the benefits of a full three-dimensional architecture.

In all of these approaches, a three-dimensional preform is first produced and is converted into a composite by one of the liquid resin molding techniques.

Even without the benefits of three-dimensional reinforcement, the preform approach has the important advantage that it is a comparatively low-cost method of manufacturing composite components compared with conventional **laminating** procedures based on **pre-preg**. Indeed, **preforms** for resin-transfer molding (RTM) and other liquid molding techniques are often produced from a two-dimensional fiber configuration by stitching or knitting.

Stitching is best applied using an industrial-grade sewing machine where two separate yarns are used. For stitching composites, the yarns are generally aramid (Kevlar), although other yarns such as glass, carbon, and nylon have also been used. A needle is used to **perforate** a pre-preg stack or fabric preform, enabling the **insertion** of a high-tensile-strength yarn in the thickness direction. The yam, normally referred to as the needle yam, is inserted from the top of the stack/preform, which is held in place using a presser foot. When the yarn reaches the bottom of the stack/preform it is caught by another yam, called the **bobbin** yam, before it re-enters the stack/preform as the needle is withdrawn from the stack/preform, thus forming a full stitch. The stack/preform is then advanced a certain distance between the presser foot and a **roller** mechanism before the needle is used to effect the next stitch. This process is repeated to form a row of stitches.

Apart from improving z-direction properties, stitching serves as an effective means of assembling preforms of dry two-dimensional tape or cloth, for example, attaching stiffeners to skin preforms, that are then consolidated using processes such as liquid molding.

Woven fabrics are made of **warp** (longitudinal) and **weft** (transverse) yarns interlaced in a regular order on mechanical **looms**. The process of weaving is already used extensively within the composite industry to produce the vast majority of the single-layer, **broadcloth** fabric that is currently used as a reinforcement. With minimal modification, the same standard industry machines can be used to manufacture flat, three-dimensional fabrics in a wide variety of yam architectures.

Three-dimensional fabrics can be woven using almost any type of **yarn**, including carbon,

glass, **aramid**, and ceramic fibers or combinations of these yarns. In addition, the proportions of the yarns in the x, y, and z directions can be controlled to **tailor** the properties of the composite for specific applications. The path that the binder yam follows as it traverses through the thickness of the woven preform plays an important part in controlling the final three-dimensional architecture and thus the resultant mechanical properties.

3-D woven composites have been studied since the 1980s, but a clear picture of their in-plane performance and how it is affected by variables such as the weave architecture is still developing. Many of the studies on the performance of three-dimensional woven composites have been conducted with comparison to two-dimensional laminates manufactured with similar, but not always the same, parameters (fiber content, lay-up, etc.), and often these differences have prevented conclusive comparisons of performance being made. Numerous investigations of the tensile properties of three-dimensional woven composites have led to **conflicting** results. Some researchers have reported the tensile modulus of three-dimensional woven composites to be reduced in comparison to similar two-dimensional **laminates**, whereas other researchers have reported an increase. However, in spite of this conflict in the reported results, it has been observed that (in the majority of cases) the tensile modulus of a three-dimensional woven composite is within 20% of the modulus of the comparable two-dimensional laminate. The studies have also shown that the modulus of the three-dimensional woven composite is not significantly influenced by the content of the z-direction reinforcement or the weave architecture. The explanation for the higher tensile modulus of some three-dimensional material is thought to be due to a slightly higher fiber content than the comparable two-dimensional laminate. The lower modulus in other cases is generally considered to be due to the increased waviness of the in-plane yarns caused by the presence of the z-direction reinforcement.

There is also no conclusive evaluation of the tensile strength of three-dimensional woven composites. The failure strength of three-dimensional woven composites has been found to be the same or (more often) less than the strength of a comparable two-dimensional laminate, but the difference is rarely more than 20%. As with tensile modulus, the strength of 3-D woven composites does not appear to be significantly affected by the z-direction reinforcement content or weave structure. The reduction in the tensile strength of three-dimensional woven composites is considered to be primarily due to the increased waviness of the in-plane yarns.

With regard to the compressive properties of three-dimensional woven composites, the modulus is generally reduced due to the z-direction yarns causing an increased waviness and local crimping of the in-plane yarns. A comparison of the compression strength of three-dimensional woven composites relative to similar two-dimensional laminates is more complex, and so far the findings have not been conclusive with both improvements and reductions in strength being observed. The compressive strength appears to be independent of weave architecture or the proportion of z-direction fiber. Degradation of the compressive strength is believed to be due to the **kinking** or microbuckling of the load-bearing yarns, which in turn is attributed to local waviness or crimping of the yarns as a result of the z-direction reinforcement. The occasional observed improvement in strength could be attributed to the initiation of delamination being suppressed by the z-direction yarn.

Knitting refers to a technic for producing textile fabrics and preforms by intermeshed loops of yarns using knitting needles. A continuous series of knitting stitches or intermeshed loops is formed by the needle, which, catching the yarn and drawing it through a previously formed loop, forms a new loop. In a knit structure, rows, known as courses, run across the width of the fabric, and columns, known as wales, run along the length of the fabric. The loops in the courses and wales are supported by and interconnected with each other to form the final fabric. Depending on the direction in which the loops are formed, knitting can be broadly categorized into one of two types—**weft knitting** and **warp knitting**. Weft knitting is characterized by loops forming through the feeding of the weft yarn at fight angles to the direction in which the fabric is produced. Warp knitting, on the other hand, is characterized by loops forming through the feeding of the warp yarns, usually from warp beams, parallel to the direction in which the fabric is produced. These basic knit architectures can be modified through the use of tuck and float loops to achieve specific macroscopic properties in the fabric. In general, the former makes a knitted fabric wider, thicker, and slightly less extensible, and the latter creates the opposite effect, as well as increases the proportion of straight yarns in the structure, which is an important consideration for many composites applications.

Since fibers are required to bend over sharp **radii** and **maneuver** sharp comers to form the knitted loops of the structure, knitting may not at first appear to be a manufacturing technique that would be suitable for use in the production of **aerospace** components[2]. However, the knitted carbon and glass fabric that can be produced on current, standard industrial knitting machines has particular properties that potentially make it very suitable for certain aerospace composite components. Current machinery is also capable of producing preforms with up to four interconnected layers of knitted fabric. Therefore, although the process is not yet able to manufacture preforms with thickness dimensions as large as weaving or braiding, it is still able to produce three-dimensional fiber architectures.

Knit architectures result in a fabric of relatively low strength and stiffness compared with tape or woven cloth, but the knitted fabric is highly conformable and is therefore ideally suited to manufacture non-structural components of complex shape. Layers of knitted fabric can be stretched to cover a relatively complex tool surface without the need to cut and **overlap** sections. This reduces material wastage and helps decrease the costs of manufacturing complex shape components such as **fairings**.

More advanced industrial knitting machines are now capable of producing very complex, net-shaped structures at high production rates with little material wastage. Through careful knit loop control, structures that are very difficult to produce using conventional fabrics can be knitted to net shape, thereby further reducing manufacturing costs. These preforms can also incorporate oriented fibers in selected areas to improve the mechanical performance of the finished component.

Three-dimensional textile manufacturing processes are an emerging field and they offer similar advantages to two-dimensional processes, **albeit** not without their restrictions. Design or manufacturing criteria that favor the use of a particular textile process for one application may not necessarily be relevant for another. It is also possible that for some structures it may be necessary to combine a number of the textile processes to achieve a cost-effective product with the required performance. Of particular importance is the **intimate** connection between the textile manufacturing process, the re-

quired preform design, the cost, and the performance of the resultant composite. A large range of possible preform architectures can now be produced, each with its own mechanical performance and associated cost. It is, therefore, critical that in the design of any component, early consideration is given to the method of manufacture because only seemingly slight, relatively unimportant changes to component shape or required performance may result in significant changes to the cost of manufacturing a preform.

In spite of the relative youth of these manufacturing techniques, advanced textile preforms are beginning to be used in the manufacture of aerospace components. The potential savings in cost and improvements in performance that can be realized through the use of these processes are sufficiently attractive that extensive efforts are being put into further developing these processes. It is not yet clear how far these developments will go, but as designers and manufacturers become more familiar, and hence confident, with the advanced textile composites on offer, the use of these techniques will become more **commonplace**.

(Selected from *Handbooks of Composites*, by S. T. Peters, 1998)

Questions

1. What disadvantages do three-dimensional composites have?
2. What is weft knitting and what is warp knitting?
3. Translate the second paragraph into Chinese.
4. What is the main point of the second paragraph?

New Words and Expressions

1. interlaminar *adj.* 层间的
2. matrix *n.* 基质
3. notch-sensitivity 切口效应
4. architecture *n.* 建筑学，建筑艺术；构造，结构
5. reinforcement *n.* 增强，加固；钢筋，构［支］架，护炉设备
6. configuration *n.* 构造，形状，外貌，轮廓
7. stitching *n.* 用 U 字钉钉箱，缝纫
8. pre-preg 含有化学增稠剂的模（型）垫；预浸渍
9. preform *v.* 预先形成；*n.* 粗加工的成品
10. laminating *n.* 层压（法），层合（法）
11. perforate *vt.* 穿孔于，在……上打眼，打齿孔
12. insertion *n.* 插入，插入物
13. bobbin *n.* 线轴，绕线筒
14. roller *n.* 滚压机；滚杠，滚柱；定型卷夹
15. woven fabrics 梭织布，编织布
16. warp *n.* 弯曲

17. weft *n.* 织物
18. loom *n.* 织布机
19. broadcloth *n.* （毛、棉、丝织成的）细平布
20. aramid *n.* 芳族聚酰胺
21. tailor *n.* & *v.* 裁缝，裁制，调整使适应
22. conflicting *adj.* 相冲突的，不一致的，相矛盾的
23. laminate *v.* （将薄片砌合在一起）制成（材料）；*n.* 层压材
24. kinking *n.* 弯纱；纽结（纱线疵点）
25. weft knitting 纬编
26. warp knitting 经编
27. radii *n.* 半径
28. maneuver *v.* & *n.* 机动
29. aerospace *n.* 航空和宇宙航行空间
30. overlap *v.* 部分重叠
31. fairing *n.* 整流罩
32. albeit *conj.* 尽管，即使
33. intimate *adj.* 亲密的，密切的
34. commonplace *adj.* 普通的，平庸的；*n.* 陈腔滥调，寻常的事物
35. knitting *n.* 编织品，针织

Notes

① There are also limits to the acceptable fiber/matrix bond strength because high bond strength can lead to increased notch-sensitivity.

参考译文：也要限制纤维与基体间的键接强度，因为高强度可能导致切口敏感性的增强。

② Since fibers are required to bend over sharp radii and maneuver sharp comers to form the knitted loops of the structure, knitting may not at first appear to be a manufacturing technique that would be suitable for use in the production of aerospace components.

参考译文：由于纤维需要顺径向弯曲而控制后者形成编织环结构，起初编织似乎并不适用于航天部件的制造。

Reading Material

Composites Fabrication Techniques

The goals of the composite manufacturing process are to:

- achieve a consistent product by controlling
  — fiber thickness,
  — fiber volume,
  — fiber directions;

- minimize voids;
- reduce **internal residual stresses**;
- process in the least costly manner.

The procedures to reach these goals involve **iterative** processes to select the three key components:

- composite material and its **configuration**;
- process.

Once material selection has been completed, the first step leading to the acceptable composite structure is the selection of **tooling**, which is intimately tied to process and material. For all curing techniques the tool must be:

- strong and stiff enough to resist the pressure exerted during cure;
- dimensionally stable through repeated heating and cooling cycles;
- light enough to respond reasonably quickly to the changes in cure cycle temperature and to be moved in the shop;
- **leakproof** so that the vacuum and pressure cycles are consistent.

The tool face is commonly the surface imparted to the outer surface of the composite and must be smooth, particularly for **aerodynamic** surfaces. The other surface frequently may be of lower finish quality and is imparted by the disposable or reusable vacuum bag. This surface can be improved by the use of a supplemental metal tool known as a **caul** plate. (Press curing, resin transfer molding, injection molding and pultrusion require a fully closed or two sided mold.) Tooling options have been **augmented** by the introduction of elastomeric tooling wherein the thermal expansion of an elastomer provides some or all of the pressure curing cure, or a rubber blanket is used as a reusable vacuum bag. The volumetric expansion of an **elastomer** can be used to fill a cavity between the uncured composite and an outer mold. The use of elastomeric tooling can provide the means for fabricating complex box-like structures such as **integrally** stiffened skins with a co-cured **substructure** in a single curing operation.

Tooling and the configuration of the reinforcement have a great influence on the curing process selected and vice-versa.

The choice between unidirectional tape and woven fabric has frequently been made on the basis of the greater strength and modulus attainable with the tape particularly in applications which compression strength is important.

Lay-up Techniques

Lay-up techniques along with composite cure control have received the greatest attention for. processing. In efforts to reduce labor costs of composite fabrication, to which lay-up has traditionally been the largest contributor, mechanically assisted, controlled tape laying and automated integrated[①]. In addition to any cost savings by the use of an automated technique for long production runs, there are two key quality assurance factors which validate the automated techniques. They are: greatly reduced chance that release paper or film could be retained, which would destroy shear and compressive strength if undetected, and reduced probability of the addition or loss of an angle **ply**

which would cause **warping** due to the laminate's lack of symmetry and balance. All curing techniques use heat and pressure to cause the matrix to flow and wet out all the fibers before the matrix solidifies.

Generally, the percent matrix weight is higher before cure initiation; the matrix flows out of the laminate and takes the excess resin with the potential voids. An **arbitrary** 1% void limit has been adopted for most **autoclaved** composites; filament wound and pultruded composites will have higher void volumes depending upon the application. An autoclave is essentially a closed, pressurized oven; many common epoxy laminates are cured at an upper temperature of 177℃ (350℉) and 6MPa (100psi). Autoclaves are still the primary tool in advanced composite processing and have been built up to 16m (55 feet) long at 6.1m (20 feet) diameter. Since autoclaves are expensive to build and operate, many other methods of curing, compacting composites have been developed. The two newest and most attractive methods are fiber placement and resin transfer molding.

Resin Transfer Molding

Previous discussions have centered on moving resin out of the laminate to reduce voids. Resin transfer involves the placement of dry fiber reinforcement into a closed mold and then injecting a catalyzed resin into the mold to **encapsulate** the reinforcement and form a composite. The **impetus** for the use of this process comes from the large cost reductions that can be realized in raw materials and **lay-up**. The process can utilize low injection pressures i.e. 55MPa (80 psi), therefore, the tooling can be lower cost plastic or a vacuum bag rather than metal. A wind eye at speeds **synchronized** with the mandrel rotation, control winding angle of the reinforcement and the fiber lay-down rate. The reinforcement may be wrapped in **adjacent** bands or in repeating bands that are stepped the width of the band and that eventually cover the mandrel surface. Local reinforcement can be added to the structure using circumferential windings, local **helical** bands, or by the use of woven or unidirectional cloth. The wrap angle can be varied from low angle helical to high angle **circumferential**.

Fiber Placement

Fiber placement, initially developed by Hercules Aerospace Co., is a cross between filament winding and automatic tape laydown, retaining many of the advantages of both. The natural **outgrowth** of adding multiple axes of control to filament winding machines results in control of the fiber laydown so that non **axisymmetric** surfaces can be wound[②]. This involves the addition of a modified tape laydown head to the filament winding machine and much more.

Filament Winding

Filament winding is a process by which continuous reinforcements in the form of **rovings** or tows (gathered, untwisted strands of fiber) are wound over a rotating **mandrel**. The mandrel can be **cylindrical**, round or any other shape as long as it does not have **re-entrant curvature**. Special machines traversing machine additions include in-process compaction, individual tow cut/start capabilities, a resin tack control system, differential tow payout, low tension on fiber and enhanced offline programming.

Pultrusion

Pultrusion is an automated process for the manufacture of constant volume/shape pro-files from

composite materials. The composite reinforcements are continuously pulled through a heated **die** and shaped and cured **simultaneously**. If the **cross-sectional** shape is conducive to the process, it is the fastest and most economical method of figurations can be fabricated with square round, hat-shaped, angled 'I' or 'T'-shaped cross-sections from vinylester, polyester, or epoxy matrices with E and S-glass, Kevlar and graphite reinforcements. The curing is effected by combinations of **dielectric** preheating and microwave or **induction** (with conductive reinforcements like carbon graphite) while the shape **traverses** the die.

Braiding, Weaving and Other Preform Techniques

Braiding, weaving, knitting and stitching represent methods of forming a shape, generally referred to as **preforming**, with the composite fibers before **impregnation**. The shape may be the final product or some intermediate form such as a woven fabric. The braiding process is continuous and is **amenable** to round or **rectangular** shapes or smooth curved surfaces and can transition easily from one shape to another. The other fabric preforming techniques are weaving, knitting and the non-structural stitching of unidirectional tapes. Stitching simply uses a non-structural thread, such as nylon or Dacron, to hold dry tapes at selected fiber angles. Preforming in this manner results in a higher-cost raw material but saves labor costs for orientation of individual lamina. The stitched preform has known, stable fiber orientations similar to woven fabric, without the **crossovers** which could reduce compressive strength.

(Selected from *Handbooks of Composites*, by S. T. Peters, 1998)

Questions

1. Describe the process of Lay-up techniques.
2. What is resin transfer molding?
3. What kind of objects may be pultruded?
4. Translate the last paragraph into Chinese.

New Words and Expressions

1. residual *adj.* 剩余的，残留的
2. internal stress 内应力
3. iterative *adj.* 重复的，反复的，迭代的
4. configuration *n.* 构造，形状，外貌，轮廓
5. tooling *v.* 加工
6. leakproof *adj.* 不会漏的，防漏的
7. aerodynamic *adj.* 空气动力学的
8. caul *n.* 胎膜，大网膜
9. augment *v.* 增加，提高，扩大
10. elastomer *n.* 弹性体，人造橡胶
11. integral *adj.* 构成整体所必需的

12. substructure *n.* 亚结构，基础
13. ply *v.* 使用（工具）固定往来；*n.*（夹板的）层片
14. warp *v.* 弄弯，变歪
15. arbitrary *adj.* 随意的，主观的
16. autoclave *n.* 热压釜
17. encapsulate *vt.* 装入胶囊
18. impetus *n.* 推动，促进，刺激
19. synchronize *v.*（使）同步；（使）同速进行
20. adjacent *adj.* 邻近的
21. circumferential *adj.* 圆周的
22. lay-up *n.* 铺叠成型
23. outgrowth *n.* 结果
24. axisymmetric *adj.* 轴对称的
25. roving *n.* 粗纱
26. mandrel *n.* 心轴；芯模
27. cylindrical *adj.* 圆柱的
28. re-entrant *adj.* 凹的（角）
29. curvature *n.* 弯曲；弯曲部分；曲率，曲度
30. helical *adj.* 螺旋状的
31. pultrusion *n.* 拉挤成型
32. die *n.* 模具
33. simultaneously *adv.* 同时地
34. cross-sectional *adj.* 横断面的
35. dielectric *n.* 电介质，绝缘体；*adj.* 非传导性的
36. induction *n.*（电或磁的）感应
37. traverse *v.* 横越，穿越，横贯
38. braiding *n.*（总称）各种编织带；编织物
39. preforming *n.* 预成型，压片
40. impregnation *n.* 浸渍
41. amenable *adj.* 柔顺的
42. rectangular *adj.* 长方形的，矩形的
43. crossover *n.* 转型；转向

Notes

① In efforts to reduce labor costs of composite fabrication, to which lay-up has traditionally been the largest contributor, mechanically assisted, controlled tape laying and automated integrated.

参考译文：为了降低复合材料的制造成本，传统上应用最广的手糊成型技术得到机械辅助，整合了自动铺带技术。

② The natural outgrowth of adding multiple axes of control to filament winding machines results

in control of the fiber laydown so that non axisymmetric surfaces can be wound.

参考译文：对纤维缠绕设备添加多轴操纵装置自然会影响纤维的叠放，所以不能够卷绕成型轴对称的表面。

5.4 The Uses of Composite Materials

Composites in Land Transportation Applications

The use of polymer composite materials in land transportation is steadily increasing because of the cost and performance advantages that composites offer over competing materials. Today, composites are extensively used in **well-established** passenger car, van and truck applications. New applications demanding higher structural performance levels are under development. Railroad cars, mass transit vehicles and a wide range of military ground transportation systems offer expanding opportunities for composite materials.

Driving forces for the use of polymer composites in ground transportation applications include low manufacturing investment cost, cost reduction through parts consolidation, weight savings, good mechanical properties, "Class A" surface quality, excellent durability characteristics, inherent dent and corrosion resistance, good noise and vibration **dampening**, styling **flexibility** and dimensional stability. Factors which tend to **mitigate** against their use are high materials costs, low modulus and the reluctance to use materials perceived to be "new and unproven".

Only those materials and processes which provide required performance at the lowest cost achieve long-term commercial success in transportation applications. For high-volume automobile and truck applications, high-speed processes must be used to manufacture parts rapidly enough to meet the production rates of the assembly plants. As a result, injection and compression molding processes are used extensively for these applications. Composites typically used in transportation applications consist of low-cost grades of thermoplastic or thermoset polymers reinforced with E-glass fibers. Often these composites also contain mineral particulate fillers. Composites containing high-modulus fibers, such as carbon, and higher-performance resins such as epoxies, are used only where the higher cost can be justified to meet special product requirements. Metal matrix composites are used very **sparingly** in ground transportation.

Over the past 50 years, the use of polymer composites generally has progressed from low-performance applications towards more demanding applications requiring excellent surface appearance, high mechanical properties, increased temperature stability or improved durability. With increasing demands to reduce vehicle weight for improved fuel economy, and to reduce investment costs for greater competitiveness, the use of composites in ground transportation is expected to increase for many decades to come.

Composites in Aerospace Equipment and Instrument Structure

It is necessary to discuss GFRP (graphite fiber reinforced plastics) thoroughly in order to understand the importance of composites in the manufacture of aerospace equipment and instrument structures. Before composite materials such as GFRP became **viable candidate** materials for aero-

space **primary structures**, or even for sporting equipment, they were first used for aerospace equipment and instrument structures. Because composites exhibited both unique and superior properties, designers were willing to pay the **prevailing** high prices to achieve their design goals. For space hardware, where a pound of weight saved was worth thousands of dollars, designers were motivated to characterize composite materials suitable to their applications. Understandably, composites for primary and secondary structure (e. g. , launch vehicles, aircraft frames, wing spars and skins, etc.) were a "hard sell", and temperature extremes were too severe for "thermosetting" GFRP to be used on missiles[①]. The quantity of GFRP required for a particular piece of aerospace equipment or instrument structure was usually minimal, so relative costs were low, and composite materials' superior properties compared to heavy **Invar**, or high coefficient of thermal expansion (CTE) **aluminum**, or very expensive **beryllium** further justified the material selection.

Consequently, numerous mirror **bezels**, telescopes, **optical benches** and **reflectors** were designed and built from GFRP in the early 1970s. As a result of these efforts, today more and more structures are being fabricated from GFRP materials, principally because specific materials matching specific property requirements are now available.

Although GFRP has dominated composite materials applications, DuPont's Kevlar-49 has been found to be ideal for antenna reflectors because of its extremely light weight and **RF** transparency. Many communication satellites utilize this type of Kevlar reflector.

For aerospace equipment and instrument structures, generally, thermoplastic versions of GFRP have not seen as much application as the thermosets due to high investment costs in tooling and facilities. Considering the relatively small quantities that are usually bought, thermoplastic applications are not often cost effective. Also, the required high temperature cures subject the laminate to **microcracking** instabilities.

Metal matrix composite applications have been limited, and knowledge of material properties and processes has been restricted due to their use on classified programs. Materials like **silicon carbides** and carbon-carbon find limited, but important, use in aerospace structures, particularly mirrors. Design selection **criteria** plays an extremely important role in determining what type of material is used on any particular component of aerospace equipment and instrument structures. The primary reasons for choosing a composite material, rather than a metal, are weight, dynamic stability and thermal stability.

The primary reason that GFRP is a material candidate for most applications is the wide range of material systems that are currently available that can compare with Kevlar, aluminum, Invar, beryllium, metal matrix composites, silicon carbide, and carbon-carbon.

Composites in Aircraft Applications

Advanced composites, composed of high strength, high modulus, low density continuous fibers **embedded** in polymer matrices, first became available some 30 years ago. Since then, composite aircraft structures have **transitioned** from laboratory **curiosities** into low-risk, light-weight alternatives to metal structures. Thousands of **safety-of-flight** composite components are flying in regular service on military and civil aircraft.

Major advantages of high-performance composite structures include weight savings, material **tailorability**, improved **fatigue** and **corrosion** resistance. Disadvantages are primarily cost related. Almost all the composite structures currently in production and service have thermoset matrices. A few aircraft parts are currently being made from thermoplastic matrix composites. Metal matrix composites are still in the development stage.

"Conventional" aircraft structural materials now include polymer matrix composites in addition to aluminum, **titanium** and steel.

Composites in the Sporting Goods Industry

In 1990 Frost & Sullivan reported that over 800 million dollars were spent by **domestic** defense/aerospace contractors for advanced composites. In the same period, $70 million worth of advanced composites were purchased from domestic producers for sporting goods.

Advanced composites are usually defined as those composites that use either carbon, **aramid**, S-glass, ceramic, **polyethylene**, **boron**, or other high strength or high stiffness fiber. In 1991, the total worldwide consumption of advanced fibers was estimated to be 27,200 **metric** tons. Approximately 10% of this fiber went into sport and recreation applications. Worldwide sport and **recreation** applications are the third largest user of advanced composites behind defense/aerospace and elastomer reinforcement (tires, hose and belts). In the USA as well, sport and recreation applications are the third largest users of advanced composites. One of the major growth markets for advanced composites over the past several years has been the sporting goods industry. Although there was a total decline in USA defense spending of only 14% from 1990 to 1994, the procurement decline was 45%. The defense **procurement** decline was disastrous for the composites industry and resulted in severe **upheavals**. Although no segment of the composites market could **offset** the defense-induced decline, the sporting goods/recreation composite segment along with most other **segments** is predicted to show positive growth in the near future[②]. This growth trend is expected to continue into the 21st century. Advances in materials and processes have reduced consumer prices for the recreational composite while providing improved performance for the athlete.

Some of the first applications for composites in sport and recreation were fiberglass boat **hulls** and **fishing poles**. Now the list of products using composites includes almost every sporting and recreation activity. Products in golf, tennis, and bicycle racing have brought attention to the superior performance of composites in sports and recreation.

Hand lay-up and roll-wrapping have been the processes generally used for most sporting goods applications. There has been an increased interest in filament winding as a preferred process for tubular products such as golf shafts, sail **masts**, ski poles, **softball bats** and bicycle frame tubing, because filament winding can lower labor costs and add a new level of design flexibility, product **consistency**, and quality for these products.

Construction

Composite materials are used by the construction industry to replace or complement conventional materials such as steel and concrete. The main reasons for the use of composite materials are corrosion resistance, **electromagnetic transparency** and weight savings Frequently, structural engi-

neers take advantage of more than one **salient** feature of composites to formulate a design that is competitive with an alternate design based on conventional materials.

Corrosion resistance is the most important advantage of composites with respect to steel for construction applications. The selection of a composite material usually begins with the selection of a resin that is capable of resisting the attack of a corrosive substance. The corrosive agent can be anything from spring water to **sulfuric** acid.

While weight saving is the main driving force behind the application of composites in aerospace, it is not so critical in construction projects. However, reduction of structural weight can be exploited as a secondary advantage to help offset the higher cost of composites as compared to conventional materials[③]. Lightweight structures require less foundation and supporting structure. In the case of bridges, a noncorrosive bridge deck can be built to replace existing steel reinforced concrete decks that corrode rapidly under the attack from **de-icing** chemicals. For example, a pultruded deck was used to construct the Wick Wire Run vehicular bridge on public road 26, in Taylor County, West Virginia (completed August 1996). An added advantage of a composite deck would be the weight reduction that supposedly would allow the user (highway department) to re-rate some bridges for a higher live load without major modifications to the existing superstructure. The live load could be increased by approximately the same amount of dead load saved with the use of the composite deck minus adjustments for dynamic effects. Other applications where weight savings are important are **cladding** of buildings, **rehabilitation** of chimneys, etc.

(Selected from *Handbooks of Composites*, by S. T. Peters, 1998)

Questions

1. What are driving forces for the use of polymer composites in ground transportation applications?
2. Why it is necessary to discuss GFRP thoroughly in order to understand the importance of composites in the manufacture of aerospace equipment?
3. List the major advantages of high-performance composite structures.
4. Can you tell what is the third largest user of advanced composites behind defense/aerospace and elastomer reinforcement?
5. How to look at Composite materials used by the construction industry?

New Words and Expressions

1. well-established *adj.* 已享有盛誉的，久负盛名的
2. dampen *v.* 减振
3. flexibility *n.* 弹性，适应性，机动性，挠性
4. mitigate *v.* 减轻，缓和
5. sparingly *adv.* 节俭地，保守地
6. viable *adj.* 切实可行的，可实施的

7. candidate *n.* 候选者
8. primary structure 一级结构；主（要）结构
9. prevailing *adj.* 占优势的，主要的，流行的
10. Invar *n.* 热膨胀系数较小的材料，也叫因瓦合金
11. aluminum *n.* 铝
12. beryllium *n.* 铍
13. bezel *n.* 表框
14. optical bench 光具座
15. reflector *n.* 反射器；反射光［热、声音］的物体
16. RF 射频（Radio Frequency），无线电频率
17. microcrack *v.* （使）产生微裂纹
18. silicon *n.* 硅
19. silicon carbide *n.* 碳化硅，金刚砂
20. criterion *n.* （批评、判断等的）标准，准则（复数形式为 criteria）
21. embed *v.* 把……嵌入，埋入
22. transition *n.* 过渡；转变；变迁
23. curiosity *n.* 奇物，珍品
24. safety-of-flight 安全飞行
25. tailorability *n.* （衣料等）可裁剪性
26. fatigue *n.* 疲劳，劳累
27. corrosion *n.* 腐蚀；受腐蚀的部位
28. titanium *n.* 钛
29. domestic *adj.* 本国的，国内的
30. aramid *n.* 芳族聚酰胺；芳纶
31. polyethylene *n.* 聚乙烯
32. boron *n.* 硼
33. metric *adj.* 米制的
34. recreation *n.* 娱乐（方式）；消遣（方式）
35. procurement *n.* 获得
36. upheaval *n.* 突然的巨变；大动荡；大变动
37. segment *n.* 部分，片段
38. offset *v.* 抵消，补偿
39. hull *n.* 船体，船身
40. fishing pole *n.* 钓鱼竿
41. tubular *adj.* 管的；管子形的
42. hand lay-up 手工制造增强塑料膜；手糊成型
43. mast *n.* 船桅，桅杆；旗杆
44. softball bat 垒球棒
45. consistency *n.* 坚实度

46. electromagnetic *adj.* 电磁的
47. transparency *n.* 透明（性）
48. salient *adj.* 显著的，重要的，主要的，（指角）凸出的
49. sulfuric *adj.* 硫磺的，含大量硫磺的
50. de-ice *v.* 除去（某物）上的冰；防止（某物）的表面结冰
51. cladding *n.* 覆层
52. rehabilitation *n.* 复原，修复

Notes

① Understandably, composites for primary and secondary structure (e. g. launch vehicles, aircraft frames, wing spars and skins, etc.) were a "hard sell", and temperature extremes were too severe for "thermosetting" GFRP to be used on missiles.

参考译文：不难理解，用于一级结构与二级结构的复合材料（比如运载火箭、飞机构架、翼梁及外壳等）是一个大难题，而且由于温度极限要求过于苛刻，热固性玻璃钢不能用于导弹。

② Although no segment of the composites market could offset the defense-induced decline, the sporting goods/recreation composite segment along with most other segments is predicted to show positive growth in the near future.

参考译文：尽管任一部分复合材料市场都不能补偿因防御引起的市场消减，但可以预期在不远的将来，体育休闲用品及其他市场将会大幅增长。

③ However, reduction of structural weight can be exploited as a secondary advantage to help offset the higher cost of composites as compared to conventional materials.

参考译文：然而，利用复合材料可以有效减轻结构的重量，这作为次要优势有助于抵消与传统材料相比的较高的材料成本。

Reading Material

Typical Properties for Advanced Composites

For a company or institution that is designing composite material structures, or **embarking** for the first time into the application of advanced composite materials for structural purposes, it is **imperative** that material properties be available. Of course it would be desirable to have a complete set of statistical Design Allowables, such as the statistical "A" values for properties, or even the "B" values. Since complete statistical Design Allowables are not available, the next sought after material properties would be "typical" properties. However "typical" properties are not defined statistically and may be defined in many different ways. Therefore it is important to discuss typical material properties and also discuss the means to achieve a set of typical properties.

The purpose of having a complete set of typical properties is to be able to design composite structures with a minimum of testing confirmation. Having a complete set of typical properties will allow design optimization, preliminary design, cost and weight optimization and other trade-offs with

a number of different materials and candidate laminates with different fiber orientations. Once an optimum material and configuration is selected, a minimum test program would then be initiated.

Having a set of typical composite materials has advantages and disadvantages. For example, if one were to design a structure utilizing only typical material properties, without the knowledge of the **scatter** that may occur in those properties, structural failure may occur. Perhaps not immediately, nor on every structure produced, but on an unknown statistical basis, at some point in time. However, prior to a final design for a structure, the normal engineering procedure is to initiate the test program. The purpose of the test program is **threefold**: one, confirmation of the design; two, determine the scatter that occurs due to variations in materials and the manufacturing process; and three, over a period of time, either to confirm the material properties database being used, or to accumulate test data for a material properties database.

One of the problems of determining typical properties is the variations that occur in the materials making up laminates. In the case of glass fiber, the types of glass fiber and number of manufacturers is considerably less than with carbon fiber.

However, even with this limitation, there are at least two major types of glass fiber, E-glass and S-2 glass. Within each of these glasses are variations in chemical composition, fiber diameter, fiber finish, fiber sizing, the number of individual fibers in a tow, roving, yarn, etc.

Manufacturers have different names for the similar type of glass, for example the higher strength, higher modulus glasses. These fiber glasses are the older S-glass (no longer available commercially), S-2 glass and the R-glass by a French manufacturer. Other countries fabricate the same type of glass, but with only minor differences in properties.

For carbon fiber, not only are there the same variations as mentioned above for glass, but in addition, there are large variations in strength and modulus and in manufacturers.

Based on the large number of variations in fibers, it would be virtually impossible to obtain complete statistical material properties for each variation. Even to obtain typical properties for each variation would not be practical.

To reduce this problem to a practical level, it is necessary to analyze the usage of glass and carbon fibers (or other fibers). The usage of advanced composite fibers by "pounds used per dollar expended", is estimated to be, in order of highest usage: E-glass, high strength carbon (modulus of 227GPa, (33×10^6 psi)) and then S-2 glass. With this list, it is possible to develop typical properties for composites fabricated from each of these fiber types.

The matrix for fiber composites can be classified into two categories, metallic and non-metallic. This discussion on typical properties involves only non-metallic **resin** matrix systems.

As was discussed for fibers, only the high usage matrix systems in advanced composites are considered as candidates for typical properties. In addition, for typical properties of advanced composites for structural applications, only structural resin systems are candidates. Structural resins are defined as resins that have similar modulus and tensile strength as standard epoxy systems. For example, an applicable resin for structural composites would have a modulus of approximately 3.5GPa (0.5×10^6psi) and a tensile strength of approximately 100MPa (15hi).

The more popular structural resins are polyester, epoxy, vinyl ester and phenolic. For typical composite properties, the use of any of these resins will allow a single typical property.

There are properties in which the resin is the significant factor. These characteristics are associated with stress concentrations and environmental considerations. Key among these characteristics are: temperature, fracture toughness, compression after impact, crack **propagation**, humidity, stress concentrations, interlaminar shear, mechanical fasteners in laminates, holes in laminates, creep, damage tolerance and compatibility with fiber finish. In determining typical properties, these characteristics are not included but, as applicable, need to be considered for the final design[①].

Fiber-reinforced composite materials are primarily used to take advantage of the high strength and stiffness of the fiber. Therefore in most applications, the laminate orientation is designed so that the strength and modulus are controlled by the fiber properties.

For the fiber fracture controlled composites, which are the main interest in structures, typical composite material properties are valid over a wide variation in resin characteristics.

The main interest in structural components is the high strength and modulus obtainable from the fiber reinforcing of the matrix. Therefore in the design of the laminate, for most of the applications, the resulting failure modes are fiber fracture critical. Unfortunately, there are cases where the matrix is the critical element in the failure mode for all laminate orientations. This does not mean that the fiber does not contribute to reinforcing the matrix in both strength and modulus, but only that the ultimate failure is the result of failure in the matrix[②].

Among the cases where the matrix is the critical failure mode are laminates that are subjected to shear, the first ply failure (limit load) of a laminate and most cases of the transverse strength property of a laminate with no 90″ plies. Even for these cases, a typical property can be determined utilizing the typical set of unidirectional properties represented by most of the epoxy systems in use by the prepreg manufacturers as well as most of the structural epoxies sold.

The acceptability of material properties in the design of structures is based on a number of factors. If a design is being produced for a customer, the customer is often the final word on the acceptability of the material properties utilized. An alternate possibility is that the customer is not interested in accepting or rejecting the material properties used, but would rather accept the product against a specification. Final acceptance is a qualification of the product through testing. The third case is where a product is produced by the company itself and sold to the consumer directly. Of course the consumer (public) is not interested in accepting or rejection the material properties database. An example of this is the automobile industry.

In the case of a company that **subcontracts** the design and fabrication of composite structures, the company may either want to review the subcontractor's material properties database, or be able to review the design of the subcontractor with the use of the company's typical properties database.

In each of the above cases, a typical material properties database can be used for cost and weight **trade-offs**, selection of the best materials, optimizations studies and **preliminary** design.

It is important to note that the final design would always go through an extensive test program to verify the material properties selected, the final design, the manufacturing process and to determine

the variability of the product.

Thus, a typical material properties database is acceptable and useful to reduce the cost of engineering design, reduce the cost of testing and allow a more intelligent and less time consuming approach to the final design.

In the above discussion, the customer requirements were mentioned as one of the criteria for acceptance or rejection of a material properties database. There are cases where the customer will insist upon enough testing to develop a **statistical** property database. For that requirement the typical material database would not be acceptable. However in any statistical database, the applicability is confined to the specific fiber, matrix and fabrication process. The statistical testing process is expensive and time consuming. In most cases, the statistical database would be limited to the laminate orientations tested, which would also be very limited.

For applications where significant environmental conditions are present, the use of typical material properties may not be applicable due to large variations in the response of different resins to these environmental conditions. These conditions were summarized above and included impact, humidity other corrosive **fluids**, **stress concentrations**, temperature, etc.

The design of composite material structures requires a knowledge of the material properties for all combinations of laminates. It is cost-prohibitive to test all combinations of laminates, even to obtain typical properties. To obtain statistical design properties for a limited number of laminate **configurations** is also expensive, but in some cases may be required by a contract. Typical composite material properties can provide useful data and be cost effective for the design engineer. The data can be generated by utilizing typical unidirectional data for each class of materials. To generate all the laminate configuration, both limit (first ply failure) and ultimate, requires a comprehensive computer program, including a failure criteria and utilizing the composite transformations equations. A typical property database for all orientations and selected materials is available, but also a typical composite material database could be generated by a company using composite engineering analysis as discussed above.

Although this discussion of typical properties has mentioned only static strength and modulus, typical properties are also available for fatigue, CTE and for elevated temperatures. Fatigue typical properties include all fatigue stress ratios. Fatigue statistical properties, of course, would be prohibitively expensive.

If users of typical composite material properties are aware of their limitations, typical properties can be a very useful database for cost effective design and analysis.

(Selected from *Handbooks of Composites*, by S. T. Peters, 1998)

Questions

1. What are the purposes of the test program?
2. What are the main interests in structural components?
3. What is the main idea of the first paragraph?

4. Describe what mean by "pounds used per dollar expended"?

New Words and Expressions

1. embark *v.* 着手
2. imperative *adj.* 必要的，紧急的，极重要的
3. scatter *n.* 离散
4. threefold *adv.* 三倍
5. resin *n.* 树脂
6. propagation *n.* 传播，扩展
7. subcontract *n.* 转包合同
8. trade-off 交换，协定，交易，平衡
9. preliminary *adj.* 初步的，预备的，开端的
10. statistical *adj.* 统计学的，以数据表示的
11. fluid *adj.* 流体的，流动的；*n.* 液体，流体
12. stress concentration 应力集中
13. configuration *n.* 构造，形状，外貌，轮廓

Notes

① In determining typical properties, these characteristics are not included but, as applicable, need to be considered for the final design.

参考译文：这些指标不是复合材料特征性能的决定因素，但在实际应用中，产品设计必须考虑。

② This does not mean that the fiber does not contribute to reinforcing the matrix in both strength and modulus, but only that the ultimate failure is the result of failure in the matrix.

参考译文：这并不是说纤维对增强基体的强度和模量没有贡献，仅是说最终的破坏是由基体破坏引起的。

科技英语翻译技巧（五）：关连词引导的句型翻译技巧（Ⅰ）

1. what 引导的句型翻译技巧

（1）what 作疑问词，译成“什么”或“哪些”。

What are the important factors influencing the structure of a casting?

影响铸件结构的重要因素是什么？

What are the electrical characteristics of the ceramics?

陶瓷的电性能有哪些？

What limits the applications of the structural composite materials?

什么局限了结构复合材料的应用？（what 既作为疑问词，又作为主语）

（2）what 具有双重作用，即起承上启下作用，可看做是连接主句的一个部分，也可看做是从句的一个成分。译成“什么”“什么样的”“怎样”或不译出。例如：

1）what 引导的句子作为主语：

What was impossible yesterday is a reality today!

昨天不可能的事在今天变成了现实！

What we should do today is to protect the environment.（what 引导的句子作为整个句子的主语，同时，what 又是主语从句中的宾语。）

今天我们应该做的就是保护环境。

2）what 本身作定语：

The question is what step we should take next.（表语从句，what 作定语）

问题在于下一步我们该采取什么措施。

This explained how these defects arise and what steps may be taken to minimize them.

这就解释了缺陷产生的原因以及采取什么样的措施能将其降到最小。

2. which 引导的句型翻译技巧

（1）which 作疑问词，译成“哪一（种）”“哪些”“哪个”等。

Which factor is the most important influencing the performance of the material?

影响材料性能的最重要的因素是哪一个？

（2）which 本身作主语，作主语相当于一个名词，翻译时可加所指代的具体事物作定语时，译成“那一（种）”“那些”“那个”等。

Ceramic materials are inorganic materials which consist of metallic and nonmetallic elements chemically bonded together.

陶瓷材料是无机材料，这些无机材料由金属和非金属元素通过化学作用连接在一起。

（3）which 本身作为宾语，作宾语时相当于一个名词，翻译时可加所指代的具体事物作定语时，译成“那一（种）”“那些”“那个”等。

The structure-property-processing relationship is also influenced by the surroundings to which the material is subjected.

材料的结构－性能－加工成型之间的关系也受到材料服役的那些环境的影响。

The engineer must recognize the type of loading to which the material is exposed.

工程师必须清楚材料承受的那些载荷的类型。

（4）which 引导的句子作为状语。

Arc welding is a process in which an electric arc is produced between a metal electrode or wire carrying high amperage current and the workpiece.

在电弧焊中，电弧主要是在大电流金属电极（或焊丝）和工件之间产生。

Normally, the yield strength, above which the material suffers a permanent change in its dimensions, is the most critical property and is usually the most important consideration in the design of a material component. （which 引导的条件状语从句，如果可从逻辑上判断条件状语的意义，则可以转译成相应的状语从句。）

通常来说，屈服强度是最重要的性能，高于它，材料就会发生永久变形。

Metals have a crystalline structure in which the atoms are arranged in an orderly manner. （为了将句子表述清楚，有必要把 in which 译出来，放在合适的位置。）

金属有晶体结构，在这个晶体结构中，原子呈有序排列。

3. when 引导的句型翻译技巧

（1）when 作疑问词，译成“何时”“什么时候”。

When did the molten metal begin to solidify?

熔融金属什么时候开始凝固？

（2）when 引导的句子作为主语，译成“……的时间”形式。

When a molten metal reaches its freezing point affects the size of the crystals which form.

熔融金属达到凝固点的时间会影响到形成晶粒的尺寸大小。

（3）when 引导的句子作为状语。

When the material engineer changes one of these three aspects of the relationship, either or both of the others also change. （when 引导的条件状语从句，如果可从逻辑上判断条件状语的意义，则可以转译成相应的状语从句。）

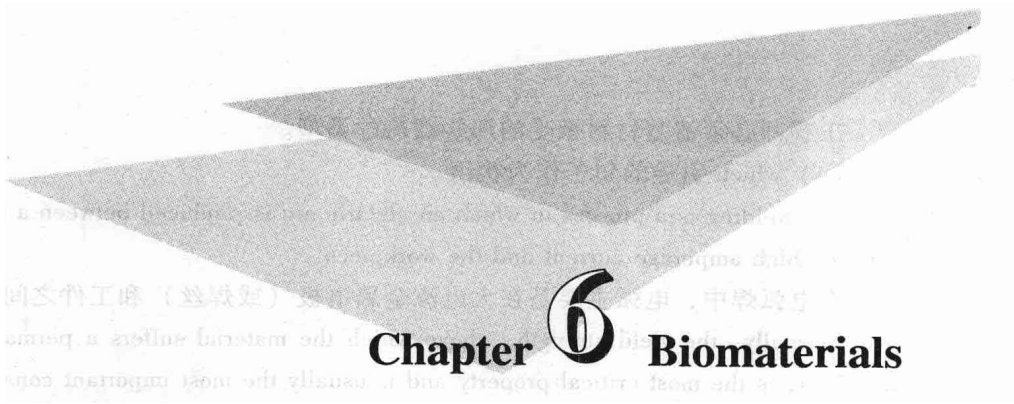
工程师如果改变了三方面的其中一个，另外两个就会发生变化，甚至同时发生变化。

Solidification will begin, and this takes place by a process of nucleation and growth, when the temperature of a molten pure metal falls to its freezing point. （不论原文中表示时间的从句是前置还是后置，根据汉语习惯，只要可从逻辑上判断时间状语的意义，都可将其译在前面。）

当熔融的纯金属的温度降低到凝固点时，就开始固化，这个过程主要通过形核和长大来进行。

When the metal first makes contact with the mould, the mould is cold and this has a chilling effect on the molten metal, which results in the formation of very small crystals. （when 引导的时间状语从句，在表达主句和从句的谓语动作同时进行时，英译汉时可以省略连词。）

金属与铸模接触后，由于铸模的温度低，对熔态金属具有激冷作用，导致非常细小的晶粒形成。



Chapter 6 Biomaterials

6.1 Biomaterials and Biomaterials Science

Biomaterials science addresses the properties and applications of materials (synthetic and natural) that are used in contact with biological systems. These materials are commonly called biomaterials. Biomaterials, an exciting field with steady, strong growth over its approximately half century of existence, **encompasses** aspects of medicine, biology, chemistry, and materials science. It sits on a foundation of engineering principles. These is also a compelling human side to **therapeutic** and **diagnostic** application of biomaterials[①].

Although biomaterials are primarily used for medical applications, they are also used to grow cells in culture, to **assay** for blood **proteins** in the clinic laboratory, in equipment for processing biomaterials for biotechnological applications, for implants to regulate **fertility** in cattle, in diagnostic gene arrays, in the aquaculture of oysters, and for investigational cell-silicon "biochips"[②]. How do we **reconcile** these diverse uses of materials into one field? The common thread is the interaction between biological systems and synthetic or modified natural materials.

In medical applications, biomaterials are rarely used as isolated materials but are more commonly integrated into devices or implants. It will quickly become apparent that the subject cannot be explored without also considering biomedical devices and the biological response to them. Indeed, both the effect of the materials/devices on the **recipient** and that of the host tissues on the devices can lead to device failure. Furthermore, a biomaterial must always be considered in the context of its final fabricated, sterilized form[③]. For example, when a **polyurethane elastomer** is cast from a solvent onto a mold to form the pump **bladder** of a heart assist device, it can elicit different blood reactions than when injection molding is used to form the same device. A **hemodialysis** system serving as an artificial kidney requires materials that must function in contact with a patient's blood and also exhibit appropriate membrane permeability and mass transport characteristics. It also must employ mechanical and electronic systems to pump blood and control flow rates.

A definition of "biomaterial" endorsed by a **consensus** of experts in the field is:

*A biomaterial is a **nonviable** material used in a medical device, intended to interact with biological systems (Williams, 1987).*

If the word "medical" is removed, this definition becomes broader and can encompass the wide

range of applications suggested above.

If the word "nonviable" is removed, this definition becomes even more general and can address many new tissue-engineering and hybrid artificial organ applications where living cells are used.

"Biomaterials science" is the physical and biological study of materials and their interaction with the biological environment. Traditionally, the most intense development and investigation have been directed toward biomaterials synthesis, optimization, characterization, testing, and the biology of host-material interactions. Most biomaterials introduce a non-specific, stereotyped biological reaction. Considerable current effort is directed toward the development of engineered surfaces that could **elicit** rapid and highly precise reactions with cells and proteins, tailored to a specific application.

Indeed, a complementary definition essential for understanding the goal (i.e. specific end applications) of biomaterials science is that of "biocompatibility".

Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application (*Williams, 1987*).

Examples of "appropriate host response" include the resistance to blood clotting, resistance to bacterial colonization, and normal, uncomplicated healing. Examples of **catheter**, or a **hip-joint** replacement **prosthesis**. Note that the hemodialysis membrance might be in contact with the patient's blood for 3 hours, the catheter may be inserted for a week, and the hip-joint may be in place for the life of the patient.

This general concept of biocompatibility has been extended recently in the broad approach called "tissue engineering" in which ***invitro*** and ***invivo*** **pathophysiological** processes are harnessed by careful selection of cells, materials, and metabolic and biomechanical conditions to regenerate functional tissues.

Thus, in these definitions and discussion, we are introduced to considerations that set biomaterials apart from most materials explored in material science④. Table 6.1 lists a few applications for

Table 6.1 Some applications of synthetic materials and modified natural materials in medicine

Application	Types of materials
Skeletal system	
Joint replacements (hip, knee)	Titanium, Ti-Al-V alloy, stainless steel, polyethylene
Bone plate for fracture fixation	**Stainless** steel, cobalt-chromium alloy
Bone cement	Poly (methyl methacrylate)
Bony defect repair	Hydroxylapatite
Artificial **tendon** and **ligament**	Teflon, **Dacron**
Dental implant for tooth fixation	Titanium, Ti-Al-V alloy, stainless steel, polyethylene
	Titanium, alumina, calcium phosphate
Cardiovascular system	
Blood vessel prosthesis	Dacron, Teflon, polyurethane
Heart valve	Reprocessed tissue, stainless steel, carbon
Catheter	Silicone rubber, Teflon, polyurethane
Organs	
Artificial heart	Polyurethane
Skin repair template	Silicone-collagen composite
Artificial kidney (**hemodialyzer**)	Cellulose, polyacrylonitrile
Heart-lung machine	Silicone rubber

(Continued)

Application	Types of materials
Senses	
Cochlear replacement	Platinum electrodes
Intraocular lens	Poly (methyl methacrylate), silicone rubber, hydrogel
Contact lens	Silicone-acrylate, hydrogel
Corneal bandage	Collagen, hydrogel

synthetic materials in the body. It includes many materials that are often classified as "biomaterials". Note that metals, ceramics, polymers, glasses, carbons, and composite materials are listed. Such materials are used as molded or machined parts, coatings, fibers, films, foams and fabrics.

(Selected from *Biomaterials Science*, edited by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, 2005)

Questions

1. What is "biomaterials science"?
2. What is the definition of "biomaterials"?
3. How long has biomaterials science existed?
4. What are the biomaterials used for? Give some application examples.
5. What is "tissue engineering"?
6. Use your own words to explain the meanings of *invitro* and *invivo*.

New Words and Expressions

1. encompass *v.* 包围，环绕，包含或包括某事物
2. therapeutic *n.* 治疗剂；*adj.* 治疗的，治疗学的
3. diagnostic *adj.* 诊断的
4. assay *n.* & *v.* 化验，分析，检定
5. protein *n.* 蛋白质；*adj.* 蛋白质的
6. fertility *n.* 繁殖能力，生育力，生产力，多产
7. aquaculture *n.* 水产业
8. oyster *n.* 牡蛎，蚝
9. polyurethane *n.* 聚亚胺脂
10. elastomer *n.* 弹性体，人造橡胶
11. bladder *n.* 膀胱，球胆
12. hemodialysis *n.* 血液透析
13. consensus *n.* 一致同意，舆论，同感
14. nonviable *adj.* 无法生活的，不能存活的
15. elicit *v.* 得出，引出，引起
16. skeletal *adj.* 骨骼的，骨架的，纲要的
17. tendon *n.* 腱

18. stainless *adj.* 不锈的，无瑕疵的，纯洁的
19. ligament *n.* 韧带
20. Dacron *n.* 涤纶，的确良
21. hemodialyzer *n.* 人造肾脏
22. corneal *n.* 角膜的
23. bandage *n.* 绷带
24. catheter *n.* 导管，导尿管
25. hip-joint 髋关节
26. prosthesis *n.* 假体（如假肢、假眼或假牙等），人体修复（术）
27. invitro *adj.* 在活体外部的
28. invivo *adj.* 在活体内的，在生物体内的
29. recipient *n.* 接受者，容器；*adj.* 容易接受的，感受性强的
30. reconcile *v.* 使和谐，使和解，协调
31. pathophysiological *adj.* 病理生理的

Notes

① These is also a compelling human side to therapeutic and diagnostic application of biomaterials.

参考译文：生物材料在疾病的诊断和治疗方面的应用也很引人注目。

② . . . , they are also used to grow cells in culture, to assay for blood proteins in the clinic laboratory, in equipment for processing biomaterials for biotechnological applications, for implants to regulate fertility in cattle, in diagnostic gene arrays, in the aquaculture of oysters, and for investigational cell-silicon "biochips".

参考译文：……，它们也用于培养细胞的生长，用来在临床实验室检测血蛋白，用在处理生物材料的应用设备上，用于移植来控制牲畜生育率，诊断基因排列，用于牡蛎的养殖，并用于研究细胞—硅的"生物芯片"。

③ . . . , a biomaterial must always be considered in the context of its final fabricated, sterilized form.

参考译文：……，一种生物材料必须要考虑它最终加工、灭菌的形式。

in the context of 译为"在……背景（情况）下"，在此句中可不译出。

④ . . . , we are introduced to considerations that set biomaterials apart from most materials explored in material science.

参考译文：……，除了材料科学所研究的大部分材料之外，我们提出考虑生物材料。

apart from 译为"除……之外"。

Reading Material

Designed Biomaterials (Ⅰ)

Silicones

Though the class of polymers known as silicone has been explored for many years, it was not

until the early 1940s that Eugene Rochow of GE pioneered the scale-up and manufacture of commercial silicones via the reaction of methyl chloride with silicon in the presence of catalysts. In Rochew's 1946 book, The Chemistry of Silicones (John Wiley & Sons, Publishers), he comments **anecdotally** on the low toxicity of silicones but did not propose medical applications. The potential for medical uses of these materials was realized shortly after this, in a 1954 book on silicones, McGregor has a whole chapter titled "Physiological Response to Silicones". **Toxicological** studies were cited suggesting to McGregor that the quantities of silicones that humans might take into their bodies should be "entirely harmless". He mentions, without citation, the application of silicone rubber in artificial kidneys①. Silicone-coated rubber grids were also used to support a **dialysis membrane** (Skeggs and Leonards, 1948).

Teflon

DuPont chemist Roy Plunkett discovered a remarkable inert polymer, **Teflon** (polytetrafluoroethylene), in 1938. William L. Gore and his wife Vieve started a company in 1958 to apply Teflon for wire insulation. In 1969, their son Bob found that Teflon, if heated and **stretched**, forms a porous membrane with attractive physical and chemical properties. Bill Gore tells the story that, on a **chairlift** at a ski resort, he pulled from his parks pocket a piece of porous Teflon tubing to show to his fellow ski lift passenger②. The skier was a physician and asked for a specimen to try as **vascular** prosthesis. Now, Goretex porous Teflon is the leading synthetic vascular **graft** and has numerous applications in surgery and biotechnology.

Polyurethanes

Polyurethanes, reaction products of **diisocyanates** and diamines, were invented by Otto Bayer and his colleagues in Germany in 1937. The chemistry of polyurethanes intrinsically offered a wide range of synthetic options leading to hard plastics flexible films, or elastomers. Interestingly, this was the first class of polymers to exhibit rubber elasticity without covalent cross-linking. As early as 1959, polyurethanes were explored for **biomedical** applications, specifically heart valves (Akutsu et al., 1959). In the mid-1960s a class of segmented polyurethanes was developed that showed both good **biocompatibility** and outstanding flex life in biological solutions at 37℃ (Boretos and Pierce, 1967). Sold under the name Biomer, these segmented polyurethanes comprised the pump **diaphragms** of the Jarvik 7 hearts that were implanted in seven humans.

(Selected from *Biomaterials Science*, edited by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, 2005)

Questions

1. How were the commercial silicones manufactured in the early 1940s?
2. Which year was Telfon discovered?
3. What are polyurethanes?

New Words and Expressions

1. anecdotally *adv.* 趣闻地，多轶事地

2. toxicological *adj.* 毒物学的
3. dialysis *n.* 透析，分离
4. membrane *n.* 膜，隔膜
5. Teflon *n.* 特氟龙，聚四氟乙烯
6. stretch *v.* & *n.* 伸长，伸展
7. chairlift *n.* （运送滑雪者或游客上、下的）升降机，高空缆车
8. vascular *adj.* 脉管的，血管的
9. graft *v.* & *n.* （皮肤等）移植，嫁接
10. diisocyanate *n.* 二异氰酸盐（脂）
11. biomedical *adj.* 生物医学的
12. biocompatibility *n.* 生物适应性，生物配伍
13. diaphragm *n.* 横膈膜，膜片，振动膜

Notes

① He mentions, without citation, the application of silicone rubber in artificial kidneys.

参考译文：他提到硅橡胶在人工肾上的应用，但没有给出引用源。

② He pulled from his parks pocket a piece of porous Teflon tubing to show to his fellow ski lift passenger.

参考译文：他从皮大衣口袋里拿出一件多孔的管形特氟龙材料给同一滑雪缆车的乘客看。

6.2 Traditional and New Generation Biomaterials

Traditional Biomaterials

Although medical implant materials have been used for at least 2,000 years (some historians trace sutures back 32,000 years), most early medical implants were doomed to failure because important concepts relating to infection, materials, and the biological reaction to materials were not yet established[①]. The modern era of medical implants might be traced back to an observation made by British **ophthalmologist** Harold Ridley in the late 1940s. While examining Spitfire **fighter pilots** who had **shards** of **canopy** plastic unintentionally implanted in their eyes from enemy machine gun fire, he noted that these shards seemed to heal without ongoing reaction. He concluded that the canopy plastic, poly(methyl methacrylate), might be appropriate for fashioning implant lenses for replacing **cataractous** natural lenses. His first implantation of such a lens was in 1949. His observation and innovation led to the development of modern **intraocular** lenses (IOLs) that are now being implanted in over 10 million human eyes each year and have revolutionized treatment for those with **cataracts**. At about the same time that Harold Ridley was innovating IOLs, Charnley was developing the hip implant, Vorhees invented the **vascular graft**, Kolff was revolutionizing kidney dialysis, and Hufnagel invented the ball and cage heart valve. These pioneers, in an era before principles for medical materials were established, proved feasibility, saved lives, and evolved the foundations that

we build on today[②]. By the late 1960s engineers, chemists, and biologists, in collaboration with physicians, were formalizing design principles and synthetic strategies for biomaterials. In particular, the idea that the release of toxic **leachables** from biomaterials will adversely affect healing was formalized—this toxicology idea is implicit in today's definition of biocompatibility. As developments took place in biology and materials science, biomaterials researchers were quick to incorporate these new ideas into biomaterials. Molecular biology concepts are now opening new frontiers for biomaterials design—a path to biomaterials that will work with the normal physiology and **seamlessly** integrate into the human body.

The appreciation of the host response (healing) of implanted materials helps us understand the performance of today's biomaterials and also aids us in envisioning how we might improve the body's response to biomaterials in the future.

A New Generation of Biomaterials

The next generation of biomaterials will be based upon knowledge of the biology of wound healing and **inflammation** and will control **bioreactor** responses with precision. One approach to achieve such healing biomaterials is to modify surfaces of existing devices to minimize the foreign body reaction and to promote normal wound healing. This approach is elaborated on shortly. For longer-term solutions, however, researchers must turn to biology to develop ways to help the body mend itself and regenerate new tissue that can last for the patient's lifetime. The only way to replace function to damaged tissue is with similar tissue that contains the appropriate tissue **architecture** of cells and **ECM**. A number of different approaches are being investigated including drug and cell delivery. In both cases, a carrier is required to deliver the drug to a particular site successfully and, in the case of cells, to provide a 3-D structure that facilitates tissue growth. Many different types of biomaterials have been investigated for both drug and cell carriers. In **tissue engineering**, a combination of drugs, cells, and a suitable carrier with tailored macroscopic properties, a well-tuned degradation profile, and specific biological cues may be necessary to promote normal tissue growth[③].

This section highlights the next generation of biomaterials, which include surface modification of biomaterials to overcome nonspecific protein adsorption in vivo, precision immobilization of signaling groups on surfaces, the development of synthetic materials with controlled and **tailored** properties for drug and cell carriers, biologically inspired materials that mimic natural processes, and finally the design of sophisticated 3-D architectures to produce well-defined patterns for developing **bioMEM** devices and tissue-engineering scaffolds. Because of the fast growth of this field, this section aims to highlight several exciting new research areas. We present some of the most recent developments in the different subfields of biomaterials and provide references to recent reviews for more in-depth discussions. This section aims to demonstrate the powerful impact that biomaterials will have on the future of medicine.

(Selected from *Biomaterials: Where we have been and where we are going*, by B. D. Ratener and S. J. Bryant, 2004)

Questions

1. What are the traditional biomaterials?
2. How many years have the medical implant materials been used for?
3. What is a new generation biomaterials?
4. What kind of approach do the healing biomaterials adopt?

New Words and Expressions

1. ophthalmologist *n.* 眼科医生，眼科专家
2. fighter pilot 战斗机飞行员
3. shard *n.* 碎片，破片
4. canopy *n.* （飞行器上的）座舱罩
5. cataractous *adj.* 白内障的
6. intraocular *adj.* 眼内的
7. cataract *n.* 白内障
8. vascular graft 血管移植，人工血管
9. leachable *adj.* 可滤去的，可滤取的
10. seamlessly *adv.* 无缝地，无伤痕地
11. inflammation *n.* 发炎，发火，燃烧
12. bioreactor *n.* 生化反应器
13. architecture *n.* 体系结构，（总体、层次）结构，建筑学，建筑式样，建筑设计
14. ECM 细胞外基质（Extra Cellular Matrix）
15. tissue engineering （生物）组织工程学
16. tailored *adj.* 裁剪的，剪裁得体的
17. bioMEM 生物微电子机械的（biological Microelectromechanical）

Notes

① . . . , most early medical implants were doomed to failure because important concepts relating to infection, materials, and the biological reaction to materials were not yet established.

参考译文：……，因为感染、材料，以及材料的生物反应等重要概念还没有建立，大部分早期的医疗植入物是注定要失败的。

② These pioneers, in an era before principles for medical materials were established, proved feasibility, saved lives, and evolved the foundations that we build on today.

参考译文：在医疗材料的原则建立前的时代，这些先驱者证明了可行性，拯救了生命，发展了我们今天所建立的基础。

③ In tissue engineering, a combination of drugs, cells, and a suitable carrier with tailored macroscopic properties, a well-tuned degradation profile, and specific biological cues may be necessary to promote normal tissue growth.

参考译文：在组织工程中，为促进正常组织的生长，药物、细胞、具有定制宏观性能的

合适载体，良好的调整降解特性和具体的生物线索的结合是必要的。

Reading Material

Designed Biomaterials (Ⅱ)

Poly(ethylene glycol)

PEG, also called Poly(ethylene oxide) (PEO) in its high-molecular-weight form, can be categorized as a **hydrogel**, especially when the chains are cross-linked. However, PEG has many other applications and **implementations**. It is so widely used today that it is best discussed in its own section.

The low reactivity of PEG with living **organisms** has been known since at least 1944 where it was examined as a possible vehicle for intravenously administering fat-soluble hormones[①] (Friedman, 1944). In the mid-1970s, Abuchowski and colleagues (Abuchowski et al., 1977) discovered that if PEG chains were attached to **enzymes** and proteins, they would have a much longer functional residence time in vivo than biomoleculares that were not PEGylated. Professor Edward Merrill of **MIT**, based upon what he called "various bits of evidence" from the literature, concluded that surface-immobilized PEG would resist protein and cell pickup. The experimental results from his research group in the early 1980s bore this conclusion out (Merrill, 1992). The application of PEGs to wide range of biomedical problems has been significantly accelerated by the synthetic chemistry developments of Dr. Milton Harris while at the University of Alabama, Huntsville.

Poly(lactic-glycolic acid)

Though originally discovered in 1833, the **anionic polymerization** from the **cyclic lactide** monomer in the early 1960s made materials with mechanical properties comparable to Dacron possible. The first publication on the application of Poly(lactic acid) in medicine may have been by Kulkarni et al. (1966). This group demonstrated that the polymer degraded slowly after implantation in **guinea pigs** or rats and was well tolerated by the organisms. Cutright et al. (1971) was the first to apply this polymer for **orthopedic** fixation. Poly(glycolic acid) and **copolymers** of lactic and **glycolic acid** were subsequently developed. Early clinic applications of polymers in this family were for sutures. The glycolic acid/**lactic acid** polymers have also been widely applied for controlled release of drugs and proteins[②]. Professor Robert Langer's group was the leader in developing these polymers in the form of porous **scaffolds** for tissue engineering (Langer and Vacanti, 1993).

(Selected from *Biomaterials Science*, edited by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, 2005)

Questions

1. What is PEG?
2. Describe the applications of PEG.
3. What is polylactic acid?

4. Can polylactic acid be used in medicine?

New Words and Expressions

1. hydrogel *n.* 水凝胶
2. implementation *n.* 执行,实现,工具,设备
3. organism *n.* 生物体,有机体
4. enzyme *n.* 酶
5. MIT 麻省理工学院(Massachusetts Institute of Technology)
6. anionic polymerization 阴离子聚合
7. cyclic *adj.* 循环的,周期的
8. lactide *n.* 丙交酯, 交酯
9. guinea pig *n.* 豚鼠,(动物实验用)小鼠
10. orthopedic *adj.* 整形外科的
11. copolymer *n.* 共聚物
12. glycolic acid 乙醇酸, 羟基乙酸
13. lactic acid 乳酸
14. scaffold 脚手架;搭架

Notes

① The low reactivity of PEG with living organisms has been known since at least 1944 where it was examined as a possible vehicle for intravenously administering fat-soluble hormones.

参考译文：至少是在 1944 年当测试聚乙二醇作为一种可能的媒介物在静脉内控制溶脂激素时，它与活体组织的低反应性已被人们所知晓。

② The glycolic acid/lactic acid polymers have also been widely applied for controlled release of drugs and proteins.

参考译文：乙醇酸/乳酸聚合物已经被广泛地用于控制药物和蛋白质的释放。

6.3 Examples of Biomaterials Applications

Heart Valve Prostheses

Diseases of heart valves often make surgical repair or replacement necessary. Heart valves open and close over 40 million times a year and they can accumulate damages sufficient to require replacement in many individuals. More than 80,000 replacement valves are implanted each year in the United States because of acquired damage to the natural valve and **congenital heart anomalies**[①]. There are many types of heart valve and congenital heart anomalies. There are many types of heart valve prostheses and they are fabricated from carbons, metals, elastomers, plastics, fabrics, and animal or human tissues chemically **pretreated** to replace their **immunologic** reactivity and to enhance **durability**. Fig. 6.1 shows a bileaflet tilting-disk mechanical heart valve, one of the most

widely used designs. Other type of heart valves are made of chemically treated pig valve or cow pericardial tissue. Generally, almost as soon as the valve is implanted cardiac function is restored to near normal levels and the patient shows rapid improvement. In spite of the overall success seen with replacement heart valves, there are problems that may differ with different types of valves; they include induction of **blood clots**, **degeneration** of tissue, mechanical failure, and infection.

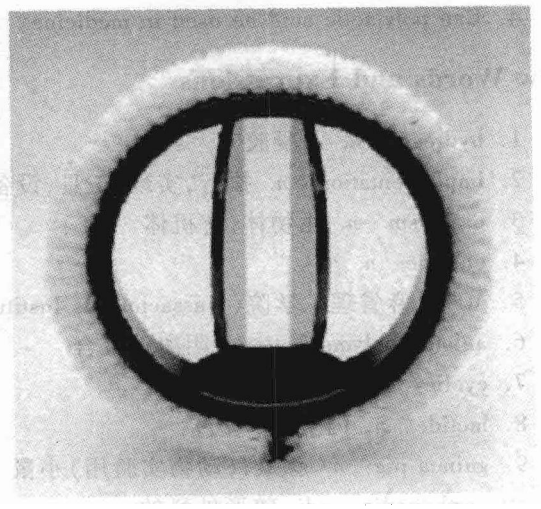


Fig. 6. 1 A replacement heart valve

Artificial Hip Joints

The human hip joint is subjected to high levels of mechanical stress and receives considerable abuse in the course of normal activity[②]. It is not surprising that after 50 or more years of cyclic mechanical stress, or because of degenerative or **rheumatological** disease, the nature joint wears out, leading to considerable loss of mobility and often confinement to a wheelchair. Hip-joint prostheses are fabricated from titanium, stainless steel, special high-strength alloys, ceramics, composites, and ultrahigh-molecular-weight polyethylene. Replacement hip joints (Fig. 6. 2) are implanted in more than 220,000 humans each year in the United States alone. With some type s of replacement hip joints and procedures that use a polymeric cement, **ambulatory** function is restored within days after surgery. For other types, a healing-in period is required for integration between bone and the implant before the joint can bear the full weight of body. In most cases, good function is restored. Even athletic activities are possible, although they are generally not advised. After 10-15 years, the implant may loosen, necessitating another operation.

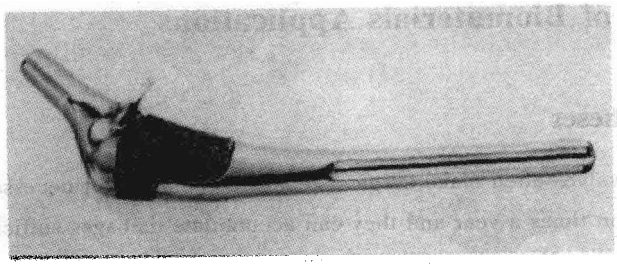


Fig. 6. 2 A metallic hip joint (photograph courtesy of Zimmer, Inc.)

Intraocular Lenses

A variety of **intraocular** lenses (IOLs) have been fabricated of poly(methyl methacrylate), silicon elastomer, soft acrylic polymers, or hydro gels and are used to replace a natural lens when it

become cloudy due to cataract formation (Fig. 6.3) By the age of 75, more than 50% of the population suffers from cataracts severe enough to warrant IOL implantation[3]. This translates to almost 4 million implantations in the United States alone each year, and double that number worldwide. Good vision is generally restored almost immediately after the lens is inserted and the success rate with this device is high. IOL surgical procedures are well developed and implantation is often performed on an **outpatient** basis. Recent observation is implanted lenses using a microscope to directly observe the implanted lens through the cornea show that inflammatory cells migrate to the surface of the lenses after implantation. Thus the **conventional healing** pathway is seen with these devices, similar to that observed with materials implanted in other sites in the body. Outgrowth of cells from the **posterior** lens capsule stimulated by the IOL can cloud the vision, and this is a significant complication.

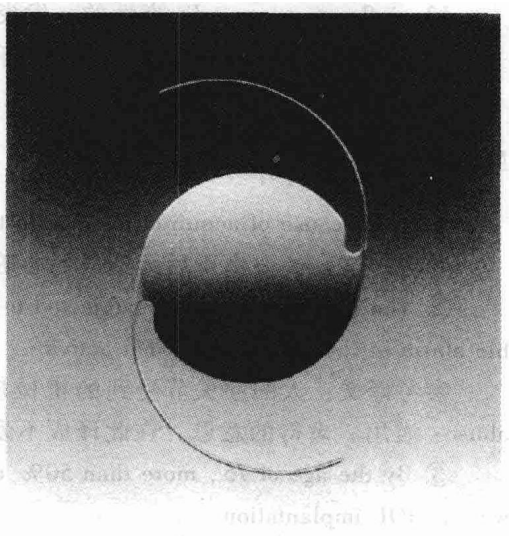


Fig. 6.3 An intraocular lens (photograph courtesy of Alcon Laboratories, Inc.)

(Selected from *Biomaterials Science*, edited by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, 2005)

Questions

1. What is heart valve prostheses?
2. Who will need artificial hip joint?
3. What kind of materials can be used to make hip-joint prostheses?
4. How many people will need IOLs implantation at age of 75?

New Words and Expressions

1. heart valve 心脏瓣膜
2. congenital heart anomalies 先天心脏异常
3. pretreat *v.* 预处理
4. immunologic *adj.* 免疫学的
5. durability *n.* 耐用性，耐久力
6. pericardial *adj.* 心包的
7. blood clot 血块
8. degenerative *adj.* 变质的，退化的
9. rheumatological *adj.* 风湿病的
10. ambulatory *adj.* 流行的，非固定的

11. intraocular *adj.* 眼内的
12. outpatient *n.* 门诊病人
13. inflammatory *adj.* 炎性的，发炎的，煽动的
14. healing *n.* 康复，复原；*adj.* 有疗效的
15. posterior *adj.* 后端的，后面的，较晚的

Notes

① . . . because of acquired damage to the natural valve and congenital heart anomalies.

参考译文：……由于后天造成的心脏瓣膜损坏和先天性心脏异常。

② The human hip joint is subjected to high levels of mechanical stress and receives considerable abuse in the course of normal activity.

参考译文：人的髋关节受到的机械应力高，在日常活动中相当多的情况对其不爱护。abuse：滥用、虐待的意思，在此译成不爱护。

③ By the age of 75, more than 50% of the population suffers from cataracts severe enough to warrant IOL implantation.

参考译文：对75岁的老年人来说，50%以上都会罹患严重的白内障，需要植入人工晶体。

Reading Material

Designed Biomaterials (Ⅲ)

Hydrogels

Hydrogels have been found in nature since life on earth evolved. Bacterial biofilms hydrated living tissues, extracellular matrix components, and plant structures are **ubiquitous**, **hydrated**, swollen **motifs** in nature[①]. **Gelatin** and **agar** were also explored early in human history. But, the modern history of hydrogels as a class of materials designed for medical applications can be accurately traced.

In 1936, DuPont scientist published a paper on recently synthesized **methacrylic** polymers. In this paper, Poly(2hydroxyethyl methacylate) (polyHEMA) was mentioned. It was briefly described as a hard, brittle, glassy polymer and clearly not considered of importance. After that paper, this polymer was essentially forgotten until 1960. Wichterle and Lim published a paper in Nature describing the polymerization of HEMA monomer and a cross-linking agent in the presence of water and other solvents (Wichterle and Lim, 1960). Instead of a brittle polymer, they obtained a soft, water-**swollen**, elastic, clear gel. This innovation led to the soft contact lens industry and to the modern field of biomedical hydrogels as we know them today.

Interest and applications for hydrogels have steadily grown over the years. Important early applications included **acrylamide** gels for **electrophoresis**, poly(vinyl alcohol) porous **sponges** (Ivalon) as implants, many hydrogel formulations as soft contact lenses, and alginate gels for cell encapsulation.

Hydroxyapatite

Hydroxyapatite is one of the most widely studied materials for healing in bone. It is both a natural component of bone (i. e., a materials of ancient history) and a synthetic material with a modern history. Hydroxyapatite can be easily made as a powder. One of the first papers to apply this material for biomedical application was by Levitt et al. (1969), in which they hot-pressed the hydroxyapatite powder into useful shape for biological experimentation. From this early appreciation of the materials science aspect of a nature biomedical, a **literature** of thousands of papers has evolved. In fact, the nacre implant described in the prehistory section may owe its effectiveness to hydroxyapatite-recent data have shown that the calcium carbonate of **nacre** can transform in **phosphate** solutions to hydroxyapatite[②] (Ni and Ratner, 2003).

(Selected from *Biomaterials Science*, edited by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, 2005)

Questions

1. Where can we find hydrogels?
2. What are the applications of hydrogels?
3. What is hydroxyapatite?
4. Could hydroxyapatite be used as a biomedical material?

New Words and Expressions

1. ubiquitous *adj.* 到处存在的，普遍存在的
2. hydrated *adj.* 含水的
3. motif *n.* 图形，图案，主题，动机
4. gelatin *n.* 凝胶，明胶
5. agar *n.* 琼胶，石花菜
6. methacylate *n.* 甲基丙烯酸酯
7. swollen *adj.* 肿胀的，肿的
8. acrylamide *n.* 丙烯酰胺
9. electrophoresis *n.* 电泳现象
10. sponge *n.* 海绵，(外科用) 棉球，纱布；*v.* 用海绵等擦拭、吸收 (液体)
11. hydroxyapatite *n.* 羟基磷灰石
12. literature *n.* 文献，著作，文学 (作品)
13. nacre *n.* 珠母贝
14. phosphate *n.* 磷酸盐

Notes

① Bacterial biofilms hydrated living tissues, extracellular matrix components, and plant structures are ubiquitous, hydrated, swollen motifs in nature.

参考译文：细菌生物膜水合活体组织、细胞外基质成分和植物结构是到处存在的，含水分，呈肿胀状。

② In fact, the nacre implant described in the prehistory section may owe its effectiveness to hydroxyapatite—recent data have shown that the calcium carbonate of nacre can transform in phosphate solutions to hydroxyapatite.

参考译文：事实上，史书中描述的珍珠贝植入可归功于羟基磷灰石的有效性——最近的数据表明在磷酸盐溶液中珍珠贝的碳酸钙可转变成羟基磷灰石。

6.4 The Future of Biomaterials

There are trends in biomaterials, many of them **highlighted** in this review, that suggest the future of biomaterials. Medical implants and in vitro systems are addressed separately.

Implanted medical devices are essential to modern medical practice, and they save lives or improve the quality of life for millions. However, they still heal like **foreign objects**—they are **encapsulated** and **walled off**[①]. With the major investment by medical-device companies in development, manufacture, marketing, **surgeon** acceptance, and regulatory **approval**, it is unlikely that medical devices as we know them will change **substantially** in the next ten years. However, by surface modification of existing medical devices, we might expect to see devices that heal in a **physiologically** normal fashion (a vascularized reconstruction of the anatomy). Such a normal healing will improve the performance of many devices that are now **hampered** by poor healing (e.g., the problems associated with the foreign body capsule). For example, with integrative healing characteristics coupled with advances in materials and **robotics**, implanted **limbs** may not only replace the functionality of lost limbs but also provide some functionality even superior to that possible in **flesh** and blood limbs.

Another area of research that will lead to improvements in the performance of implants is a reduction in the **propensity** toward infection. This may be accomplished through **antibacterial** surface treatments, nonfouling surfaces, and **antibiotic** controlled release strategies. Also, general advances in controlled drug release will permit the development of devices with both device and drug functionality. The potential of this approach is now being realized with drug **eluting cardiovascular stents** that inhibit **restenosis**. Finally, advanced smart materials may be used for tissue, organ, and system replacement. A polymeric **artificial muscle** or an **insulin-releasing system** that intrinsically responds to blood glucose are examples of possible in vivo systems that use smart materials concepts and also may substantially advance the treatment of diseases or organ/tissue replacement.

Two technologies, tissue engineering and **regenerative** medicine, both in development now, will ultimately revolutionize medical implants[②]. Tissue engineering will allow replacement of many tissues and organs with living, functional replacements. Tissue-engineering advances will rest upon advances in **biodegradable** polymers, **rapid prototyping**, drug delivery, cell culture, stem cell **methodologies**, **angiogenesis**, and biomimetic strategies for **recreating** extracellular, matrix-like **biomimetics**. Also, advances in cell culture, gene delivery, cell and tissue storage, **sterilization**, and surgery will be needed to fully realize the potential of tissue engineering. Regenerative medi-

cine, permitting in vivo regeneration of whole organs and tissues, will ultimately replace tissue engineering. Technologies important to making regenerative medicine a reality include advances in biology, gene delivery, and controlled release.

With respect to in vitro systems, regulatory issues are not so constraining, and we can expect to see substantial advances in devices both for **diagnostics** and **therapeutics**. Smart materials, **nonfouling** surfaces, and MEMS concepts will enter into these devices. A chip array with **complementary** DNA to 100 different bacteria can rapidly recognize the origin of a bacterial infection[3]. An **array** device with the whole human genome on it will permit infants to be diagnosed at birth with problems likely to crop up later in life. **Preventative** medicine, **buttressed** by this **foreknowledge** of conditions that probably will develop later, can greatly improve the quality of life. Possibly, a MEMS device containing a living culture of cells from a person's body might be used to synthesize on demand specific **pharmaceuticals** tuned to the physiology of the individual. The possibilities are almost limitless for developments using smart systems and micro-and nanofabrication. These in vitro systems of the future will be grounded in an advanced understanding of the way biological systems interact with synthetic surfaces. Careful **ethical deliberation** will also enter into these new technologies that have the potential to alter the expectations for humans.

(Selected from *Biomaterials: Where we have been and where we are going*, by B. D. Ratener and S. J. Bryant; Annu. Rev. Biomed. Eng., 2004)

Questions

1. Why implanted medical devices are essential to modern medical practice?
2. What is tissue engineering?
3. What is regenerative medicine?

New Words and Expressions

1. highlight *n.* 提示区，加亮区，最显著（重要）部分；*v.* 加亮，标出，增加亮度
2. foreign object 异物
3. encapsulate *v.* 装入胶囊，形成包封，压缩
4. walled off （用墙）隔开
5. surgeon *n.* 外科医生
6. approval *n.* 承认，赞成，正式批准
7. substantially *adv.* 充分地
8. physiological *adj.* 生理学的，生理学上的
9. hamper *v.* 妨碍，牵制
10. robotics *n.* 机器人学，机器人技术
11. limb *n.* 肢，翼，分支
12. flesh *n.* 肉，肉体，人体；*v.* 用肉喂，长胖
13. propensity *n.* 倾向

14. antibacterial *n.* 抗菌药；*adj.* 抗菌的
15. antibiotic *n.* 抗生素；*adj.* 抗生的
16. eluting *v.* 洗提
17. cardiovascular stent 心血管支架
18. restenosis *n.* （心瓣手术后的）再狭窄
19. artificial muscle 人造肌肉
20. insulin-releasing system 胰岛素释放系统
21. regenerative *adj.* 再生的，更生的
22. biodegradable *adj.* 生物降解的，生物能分解的
23. rapid prototype 快速成型，快速原型
24. methodology *n.* 方法学，方法论
25. angiogenesis *n.* 血管再生术，血管新生
26. recreate *v.* 得到休养，得到娱乐
27. biomimetics *n.* 仿生学
28. sterilization *n.* 杀菌，绝育
29. diagnostics *n.* 诊断，诊断学
30. therapeutics *n.* 疗法，治疗学
31. nonfouling *adj.* 未污染的，未弄脏的
32. complementary *adj.* 补充的，补足的
33. array *n.* 排列，编队；*v.* 部署，排列
34. genome *n.* 基因组，染色体组
35. preventative *adj.* 预防性的
36. buttress *n.* 支撑物；*v.* 支持，扶住
37. foreknowledge *n.* 预知，先见之明
38. pharmaceutical *n.* 药物；*adj.* 制药的，药学的
39. ethical *adj.* 与伦理有关的，民族的，民族特有的
40. deliberation *n.* 熟思，商议，考虑，从容

Notes

① However, they still heal like foreign objects—they are encapsulated and walled off.

参考译文：然而，它们愈合后仍像外来物——包封着、与身体不融合。

Walled off 有隔离开的意思，这里指植入物愈合后仍独成一体没有真正长入身体。

② Two technologies, tissue engineering and regenerative medicine, both in development now, will ultimately revolutionize medical implants.

参考译文：两项技术——组织工程和再生药物，现在都在发展中，将会从根本上改革医疗植入物。

③ A chip array with complementary DNA to 100 different bacteria can rapidly recognize the origin of a bacterial infection.

参考译文：带有 100 种不同细菌补充 DNA 数据的芯片可以迅速地识别细菌感染源。

Reading Material

Designed Biomaterials (Ⅳ)

Titanium

In 1791, William Cregor, a Cornish **amateur** chemist, used a **magnet** to extract the ore that we know as **ilmenite** from a local river. He then **extracted** the iron from this black powder with **hydrochloric acid** and was left with a **residue** that was the **impure** oxide of **titanium**①. After 1932, a process developed by William Kroll permitted the commercial extraction of titanium from mineral sources. At the end of World War Ⅱ, titanium metallurgy methods and titanium materials made their way from **military** application to peacetime uses. By 1940, satisfactory results had already been achieved with titanium implants (Bothe et al., 1940). The major breakthrough in the use of titanium for **bony tissue** implants was the Branemark discovery of **osseointegration**.

Bioglass

Bioglass is important to biomaterials as one of the first completely synthetic materials that seamlessly bonds to bone②. It was developed by Professor Larry Hench and colleagues. In 1967, Hench was an assistant professor at the University of Florida. At that time his work focused on glass materials and their interaction with nuclear radiation. In August of that year, he shared a bus ride to an Army Materials Conference in Sagamore, New York, with a U. S. Army Colonel who had just return from Vietnam where he was in charge of supplies to **15 MASH units**. He was not terribly interested in the **radiation** resistance of glass. Rather, he challenged Hench with the following: hundreds of limbs a week in Vietnam were being amputated because the body was found to reject the metals and polymer materials used to repair the body. "If you can make a materials that will resist **gamma rays**, why not make a material the body won't resist?"

Hench returned from the conference and wrote a proposal to the U. S. Army Medical R and D Command. In October 1969 the project was funded to test the hypothesis that **silicate**-based glasses and glass-ceramics containing critical amounts of Ca and P ions would not be rejected by bone. In November 1969 Hench made small **rectangles** of what he called 45S5 glass (44.5% SiO_2 by weight) and Ted Greenlee, Assistant Professor of **Orthopedic** Surgery at the University of Florida, implanted them in rat **femurs** at V A Hospital in Gainsville. Six weeks later Greenlee called "Larry, what are those samples you gave me? They will not **come out of** bone. I have pulled on them, I have pushed on them, I have cracked the bone and they are still bonded in place." Bioglass was born, and with the first composition studied! Later studies by Hench using surface analysis equipment showed that the surface of the Bioglass, in biological **fluids**, transformed from a silicate-rich composition to a phosphate-rich structure, possible with **resemblance** to hydoxyapatite (Clark et al., 1976).

(Selected from *Biomaterials Science*, edited by B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, 2005)

Questions

1. What did William Cregor discover in 1791?
2. What is the main application of titanium as a biomaterial?
3. Who invented bioglass in 1969? How did he?

New Words and Expressions

1. amateur *n.* 业余爱好者，业余艺术家
2. magnet *n.* 磁体，磁铁
3. ilmenite *n.* 钛铁矿
4. extract *n.* 榨出物，摘录，选粹；*v.* 拔出，榨取，提取，开方
5. hydrochloric acid 盐酸
6. residue *n.* 剩余物，残余，留数
7. impure *adj.* 不纯的
8. titanium *n.* 钛
9. military *adj.* 军用的，军事的
10. bony tissue 骨组织
11. osseointegration 骨结合
12. 15 MASH units （美军）第 15 机动军医院
13. radiation *n.* 辐射，放射线，放射物
14. amputate *v.* 切除（手臂、腿等）
15. gamma ray 伽马射线
16. silicate *n.* 硅酸盐
17. rectangle *n.* 长方形，矩形
18. orthopedic *adj.* 骨科的
19. femurs *n.* 大腿骨，腿节，股节
20. come out of 由……产生，从……出来
21. fluid *n.* 液体，流体，流动性；*adj.* 流动的，不固定的，流畅的
22. resemblance *n.* 类同之处

Notes

① He then extracted the iron from this black powder with hydrochloric acid and was left with a residue that was the impure oxide of titanium.

参考译文：然后，他用盐酸从这种黑色粉末里提取铁，剩下的残留物是不纯的钛氧化物。

② Bioglass is important to biomaterials as one of the first completely synthetic materials that seamlessly bonds to bone.

参考译文：作为一种与骨头能无缝结合的完全合成材料，生物玻璃是重要的生物材料。

科技英语翻译技巧（六）：关连词引导的句型翻译技巧（Ⅱ）

1. where 引导的句型翻译技巧

（1）where 作疑问词，译成“什么地方”。

Where can three phases coexist in an equilibrium diagram of a binary showing complete insolubility in the solid state?

在一个固态完全不互溶的二元相图上，三相共存于相图的什么地方？

（2）where 引导的句子作为主语，引导主语从句时译成“……地方”“……的位置”“……的地点”“在……地方”“在……部位”“什么地方”。

Where hardness peaks occur largely depends on the preheating of the parent metal and the heat input at the time the weld is made.（where 引导的句子作为主语，peak 译为“峰值”不太妥，将其意译为“最大硬度”。）

最大硬度出现的位置很大程度上依赖于母材的预热和焊接的热量。

（3）where 引导的句子作为状语。

1）引导地点状语从句时译成“……的地方或“在……处”，也可不译出连词。

Three phases can only coexist at a point referred to as an invariant point, where the temperature and composition are fixed.（where 引导的句子作地点状语）

三相只能共存于一个固定点，在这一点上，温度和组分是不变的。

Stresses may also develop in the heat affected zones of steel welds, where a very hard constituent (called martensite) may have been formed so that cracking may take place.（where 引导的地点状语从句，如果可从逻辑上判断地点状语的意义，则可以转译成相应的状语从句。）

应力也可能产生在焊接金属的热影响区，在热影响区，形成很硬的马氏体相，从而可能产生裂纹。

Even after solidification the slag continues to protect the weld metal until it cools to the point where reaction with the air is negligible.

即使固化了，熔渣也能对焊接金属起到保护作用，除非一直冷到几乎与空气不发生反应。

2）where 引导的看似是地点状语，实际是条件状语从句。where 不译出来，不能简单译成“哪里”。

In welding where the workpiece is the positive pole and the electrode is negative, the hookup is referred to as being straight polarity (dcsp).

工件接正极电极接负极的焊接，称为直流正接。

Where it is necessary to keep the workpiece as cool as possible, reverse polarity is the best choice.（科技英语翻译中，有时要将地点状语转译成条件状语，有时要将条件状语转译成地点状语。）

如果工件必须尽可能地冷却，最好选择直流反接。

2. how 引导的句型翻译技巧

（1）how 作疑问词，译成“怎样”。

How do physical properties depend on atomic and electronic structure?

物理性能是怎样依赖于原子和电子结构的呢?

(2) how 引导的句子作宾语，how 具有双重作用，即起承上启下作用，可看做是连接主句的一个部分，也可看做是从句的一个成分，译成“怎样的”“什么样的”“怎样”或不译出。

Furthermore, the electronic arrangement influences how the atoms are bonded to one another and helps determine the type of material—metal, ceramic, or polymer. (how 引导的句子作宾语从句)

而且，原子与原子之间的结合方式受到电子排列影响，并且电子排列有助于确定材料的类型——金属、陶瓷还是高聚物。

(3) how 本身作定语，how 具有双重作用，即起承上启下作用，可看做是连接主句的一个部分，也可看做是从句的一个成分。

The mechanical properties not only determine how well the material performs in service, but also determine the ease with which the material can be formed into a useful shape. (how 引导宾语从句，how 本身作定语，不能简单译成“什么样的”“怎样”。)

机械性能不仅决定了材料服役时性能的好坏，而且决定了材料加工成形的难易。

(4) how 引导的句子作主语。

How the structure-property-processing interrelate in order to finally produce the required product is determined. (how 引导的句子作主语)

为了最终获得满意的产品，我们必须确定结构—性能—加工三者之间有着怎样的关联。

Chapter 7 Nanotechnology and Nanomaterials

7.1 What Are Nanomaterials?

Engineered nanomaterials are materials designed at the molecular (nanometre) level to take advantage of their small size and novel properties which are generally not seen in their conventional, bulk **counterparts**. The two main reasons why materials at the **nanoscale** can have different properties are increased relative surface area and new **quantum** effects. Nanomaterials have a much greater surface area to volume ratio than their conventional forms, which can lead to greater chemical reactivity and affect their strength. Also at the nanoscale, quantum effects can become much more important in determining the material's properties and characteristics, leading to **novel** optical, electrical and magnetic behaviours.

Nanomaterials have extremely small size as their defining characteristic, although there is as yet no agreed national or international definition for nanomaterials[①]. The current working definition of nanomaterials is a material having at least one dimension 100 nanometres or less. To put nanomaterials into **perspective**, up to 10,000 could fit across a human hair. Nanomaterials can be nanoscale in one dimension (e.g., surface films), two dimensions (e.g., **strands** or fibres), or three dimensions (e.g. particles). They can exist in single, fused, aggregated or **agglomerated** forms with spherical, tubular, and irregular shapes. Common types of nanomaterials include nanotubes, **dendrimers**, quantum dots and **fullerenes**.

Products containing engineered nanomaterials are already in commercial use, with some having been available for some time. The range of commercial products available today is very broad, including **stain-resistant** and **wrinkle-free** textiles, **cosmetics**, **sunscreens**, electronics, paints and **varnishes**. Nanocoatings and nanocomposites are finding uses in **diverse** consumer products, such as windows, sports equipment, bicycles and automobiles. There are novel UV-blocking coatings on glass bottles which protect **beverages** from damage by sunlight, and **longer-lasting** tennis balls using **butyl-rubber**/nano-clay composites. Nanoscale **titanium dioxide**, for instance, is finding applications in cosmetics, **sun-block creams** and self-cleaning windows, and nanoscale **silica** is being used as **filler** in a range of products, including cosmetics and dental fillings[②].

(Selected from *www. nicnas. gov. au*, 2009)

Questions

1. What are engineered nanomaterials?
2. Why materials at the nanoscale can have different properties?
3. How about the size of nanomaterials?
4. How about commercial use of nanomaterials?

New Words and Expressions

1. nanomaterial *n.* 纳米材料
2. novel *adj.* 新颖的，异常的；*n.* 小说
3. counterpart *n.* 相对应的人或物，副本
4. nanoscale *n.* 纳米尺度，纳米等级
5. quantum *n.* 量子，量子论
6. perspective *n.* 观察，看法，远景，前途，透视图
7. strand *n.* 线，绳；*v.* 搓
8. agglomerate *v.* 成团，凝聚；*n.* 大团，大块；*adj.* 成块的
9. spherical *adj.* 球形的，球的
10. dendrimer *n.* 树形分子
11. quantum dot 量子圆点
12. fullerene *n.* 富勒烯
13. stain-resistant 耐污的
14. wrinkle-free 不皱的
15. cosmetic *n.* 化妆品；*adj.* 化妆用的
16. sunscreen *n.* （防晒油中的）遮光剂
17. varnish *n.* 清漆，光泽面；*v.* 修饰
18. diverse *adj.* 不同的，变化多的
19. beverage *n.* 饮料
20. longer-lasting 更耐用的，更耐久的
21. butyl-rubber 丁基橡胶，异丁橡胶
22. titanium dioxide 二氧化钛
23. sun-block cream 防晒霜，紫外线防护霜
24. silica *n.* 硅石，硅土，无水硅酸
25. filler *n.* 填充物，漏斗

Notes

① Nanomaterials have extremely small size as their defining characteristic, although there is as yet no agreed national or international definition for nanomaterials.

参考译文：虽然目前没有纳米材料国内或国际的统一定义，但是拥有极小的尺寸是纳米材料的本质特征。

② Nanoscale titanium dioxide, for instance, is finding applications in cosmetics, sun-block creams and self-cleaning windows, and nanoscale silica is being used as filler in a range of products, including cosmetics and dental fillings.

参考译文：例如，纳米尺度的二氧化钛，被用于美容品、防晒霜和自洁式的窗户，同样纳米二氧化硅在包括美容品和牙科材料等一系列产品里被用做填充剂。

a range of：一系列的，广泛的。

Reading Material

How Are Nanomaterials Made?

Nanomaterials can be natural or manmade. For example, **nanoparticles** are produced naturally by plants, algae and **volcanic** activity. They have also been created for thousands of years as products of cooking and burning, and more recently from vehicle **exhausts**①. Some proteins in the body, which control things like **flexing** muscles and repairing cells, are nanosized. We can set out to make nanomaterials in a variety of different ways. Some nanomaterials can assemble themselves from their components. Carbon fragments, for example, can self-assemble into nanotubes in this way. Another approach, used in the production of computer chips, is to etch nanomaterials from larger pieces of material. Increasingly, these two methods are **converging**, leading to exciting new production techniques.

Powerful microscopes have been developed which allow researchers not only to look more closely at atoms and molecules, but also to pick them up and move them around to form basic nanostructures. This allows some nanomaterials to be built molecule by molecule. For instance, this technique was used to **manipulate** atoms to spell out the IBM logo (Fig. 7.1). However at present this technique is extremely laborious and **unsuitable** as an industrial process.

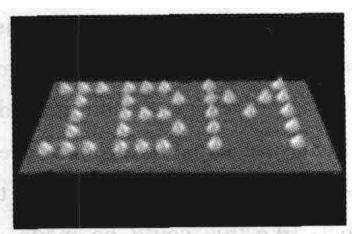


Fig. 7.1 Xenon atoms spelling out the IBM logo. Each letter is about 5nm from top to bottom.

Are Nanotechnologies Safe?

Most current and future nanotechnologies, such as computer chips and **catalysts**, **pose** no new health or safety risks. This is because the nanomaterial is **fixed** or etched onto a larger object and therefore unable to stray into the environment.

But concerns do exist about the possible impacts of manufactured nanoparticles and nanotubes that are free to move around rather than being fixed or **embedded** into a bulk material. Although these represent just a tiny fraction of all nanotechnologies, there is some evidence that their small size may increase any potential **toxicity**. Certainly, the toxicity of a material in larger form does not tell us what its toxicity will be when it is nanosized.

The worry is that free nanoparticles could be inhaled, ingested or enter the body via the skin, and then cause damage to cells. Nanotubes, for example, are structurally similar to **asbestos** fibres, which can cause respiratory problems when **inhaled** in large amounts over long periods.

So the Royal Society and **Royal** Academy of Engineering Report calls for:

- Free nanoparticles to be treated and labeled as new chemicals.
- Research into potential **hazards** to keep pace with new developments.
- The UK Government to provide funds for a new research centre to address safety concerns.

Currently, there is only very limited knowledge about the effects of inhaling nanoparticles or nanotubes, but its thought that any risk would be linked to large doses. This means that any hazard applies mainly to workers and researchers involved in their manufacture. The Health and Safety Executive (HSE) already has interim guidelines in place on the use of nanoparticles in the workplace, so the report calls for:

- The HSE to review existing regulations and consider setting lower exposure levels for manufactured nanoparticles.
- Workplace exposure to be carefully monitored.

It is thought that the nanoparticles in sunscreens and cosmetics cannot **penetrate** the skin, but further studies are needed to confirm this. So the report recommends that:

- Industry publishes the manner in which their safety tests have taken the special properties of nanoparticles into account[②].
- Consumer products containing manufactured nanoparticles should be approved by an independent safety committee before hitting the shelves.

At present, almost nothing is known about the potential effects of free nanoparticles and nanotubes on the environment. But it is possible that they could enter the food chain, and affect plants and animals. So the report recommends that:

- Their release be minimised until their effects are better understood.

Some are concerned about grey goo, a fictitious notion in which **self-replicating**, man-made, nano-robots devour the Earth and turn it into a grey goo. But there is no evidence to suggest that nanobots like this could be made. The originator of the grey goo scenario, Dr. Eric Drexler, has even retracted his original proposition.

Miniature Medicines

Simon Biggs is Royal Academy of Engineering/BNFL Professor of Particle Science and Technology at the University of Leeds. He studies the behaviour of nanoparticles and one of his key projects is to develop new materials for use in drug delivery. Working with chemists at the University of Sussex, he is looking at new materials which could carry drug molecules around the body and provide controlled drug release.

(Selected from *royalsociety. org*, 2008)

Questions

1. How can we make nanomaterials?
2. How can we observe basic nanostructures?
3. Tell some examples of nanotechnologies? Are they safe?

4. How does the pepople consider the effect of the nanomaterial to cell?

New Words and Expressions

1. nanoparticle *n.* 纳米颗粒
2. volcanic *adj.* 火山的，暴烈的
3. exhaust *v.* 弄空，耗尽
4. flexing *n.* 挠曲，可挠性
5. converging *adj.* 收敛的，趋同的
6. manipulate *v.* 使用，利用，熟练控制
7. unsuitable *adj.* 不合适的
8. catalysts *n.* 催化剂，促进因素
9. pose *v.* 摆姿势，提出
10. fixed *adj.* 固定的，确定的
11. embedded *adj.* 植入的
12. toxicity *n.* 毒性
13. asbestos *n.* 石棉
14. inhale *v.* 吸入
15. royal *adj.* 王室的，第一流的
16. hazard *n.* & *v.* 危险，冒风险
17. penetrate *v.* 穿过，渗透，了解
18. self-replicating 自我复制的

Notes

① They have also been created for thousands of years as products of cooking and burning, and more recently from vehicle exhausts.

参考译文：它们（纳米材料）作为做饭和燃烧的产物已被创造出几千年，也存在于近年来车辆排出的废气中。

② Industry publishes the manner in which their safety tests have taken the special properties of nanoparticles into account.

参考译文：工业界公布了安全性测试的方式，其中已经考虑到纳米颗粒的特殊性能。

7.2 What Is Nanotechnology?

What Is Nanotechnology?

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.

What Is Special About the Nanoscale?

Unusual physical, chemical, and biological properties can emerge in materials at the nanoscale. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules: some are better at conducting electricity or heat, some are stronger, some have different magnetic properties, and some reflect light better or change colors as their size is changed. Nanoscale materials also have far larger surface areas than similar volumes of larger scale materials, meaning that more surface is available for interactions with other materials around them.

How Small Is a Nanometer?

It's defined as one billionth of a meter. How small is that? Some ways to think about just how small a nanometer is (Fig. 7.2):

- A sheet of paper is about 100,000 nanometers thick.
- Blond hair is probably 15,000 to 50,000 nanometers in diameter, but black hair is likely to be between 50,000 and 180,000 nanometers.
- There are 25,400,000 nanometers in an inch.
- A nanometer is a millionth of a **millimeter**.

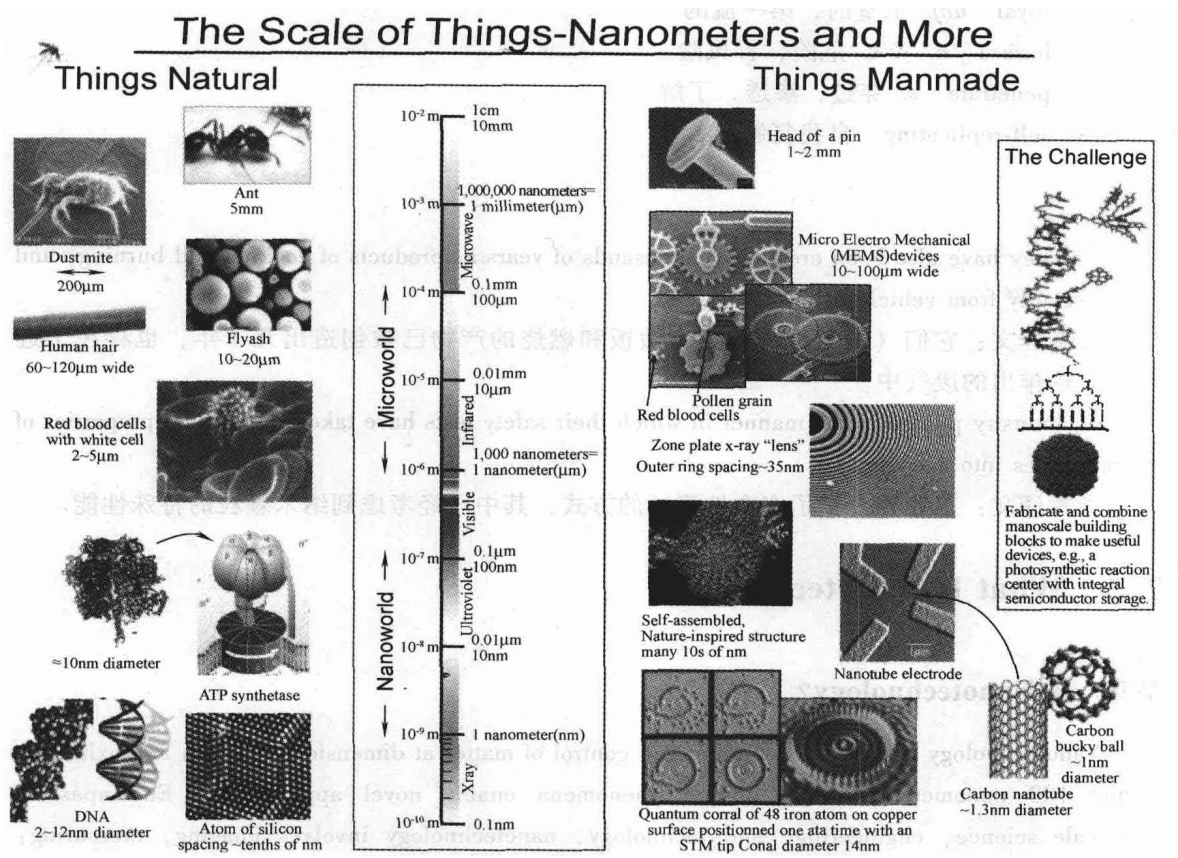


Fig. 7.2 The scale of things

Where Are Nanoscale Materials Found?

If scientists can create artificial spider silk economically, the superstrong, **lightweight** materials could be used in sports helmets, armor, tethers and other products[①]. Nanoscale materials and effects are found in nature all around us (Fig. 7.3). Nature's secrets for building from the nanoscale create processes and machinery that scientists hope to imitate. Researchers already have copied the nanostructure of lotus leaves to create water **repellent** surfaces used today to make stain-proof clothing, other **fabrics**, and materials. Others are trying to imitate the strength and flexibility of **spider** silk, which is naturally reinforced by nanoscale crystals.

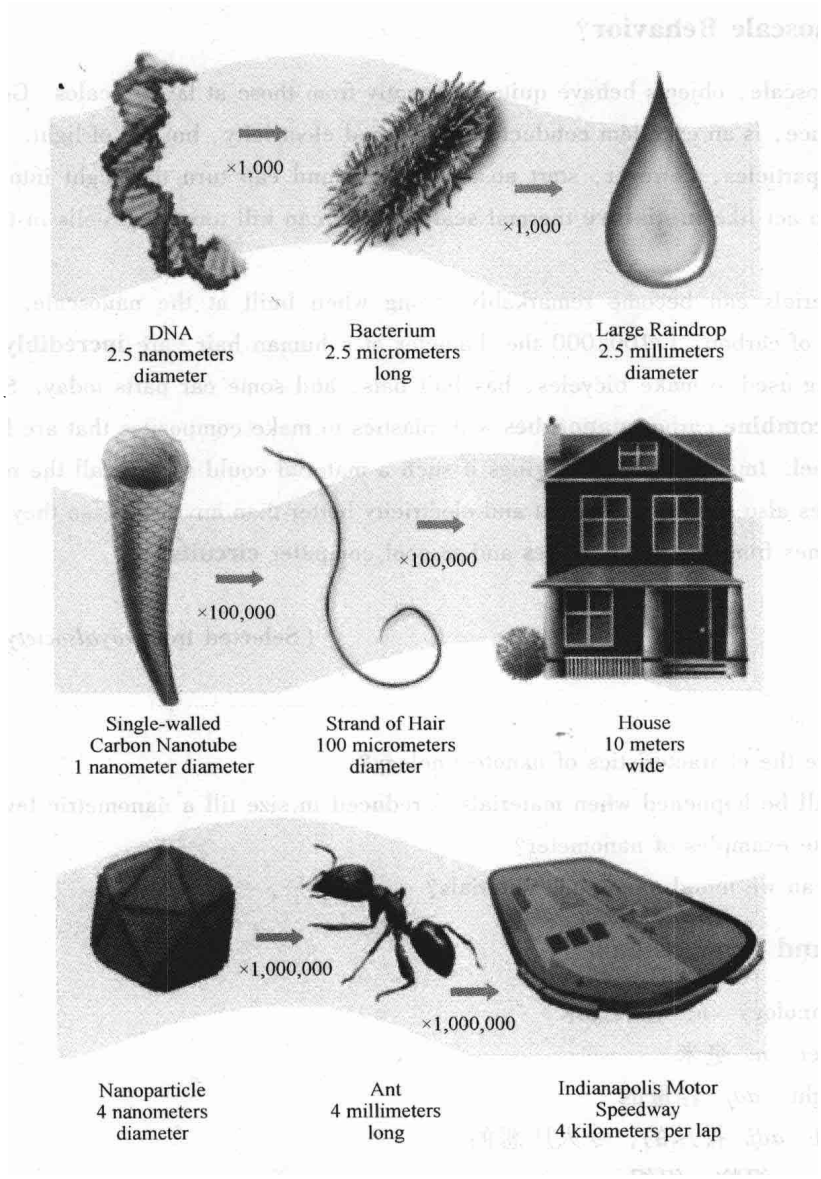


Fig. 7.3 Three examples at the nanoscale

Many important functions of living organisms take place at the nanoscale. Our bodies and those of all animals use natural nanoscale materials, such as **proteins** and other molecules, to control our bodies' many systems and processes. A typical protein such as **hemoglobin**, which carries oxygen through the bloodstream, is 5 nanometers, or 5 billionths of a meter, in diameter.

Nanoscale materials are all around us, in smoke from fire, volcanic ash, sea spray, as well as products resulting from burning or combustion processes. Some have been put to use for centuries. One material, nanoscale gold, was used in stained glass and ceramics as far back as the 10th century. But it took 10 more centuries before high-powered microscopes and precision equipment were developed to allow nanoscale materials to be imaged and moved around.

What Is Nanoscale Behavior?

At the nanoscale, objects behave quite differently from those at larger scales. Gold at the bulk scale, for instance, is an excellent conductor of heat and electricity, but not of light. Properly structured gold nanoparticles, however, start absorbing light and can turn that light into heat, enough heat, in fact, to act like **miniature** thermal **scalpels** that can kill unwanted cells in the body, such as cancer cells[②].

Other materials can become remarkably strong when built at the nanoscale. For example, nanoscale tubes of carbon, 1/100,000 the diameter of a human hair, are **incredibly** strong. They are already being used to make bicycles, baseball bats, and some car parts today. Some scientists think they can **combine** carbon **nanotubes** with plastics to make composites that are far lighter, yet stronger than steel. Imagine the fuel savings if such a material could replace all the metal in a car! Carbon nanotubes also conduct both heat and electricity better than any metal, so they could be used to protect airplanes from lightning **strikes** and to cool computer **circuits**.

(Selected from *royalsociety. org*, 2008)

Questions

1. What are the characteristics of nanotechnology?
2. What will be happened when materials is reduced in size till a nanometric levels?
3. Tell some examples of nanometer?
4. Where can we found nanoscale materials?

New Words and Expressions

1. nanotechnology *n.* 纳米技术
2. millimeter *n.* 毫米
3. lightweight *adj.* 轻量的
4. repellent *adj.* 排斥的，令人厌恶的
5. fabrics *n.* 织物，组织
6. spider *n.* 蜘蛛

7. protein *n.* 蛋白质
8. hemoglobin *n.* 血色素
9. miniature *adj.* 小型的
10. scalpel *n.* 解剖刀，外科手术刀
11. incredibly *adv.* 不能相信地
12. combine *v.* 联合，结合；*n.* 联合企业，联合收割机
13. nanotube *n.* 纳米管
14. strike *v.* 打，击，敲响
15. circuit *n.* 电路，环形

Notes

① If scientists can create artificial spider silk economically, the superstrong, lightweight materials could be used in sports helmets, armor, tethers and other products.

参考译文：如果科学家能经济地制造出人造蜘蛛丝，那么这种超强的、轻质的材料可用于制造运动头盔、盔甲、绳索及其他产品。

② Properly structured gold nanoparticles, however, start absorbing light and can turn that light into heat, enough heat, in fact, to act like miniature thermal scalpels that can kill unwanted cells in the body, such as cancer cells.

参考译文：然而，合适结构的纳米颗粒，开始吸收光线，可以将光线转化为热量，事实上，足够的热量可以作为微型热解剖刀，可以杀掉人体内不需要的细胞，比如癌细胞。

Reading Material

Nanoscale Properties (Ⅰ)

Nanoscience and Nanotechnology have emerged within the **borderland** between physics, chemistry and biology. When a material is reduced in size till a **nanometric** levels, its properties and behavior are described by quantum physics and chemistry not the **classical** science. There is not a defined limit between classical and quantum science but as while the material is reducing its size the energy levels, those that say us how the materials behave, are more discrete going from classical to quantum physics and chemistry.

Quantum Science is not so common to us because we are living in a **macroscopic world** where we can easily understand the **trajectory** of a ball in a basketball match but not the route of an electron because it is described by probabilities[①]. However the quantum world is now quite present in our modern live because it plays an important role in the way the semiconductors, superconductors, lasers, and now nanomaterials work. In the future, we should like to control and organize them into new structures with new abilities.

Electrical Properties of Nanomaterials

Nanomaterials can hold **considerably** more energy than conventional because of their large

grain boundary (surface) area. They are materials in which an optical absorption band can be introduced, or an existing band can be **altered** by the passage of current through these materials, or by the application of an electric field.

Applications of Electrical Properties of Nanomaterials

1. High energy density batteries

Conventional and **rechargeable batteries** are used in almost all applications that require electric power. The energy density (storage capacity) of these batteries is quite low requiring frequent recharging. **Nanocrystalline** materials are good **candidates** for separator plates in batteries because they can hold considerably more energy than conventional ones. Nickel-metal **hydride** batteries made of nanocrystalline nickel and metal hydrides are **envisioned** to require far less frequent recharging and to last much longer.

2. Large electrochromic display devices

An electrochromic device consists of materials in which an optical absorption band can be introduced, or an existing band can be altered by the passage of current through the materials, or by the application of an electric field[②]. They are similar to **liquid-crystal displays** (**LCD**) commonly used in calculators and watches and are primarily used in public **billboards** and **ticker boards** to **convey** information. The **resolution**, brightness, and contrast of these devices depend on the **tungstic acid** gel's grain size. Hence, nanomaterials, such as tungstic oxide gel, are being explored for this purpose

(Selected from *Nanoscale Properties and Materials*, by Miguel J. Yacaman, 2005)

Questions

1. What are of science of nanomaterial and nanotechnology?
2. What will quantum world will be like, for examples?
3. How about the electrical properties of nanomaterials?
4. What purpose is tungstic oxide gel being explored?

New Words and Expressions

1. borderland *n.* 边界地，边陲
2. nanometric *adj.* 纳米的
3. classical *adj.* 经典的，古典的，正统的
4. quantum Science 量子科学
5. macroscopic world 宏观世界
6. trajectory *n.* 轨道，轨迹，弹道
7. considerably *adv.* 相当地
8. alter *v.* 改变，变更
9. rechargeable battery 充电电池

10. nanocrystalline *adj.* 纳米晶的
11. candidate *n.* 选择物，候选者
12. hydride *n.* 氢化物
13. *envision* *v.* 想象，预想
14. electrochromic 电泳动，电致变色
15. liquid-crystal display（LCD） 液晶显示屏（器）
16. billboard *n.* 广告牌，布告板
17. ticker board （股票交易、机场、火车站等处随时变化的）信息栏，信息显示板
18. convey *v.* 传送，传达，搬运，转让
19. resolution *n.* 分辨率，清晰度，决心，决议
20. tungstic acid 钨酸

Notes

① Quantum Science is not so common to us because we are living in a macroscopic world where we can easily understand the trajectory of a ball in a basketball match but not the route of an electron because it is described by probabilities.

参考译文：因为我们居住在一个宏观尺度的世界，量子科学并不常见，我们可以很容易理解一场篮球比赛中的篮球的轨迹，但不容易理解概率描述的电子轨迹。

② An electrochromic device consists of materials in which an optical absorption band can be introduced, or an existing band can be altered by the passage of current through the materials, or by the application of an electric field.

参考译文：电致变色器件包含光波段吸收材料，改变通过材料的电流或施加电场可改变业已存在的光波段。

7.3 Nano-Crystalline Metal and Nano Metal Foam

Nano-Crystalline Nickel

Nickel may one day compete with other materials in lightweight applications such as aerospace components, sporting goods and **armour** systems for defense.

A Canadian nano-technology company, Integran Technologies, has developed a relatively low-cost electroforming process that can manufacture a variety of nano-crystalline forms, such as plates and strips, with a higher strength-to-weight ratio than some of the strongest lightweight alloys made of titanium and aluminum.

For example, the company's nickel-iron (50% nickel) armour plating is 2.5 times tougher than the required specifications for U. S. military vehicles, whereas its body armour is seven times stronger than that currently worn by soldiers and police. This increase in strength is accompanied by a decrease in weight.

Integran has partnered with the U. S. Department of Defense to design new products based on

these properties.

On the consumer front, potential applications include lightweight helmets that use nano-metal foam technology, lightweight coatings to add stiffness to tennis rackets and golf clubs, and corrosion-resistant, durable edges for skates, skis and snowboards.

The key to the technology is a single-step process that produces nano-materials with a grain size a thousand times smaller than conventional alloys without sacrificing **ductility**. The tiny grain size makes the metal stronger and more resistant to **wear**.

Although first tested in the lab in the early 1980s, it was another decade before the technology found commercial applications.

The breakthrough occurred in the 1990s, when Ontario Hydro, a government-owned power company in Canada, was seeking an *in-situ* repair technology for the degraded tubes in its nuclear steam generator. Although nickel seemed like the ideal choice, because of its resistance to corrosion and stress corrosion cracking in nuclear reactors, its use was limited by poor mechanical strength.

Nano-crystalline nickel saved the day, as it is four times stronger than conventional nickel while retaining all of the metal's other **attributes**[①]. The resulting nano-crystalline "electro-sleeves" were fitted over the original tubes to provide resistance to pitting, **denting**, **cracking** and other forms of **degradation**. They remain **intact** today.

More recently, Integran has been working on bringing other applications to market. The versatility of the company's process allows for a wide range of product forms including powders, foams and complex net-shape components.

"The electro-sleeve process remains one of the first-ever large-scale applications for nano-structured materials," says Gino Palumbo, Integran's president and CEO. "But we're still only scratching the surface in terms of applications for nano-nickel products. Our main limitation in promoting our technology in the nickel community has been in identifying the areas where our materials can best be of benefit."

Recent breakthroughs in nano-crystalline nickel have included its use in a nickel-iron coating with superior magnetic properties and as an environmentally benign substitute for nickel-beryllium alloys with better strength, resilience and electrical conductivity. Equally valuable are nano-structured analogs of nickel-iron alloys with low **thermal expansion coefficient**, such as those used in the shadow masks of televisions and computer monitors.

Palumbo also sees a future for nano-crystalline nickel-iron alloys in the manufacture of micro-electro-mechanical devices by electro-deposition. The current electro-deposits fall short on reliability because of their unpredictable properties. Electro-deposited bulk nano-structures promise to overcome this challenge by providing a uniform fine-grain structure throughout the device.

(Selected from *Nano-crystalline Nickel*, by Virginia Heffernan, 2004)

Nano World: Metal Foams for Catalysis

Metal foams made of grains and pores only nanometers or billionths of a meter wide are lighter

than **Styrofoam**, enough to float on water. The extraordinarily high surface areas these unprecedented foams possess suggest they could serve as excellent platforms for chemical reactions that for instance help generate electricity or remove pollutants, experts told UPI's Nano World.

The methods used for making metal foams have until now been limited mainly to a handful of metals such as aluminum. These produce relatively dense, heavy foams or low-density foams with large pores and low surface areas. The new and simple technique energetic materials chemist Bryce Tappan and a **multidisciplinary** team of his colleagues at Los Alamos National Laboratory in New Mexico developed produce unprecedented ultra-low density foams with pores as little as 10 nanometers wide from metals scientists could not foam in the past.

"This is the first time that both a practical and scalable process has become available for producing a variety of metal foams," said Dennis Wilson, founder, chairman of the board and chief technical officer at Nanotechnologies in Austin, Texas.

The scientists discovered their new method accidentally. They were investigating how pellets of metallic compounds rich in nitrogen burned. Normally such compounds combust very rapidly or even detonate. However, the researchers saw pellets burned rapidly but steadily when in an inert atmosphere. While the heated metal atoms attracted each other and ultimately **coalesced** into monoliths of nanoparticles, the resulting gases, such as hydrogen and nitrogen, blew tiny holes through the molten metal to form pores. The results are iron, copper, silver or **cobalt** foams[②].

Without the gases, "there would just be a pool of metal," Tappan said. Why the foams "don't fly apart into clusters or small particles is quite surprising," he added, and not quite understood at the **molecular** level. Tappan and his colleagues reported their findings in the Journal of the American Chemical Society.

These foams could find use in catalysts, the market for which in the year 2000 approached $27 billion in the United States alone. They could also find use in advanced chemical sensors for explosives and other harmful agents, Tappan said, in **storing** hydrogen fuel, or even as coatings for pellets in nuclear **fusion** experiments.

Membranes based on the **porous** foams could also find use in gas separation or water **remediation**, Wilson added. The foams might also be used in **electrodes** for batteries, fuel cells, solar cells or **supercapacitors**, he added. "The efficiency of an electrode relates to its surface area," Wilson explained, and these foams are high in surface area.

Future research can **investigate** into creating foams from other kinds of metals, as well as **optimizing** foams for applications by controlling their structures during manufacture, such as by tuning how much gas is generated or by tinkering with the levels and duration of the gas pressure during burning, Tappan said.

(Selected from *United Press International*, 2006)

Questions

1. What are metal foams made of?

2. Tell about some details of research progress of nano-crystalline nickel?
3. Why metal foams can float on water?
4. What kind of metals can make metal foams?

New Words and Expressions

1. armour *n.* 盔甲，装甲
2. ductility *n.* 延展性
3. wear *v.* 磨损，耐穿
4. nano-crystalline 纳米晶
5. attribute *n.* 性能，特性
6. dent *n.* 凹坑
7. crack *n.* 裂缝；*v.* 开裂
8. degradation *n.* 退化
9. intact *adj.* 完整无缺的
10. thermal expansion coefficient 热膨胀系数
11. foam *n.* 泡沫材料
12. catalysis *n.* 催化作用
13. Styrofoam *n.* 聚苯乙烯泡沫塑料
14. multidisciplinary *adj.* 包括各种学科的
15. coalesce *v.* 合并
16. cobalt *n.* 钴
17. molecular *adj.* 分子的
18. fusion *n.* 融合，联合
19. store *v.* 保管，存储
20. porous *adj.* 能渗透的，气孔的
21. remediation *n.* 补习，辅导
22. electrode *n.* 电极
23. supercapacitor *n.* 超级电容器
24. investigate *v.* 调查
25. optimize *v.* 使最优化

Notes

① Nano-crystalline nickel saved the day, as it is four times stronger than conventional nickel while retaining all of the metal's other attributes.

参考译文：纳米镍晶帮了大忙，它比传统镍金属强四倍并具有镍金属的所有其他特性。

saved the day：帮了大忙；扭转败局。

② While the heated metal atoms attracted each other and ultimately coalesced into monoliths of nanoparticles, the resulting gases, such as hydrogen and nitrogen, blew tiny holes through the molten metal to form pores. The results are iron, copper, silver or cobalt foams.

参考译文：当被加热的金属原子相互吸引并最终合并为单相的纳米颗料时，所产生的气体，比如氢气和氮气，在融化金属上吹出细小的孔从而形成孔洞。这就形成了铁、铜、银、钴泡沫金属。

Reading Material

Nanoscale Properties (Ⅱ)

Mechanical Properties of Nanomaterials

Scientific challenges in nanoscience and nanotechnology include the development of nanomaterials with novel mechanical properties. The need for **scratch**, mar and/or abrasion resistance is well established in various markets, including **fingernail** polishes, flooring, **plastic glazing**, headlamp covers and other automotive parts, transportation windows and optical lenses, where clear scratch-resistant coatings are used. Because the nanosize, many of their mechanical properties of the materials is modified, among others, hardness and elastic modulus, fracture toughness, scratch resistance, **fatigue strength**, and hardness. **Energy dissipation**, **mechanical coupling** within arrays of components, and mechanical nonlinearities are influenced by structuring components at the nanometer scale. This includes also the interpretation of unusual mechanical behavior (e. g., strengths approaching the theoretical limit) and the exploration of new ways to integrate diverse classes of mechanically functional materials on the nanosize.

Applications of Mechanical Properties of Nanomaterials

1. Tougher and harder cutting tools

Cutting tools made of nanomaterials, such as tungsten **carbide**, **tantalum** carbide, and titanium carbide, are much harder, much more wear-resistant, erosion-resistant, and last longer than their conventional (large-grained) counterparts. Also, for the miniaturization of microelectronic circuits, the industry needs micro drills (drill bits with diameter less than the thickness of an average human hair or 100 μm) with enhanced edge **retention** and far better wear resistance. Since nanocrystalline carbides are much stronger, harder, and wear-resistant, they are currently being used in these micro drills.

2. Automobiles with greater fuel efficiency

In automobiles, since nanomaterials are stronger, harder, and much more wear-resistant and erosion-resistant, they are envisioned to be used in spark plugs. Also, automobiles waste significant amounts of energy by losing the thermal energy generated by the engine. So, the engine cylinders are envisioned to be coated with nanocrystalline ceramics, such as zirconia and alumina, which retain heat much more efficiently that result in complete and efficient combustion of the fuel.

3. Aerospace components with enhanced performance characteristics

One of the key properties required of the aircraft components is the fatigue strength, which decreases with the component's age. The fatigue strength increases with a reduction in the grain size of

the material. Nanomaterials provide such a significant reduction in the grain size over conventional materials that the fatigue life is increased by an average of 200% -300%. In spacecrafts, elevated-temperature strength of the material is **crucial** because the components (such as rocket engines, **thrusters**, and **vectoring nozzles**) operate at much higher temperatures than aircrafts and higher speeds. Nanomaterials are perfect candidates for spacecraft applications, as well.

4. Ductile ceramics

Ceramics are very hard, brittle, and hard to machine even at high temperatures. However, with a reduction in grain size, their properties change drastically[①]. Nanocrystalline ceramics can be pressed and sintered into various shapes at significantly lower temperatures. Zirconia, for example, is a hard, brittle ceramic, has even been rendered **superplastic**, i. e., it can be deformed to great lengths (up to 300% of its original length). However, these ceramics must possess nanocrystalline grains to be superplastic. Ceramics based on silicon nitride (Si_3N_4) and silicon carbide (SiC), have been used in automotive applications as high-strength springs, ball bearings, and valve lifters, and because they possess good **formability** and **machinabilty** combined with excellent physical, chemical, and mechanical properties. They are also used as components in high-temperature furnaces.

5. Better insulation materials

Aerogels are nanocrystalline **porous** and extremely lightweight materials and can withstand 100 times their weight. They are currently being used for insulation in offices, homes, etc. They are also being used as materials for "smart" windows, which darken when the sun is too bright and they lighten themselves otherwise.

(Selected from *Nanoscale Properties and Materials*, by Miguel J. Yacaman, 2005)

Questions

1. How about the mechanical properties of nanomaterials?
2. Please intruduce the applications of nanomaterials.
3. Tell the propertieds of ductile ceramics and intruduce some examples of them.

New Words and Expressions

1. scratch *v.* 抓，擦；*n.* 抓痕，擦伤；*adj.* 凑合的
2. fingernail *n.* 手指甲
3. plastic glazing 有机玻璃
4. fatigue strength 疲劳强度
5. energy dissipation 能量损耗
6. mechanical coupling 机械轴节
7. carbide *n.* 碳化物
8. tantalum *n.* 钽
9. retention *n.* 保持，保留

10. crucial *adj.* 至关紧要的
11. thruster *n.* 推进器
12. vectoring nozzle 向量喷嘴，变向喷嘴
13. superplastic *adj.* 超塑性
14. formability *n.* 可成形性
15. machinabilty *n.* 可加工性，可切削性
16. aerogel *n.* 气凝胶
17. porous *adj.* 多孔的

Notes

① Ceramics are very hard, brittle, and hard to machine even at high temperatures. However, with a reduction in grain size, their properties change drastically.

参考译文：陶瓷是非常硬，甚至在高温下都非常难加工的材料。然而，当减小晶粒尺寸后，它们的性能将发生彻底的改变。

7.4 Applications of Nanotechnology

The special nature of carbon combined with the molecular perfection of single-walled nanotubes to **endow** them with exceptional material properties, such as very high electrical and **thermal conductivity**, **strength**, **stiffness**, and **toughness**. No other element in the periodic table bonds to itself in an extended network with the strength of the carbon-carbon bond. The **delocalized** pi-electron **donated** by each atom is free to move about the entire structure, rather than remain with its donor atom, giving rise to the first known molecule with metallic-type electrical conductivity. Furthermore, the high-frequency carbon-carbon bonds **vibrations** provide an **intrinsic** thermal conductivity higher than even diamond. In most conventional materials, however, the actual observed material properties—strength, electrical conductivity, etc. —are degraded very substantially by the occurrence of defects in their structure. For example, high-strength steel typically fails at only about 1% of its theoretical breaking strength. CNTs, however, achieve values very close to their theoretical limits because of their molecular perfection of structure.

This aspect is part of the unique story of CNTs. CNTs are an example of true nanotechnology: they are under 100 nanometers in diameter, but are molecules that can be manipulated chemically and physically in very useful ways①. They open an incredible range of applications in materials science, electronics, chemical processing, energy management, and many other fields. CNTs have extraordinary electrical conductivity, heat conductivity, and mechanical properties. They are probably the best electron field-emitter possible. They are polymers of pure carbon and can be reacted and manipulated using the well-known and the tremendously rich chemistry of carbon. This provides opportunity to **modify** their structure, and to optimize their solubility and dispersion. Very significantly, CNTs are molecularly perfect, which means that they are normally free of property-degrading flaws in the nanotube structure. Their material properties can therefore approach closely the very

high levels intrinsic to them. These extraordinary characteristics give CNTs potential in numerous applications.

Field Emission

CNTs are the best known **field emitters** of any material. This is understandable, given their high electrical conductivity, and the incredible sharpness of their tip. The smaller the tip's radius of curvature, the more concentrated the electric field will be, leading to increased field emission. The sharpness of the tip also means that they emit at especially low voltage, an important fact for building low-power electrical devices that utilize this feature. CNTs can carry an astonishingly high current density. Furthermore, the current is extremely stable. An immediate application of this behavior receiving considerable interest is in field-emission flat-panel displays. Instead of a single electron gun, as in a traditional cathode ray tube display, in CNT-based displays there is a separate nanotube electron gun for each individual pixel in the display. Their high current density, low turn-on and operating voltages, and steady, long-lived behavior make CNTs very attractive field emitters in this application. Other applications utilizing the field-emission characteristics of CNTs include general types of low-voltage cold-cathode lighting sources, lightning arrestors, and electron **microscope** sources.

Conductive or Reinforced Plastics

Much of the history of plastics over the last half-century has involved their use as a replacement for metals. For structural applications, plastics have made tremendous headway, but not where electrical conductivity is required, because plastics are very good electrical insulators. This deficiency is overcome by loading plastics up with conductive fillers, such as carbon black and larger **graphite fibers**. The loading required to provide the necessary conductivity using conventional fillers is typically high, however, resulting in heavy parts, and more importantly, plastic parts whose structural properties are highly degraded. It is well-established that the higher the aspect ratio of the filler particles, the lower the loading required to achieve a given level of conductivity.

CNTs are ideal in this sense, since they have the highest aspect ratio of any carbon fiber. In addition, their natural tendency to form ropes provides inherently very long conductive **pathways** even at ultra-low loadings. Applications that exploit this behavior of CNTs include EMI/RFI **shielding composites**; coatings for **enclosures**, **gaskets**, and other uses such as electrostatic dissipation; **antistatic** materials, transparent conductive coatings; and radar-absorbing materials for **stealth** applications.

A lot of automotive plastics companies are using CNTs as well. CNTs have been added into the side mirror plastics on automobiles in the US since the late 1990s. I have seen forecasts predicting that GM alone will consume over 500 pounds of CNT masterbatches in 2006 for using in all areas of automotive plastics. Masterbatches normally contain 20 wt% CNTs which are already very well dispersed. Manufacturers then need to perform a "let down" or dilution procedure prior to using the masterbatch in production.

Energy Storage

CNTs have the intrinsic characteristics desired in material used as electrodes in batteries and **capacitors**, two technologies of rapidly increasing importance. CNTs have a tremendously high sur-

face area, good electrical conductivity, and very importantly, their linear geometry makes their surface highly accessible to the electrolyte.

Research has shown that CNTs have the highest reversible capacity of any carbon material for use in **lithium** ion **batteries**. In addition, CNTs are outstanding materials for super capacitor electrodes and are now being marketed for this application. CNTs also have applications in a variety of fuel cell components. They have a number of properties, including high surface area and thermal conductivity, which make them useful as electrode catalyst supports in PEM fuel cells. Because of their high electrical conductivity, they may also be used in gas **diffusion** layers, as well as current collectors. CNTs' high strength and toughness-to-weight characteristics may also prove valuable as part of composite components in fuel cells that are deployed in transport applications, where durability is extremely important.

Conductive Adhesives and Connectors

The same properties that make CNTs attractive as conductive fillers for use in electromagnetic shielding, ESD materials, etc., make them attractive for electronics packaging and interconnection applications, such as adhesives, potting compounds, **coaxial** cables, and other types of connectors.

Molecular Electronics

The idea of building electronic circuits out of the essential building blocks of materials—molecules—has seen a revival the past few years, and is a key component of nanotechnology. In any electronic circuit, but particularly as dimensions shrink to the nanoscale, the interconnections between switches and other active devices become increasingly important. Their geometry, electrical conductivity, and ability to be precisely derived, make CNTs the ideal candidates for the connections in molecular electronics. In addition, they have been demonstrated as switches themselves.

There are already companies such as Nantero from Woburn, MA that are already making CNT based non-volatile random access memory for PC's. A lot of research is being done to design CNT based **transistors** as well.

Thermal Materials

The record-setting anisotropic thermal conductivity of CNTs is enabling many applications where heat needs to move from one place to another. Such an application is found in electronics, particularly heat sinks for chips used in advanced computing, where uncooled chips now **routinely** reach over 100℃. The technology for creating aligned structures and ribbons of CNTs is a step toward realizing incredibly efficient heat conduits. In addition, composites with CNTs have been shown to **dramatically** increase their bulk thermal conductivity, even at very small loadings.

Structural Composites

The superior properties of CNTs are not limited to electrical and thermal conductivities, but also include mechanical properties, such as stiffness, toughness, and strength. These properties lead to a wealth of applications exploiting them, including advanced composites requiring high values of one or more of these properties.

Fibers and Fabrics

Fibers spun of pure CNTs have recently been demonstrated and are undergoing rapid develop-

ment, along with CNT composite fibers. Such super-strong fibers will have many applications including body and vehicle armor, transmission line cables, woven fabrics and textiles.

Catalyst Support

CNTs intrinsically have an enormously high surface area; in fact, for single walled nanotubes every atom is not just on one surface—each atom is on two surfaces, the inside and the outside of the nanotube! Combined with the ability to attach essentially any chemical species to their sidewalls this provides an opportunity for unique catalyst supports. Their electrical conductivity may also be exploited in the search for new catalysts and catalytic behavior.

CNT Ceramics

A ceramic material reinforced with carbon nanotubes has been made by materials scientists at UC Davis. The new material is far tougher than conventional ceramics, conducts electricity and can both conduct heat and act as a thermal barrier, depending on the orientation of the nanotubes. Ceramic materials are very hard and resistant to heat and chemical attack, making them useful for applications such as coating turbine blades, but they are also very brittle.

The researchers mixed powdered alumina (aluminum oxide) with 5 to 10 percent carbon nanotubes and a further 5 percent finely milled niobium. The researchers treated the mixture with an electrical pulse in a process called spark-plasma sintering. This process consolidates ceramic powders more quickly and at lower temperatures than conventional processes.

The new material has up to five times the fracture toughness—resistance to cracking under stress—of conventional alumina. The material shows electrical conductivity seven times that of previous ceramics made with nanotubes. It also has interesting thermal properties, conducting heat in one direction, along the **alignment** of the nanotubes, but reflecting heat at right angles to the nanotubes, making it an attractive material for thermal barrier coatings.

Biomedical Applications

The exploration of CNTs in **biomedical** applications is just underway, but has significant potential. Since a large part of the human body consists of carbon, it is generally thought of as a very **biocompatible** material. Cells have been shown to grow on CNTs, so they appear to have no toxic effect. The cells also do not adhere to the CNTs, potentially giving rise to applications such as coatings for **prosthetics** and surgical implants. The ability to functionalize the sidewalls of CNTs also leads to biomedical applications such as vascular stents, and neuron growth and regeneration. It has also been shown that a single strand of DNA can be bonded to a nanotube, which can then be successfully inserted into a cell; this has potential applications in gene therapy.

Air, Water and Gas Filtration

Many researchers and corporations have already developed CNT based air and water filtration devices. It has been reported that these filters can not only block the smallest particles but also kill most bacteria. This is another area where CNTs have already been commercialized and products are on the market now. Someday CNTs may be used to filter other liquids such as fuels and lubricants as well.

A lot of research is being done in the development of CNT based air and gas **filtration**. Filtra-

tion has been shown to be another area where it is cost effective to use CNTs already. The research I've seen suggests that 1 gram of MWNTs can be dispersed onto 1 sq. ft. of filter media. Manufacturers can get their cost down to 35 cents per gram of purified MWNTs when purchasing ton quantities.

Other Applications

Some commercial products on the market today utilizing CNTs include stain resistant textiles, CNT reinforced tennis rackets and baseball bats[②]. Companies like Kraft foods are heavily funding CNT based plastic packaging. Food will stay fresh longer if the packaging is less permeable to atmosphere. Coors **Brewing** company has developed new plastic beer bottles that stay cold for longer periods of time. Samsung already has CNT based flat panel displays on the market. A lot of companies are looking forward to being able to produce transparent conductive **coatings** and phase out ITO coatings. Samsung uses align SWNTs in the **transparent** conductive layer of their display manufacturing process.

(Selected from *www. nanowork. com*, 2008)

Questions

1. Tell some details about CNTs nanotechnology.
2. Tell some characters of Molecular Electronics.
3. Tell some applications of nanomaterial in water treatment.
4. What is the mechanism of nanomaterials used in filtration?

New Words and Expressions

1. endow *v.* 捐钱，资助
2. thermal conductivity 导热性
3. strength *n.* 强度
4. stiffness *n.* 硬度
5. toughness *n.* 韧性
6. delocalize *v.* 使离开原位
7. donate *v.* 捐赠，赠送
8. vibration *n.* 振动
9. intrinsic *adj.* 固有的，内在的
10. modify *v.* 修改，修饰
11. field emitter 场发射极
12. microscope *n.* 显微镜
13. reinforce *v.* 增强
14. plastics *n.* 塑料
15. graphite fiber 石墨纤维
16. pathway *n.* 路径

17. shielding composite 防护复合材料
18. enclosure *n.* 围绕，圈占
19. gasket *n.* 垫圈
20. antistatic *adj.* 抗静电的
21. stealth *n.* 秘密行动
22. energy storage 能量储存
23. capacitor *n.* 电容器
24. lithium *n.* 锂
25. battery *n.* 电池
26. diffusion *n.* 扩散，漫射
27. adhesive *adj.* 粘合剂
28. coaxial *adj.* 同轴的
29. transistor *n.* 晶体管
30. routinely *adv.* 例行公事地
31. dramatically *adv.* 戏剧地
32. fabrics *n.* 织物，构造
33. catalytic *adj.* 接触反应的
34. alignment *n.* 排成直线
35. biomedical *adj.* 生物医学的
36. biocompatible *adj.* 生物适合的
37. prosthetics *n.* 弥补术
38. filtration *n.* 过滤，筛选
39. brewing *n.* 酿造
40. coating *n.* 涂层
41. transparent *adj.* 透明的

Notes

① This aspect is part of the unique story of CNTs. CNTs are an example of true nanotechnology: they are under 100 nanometers in diameter, but are molecules that can be manipulated chemically and physically in very useful ways.

参考译文：这方面是碳纳米管（CNT）独特趣闻的一部分。碳纳米管是真正纳米技术的一个例子：它们的直径不到100nm，却是可用化学和物理方法操纵的有用分子。

② Some commercial products on the market today utilizing CNTs include stain resistant textiles, CNT reinforced tennis rackets and baseball bats.

参考译文：如今市场上的一些碳纳米管商业产品包括了耐污纺织品、碳纳米管增强的网球拍和棒球棒。

Reading Material

Nanoscale Properties (Ⅲ)

Optical Properties of Nanomaterials

Nanocrystalline systems have attracted much interest for their novel optical properties, which differ remarkably from bulk crystals. Key contributory factors include quantum **confinement** of electrical carriers within nanoparticles, efficient energy and charge transfer over nanoscale distances and in many systems a highly enhanced role of interfaces. With the growing technology of these materials, it is increasingly necessary to understand the detailed basis for **nanophotonic** properties. The linear and nonlinear optical properties of such materials can be finely tailored by controlling the crystal dimensions, and the chemistry of their surfaces, fabrication technology becomes a key factor for the applications.

Surface Plasmons (SP) are the origin of the color of nanomaterials. An SP is a natural **oscillation** of the electron gas inside a given **nanosphere**. If the sphere is small compared to a wavelength of light, and the light has a frequency close to that of the SP, then the SP will absorb energy. The frequency of the SP depends on the dielectric function of the nanomaterial, and the shape of the nanoparticle. For a gold spherical particle, the frequency is about 0.58 of the bulk plasma frequency. Thus, although the bulk **plasma** frequency is in the UV, the SP frequency is in the visible (close to 520nm).

Suppose we have a **suspension** of nanoparticles in a host. If a wave of light is applied, the local electric field may be hugely enhanced near an SP resonance. If so, one expects various nonlinear susceptibilities, which depend on higher powers of the electric field, to be enhanced even more.

Glues containing nanoparticles have optical properties that give rise to uses in optoelectronics. Casings, containing nanoparticles used in electronic devices, such as computers, offer improved shielding against electromagnetic interference. Electrochromic, devices are similar to liquid-crystal displays (LCD), are been developed with nanomaterials. The incorporation of nanomaterials in surface coatings can provide long-term abrasion resistance without significantly effecting optical clarity, gloss, color or physical properties.

Chemical Properties of Nanomaterials

One of the important factors for the chemical applications of nanomaterials is the **increment** of their surface area which increases the **chemical activity** of the material.

Due to their enhanced chemical activity, nanostructural materials can be used as catalysts to react with such **noxious** and toxic gases as **carbon monoxide** and nitrogen oxide in automobile catalytic converters and power generation equipment to prevent environmental pollution arising from burning gasoline and coal[①]. Fuel cell technology is another important application of the noble metal nanoparticles relating the catalysis of the reactions. In the present, the fuel cell catalysts are based on **platinum** group metals (PGM). Pt and Pt-Ru alloys are some of the most frequently used catalysts from this group. In fact, the use of these metals is one major factor for cell costs, which has been one of

the major drawbacks preventing it from growing into a more important technology. One possibility to produce economical catalysts is the use of **bimetallic** nanoparticles.

Magnetic Properties of Nanomaterials

The strength of a magnet is measured in terms of **coercivity** and **saturation magnetization** values. These values increase with a decrease in the grain size and an increase in the specific surface area (surface area per unit volume) of the grains. Therefore nanomaterials present also good properties in this field.

Magnets made of nanocrystalline yttrium-samarium-cobalt grains possess very unusual magnetic properties due to their extremely large surface area. Typical applications for these high-power **rare-earth** magnets include quieter **submarines**, automobile alternators, land-based power generators, and motors for ships, ultra-sensitive analytical instruments, and **magnetic resonance** imaging (MRI) in medical **diagnostics**.

(Selected from *Nanoscale Properties and Materials*, Miguel J. Yacaman, 2005)

Questions

1. How about optical properties of nanomaterials?
2. Tell some properties of liquid-crystal displays (LCD).
3. What are the magnetic properties of nanomaterials?

New Words and Expressions

1. confinement *n.* (被) 限制, (被) 禁闭, 分娩
2. nanophotonic *adj.* 纳米光电的, 纳米光子的
3. Surface Plasmons 表面等离子激元
4. oscillation *n.* 振动, 振荡, 摆动
5. nanosphere *n.* 纳米球
6. plasma *n.* 等离子体
7. suspension *n.* 吊, 悬浮, 悬浮液, 暂停
8. increment *n.* 增加, 增量
9. chemical activity 化学活性
10. noxious *adj.* 有害的
11. toxic *adj.* 有毒的, 中毒的
12. carbon monoxide 一氧化碳
13. platinum *n.* 白金, 铂
14. bimetallic *adj.* 双金属的
15. coercivity *n.* 矫顽力, 矫顽性
16. saturation magnetization 饱和磁化, 磁饱和
17. rare-earth 稀土
18. submarine *n.* 潜水艇; *adj.* 水下的, 海底的

19. magnetic resonance 磁共振

20. diagnostics *n.* 诊断，诊断学

Notes

① Due to their enhanced chemical activity, nanostructural materials can be used as catalysts to react with such noxious and toxic gases as carbon monoxide and nitrogen oxide in automobile catalytic converters and power generation equipment to prevent environmental pollution arising from burning gasoline and coal.

参考译文：由于其先进的化学活性，纳米结构材料可以用做催化剂，在汽车催化转换器及发电设备中与那些有害或有毒气体例如一氧化碳和氮氧化物相作用，以防止汽油和煤炭燃烧产生的环境污染。

科技英语翻译技巧（七）：并列句和复合句

1. 并列句

并列句是由两个或两个以上相互独立相互平等的简单句构成的。两个简单句常用并列连词连在一起。

Sometimes the reverse is the case, and design engineers have a problem in their design which requires a new material to be created by research scientists and engineers.

有时候情况相反，设计工程师在设计中遇到问题需要研究人员开发新材料。

Glassy polyethylene is transparent while crystalline polyethylene is translucent.

玻璃态的聚乙烯是透明的，而晶态的聚乙烯则是半透明的。

This stage of the processing is called fixing and must be carefully carried out, otherwise any unexposed silver bromide would slowly change color.

这个过程叫做定影，必须仔细操作，否则一些未曝光的溴化银就会慢慢变色。

2. 复合句

复合句由一个主句和一个或一个以上的从句组成，包含两个或多个主谓结构，并且，其中一个主谓结构充当主句，另一个或多个主谓结构为从句，从句充当复合句中的某个成分，它本身不能单独存在。主句和从句一般由关联词相连。按照从句在复合句中所充当的成分不同，可分为主语从句、宾语从句、表语从句、定语从句和状语从句。

The sketches explained why the hardness materials were chosen.（宾语从句）

这些图解释了选择硬材料的原因。

When the engineer changes the structure of the material, the properties also change.（状语从句）

当工程师改变材料的结构时，材料的性能也会发生改变。

The engineer produced a component that had the proper shape and properties to perform its task.（定语从句）

工程师制造出了具有适当的形状和性能的新工件，以满足需要。

The most important was how to change the structure of the materials to meet the need.（表语从句）

最重要的是怎样改变材料的结构才能满足需要。

3. 简单句和复合句的倒装

（1）简单句的倒装。

No sooner is stress removed than the strain produced in a stressed material is completely removed in elastic behavior.

在弹性范围内，一旦去掉应力，相应的应变就会完全消失。

Only by heat treatment can we refine the crystal of this material.

只有热处理才能细化这种材料的晶粒。

Not only shows the material excellent corrosion performance but also it shows the excellent physical performance.

这种材料不仅显示了优异的耐蚀性能，而且显示了优异的物理性能。

Not until World War Ⅱ did jet plane come into use.

直到第二次世界大战才开始使用喷气式飞机。

(2) 复合句的倒装。

Only when you have obtained sufficient date can you come to a proper conclusion. (强调条件状语，句子倒装)

只有获得足够的数据，才能得出正确的结论。

Hardly have we touched on their mechanical properties when our focus has been on amorphous polymers in the preceding discussion.

接下来讨论中，我们主要针对高分子材料，但基本不提及它们的机械性能。

Brittle as it is, there is no material more properly than it. (as 引导比较状语从句，句子倒装)

虽然这种材料很脆，但没有哪种材料比它更合适。

Had I known the new technology, I would have produced new product. (虚拟语气倒装)

如果我知道新工艺，我就会开发新产品。

Chapter 8 Recent Advances in Materials Science and Technology and Future Trends

8.1 Recent Advances in Materials Science and Technology

In recent decades, a number of exciting initiatives in materials science have been undertaken that could potentially revolutionize the future of the field. Smart materials and devices at micrometer size scale and nanomaterials are two classes of materials that will critically affect all major industries.

Smart Materials

Some smart materials have been around for years but are finding more applications. They have the ability to sense external environmental stimuli (temperature, stress, light, **humidity**, and electric and magnetic fields) and respond to them by changing their properties (mechanical, electrical, or appearance), structure, or functions. These materials are **generically** called smart materials. Smart materials or systems that use smart materials consist of sensors and **actuators**. The **sensory** component detects a change in the environment, and the actuators component performs a specific function or a response. For instance, some smart materials change or produce color when exposed to changes in temperature, light intensity, or an electric current.

Some of the more technologically important smart materials that can function as actuators are **shape-memory alloys** and **piezoelectric** ceramics. Shape-memory alloys are metal alloys that, once strained, **revert** back to their original shape upon an increase in temperature above a **critical transformation temperature**. The change in shape back to the original is due to a change in the crystal structure above the transformation temperature. One biomedical application of a shape-memory alloy is a **stent** for supporting weakened artery walls or for expanding narrow arteries[①]. The deformed stent is first delivered in the appropriate position in the artery using a probe. The stent expands to its original shape and size after increase its temperature to body temperature. For comparison, the conventional method of expanding or supporting an artery is through the use of a **strainless** steel tube that is expanded using a balloon. Examples of shape-memory alloy are nickel-titanium and copper-zinc-aluminum alloys.

Actuators may also be made of piezoelectric materials. The materials produce an electric field when exposed to a mechanical force. **Conversely**, a change in an external electric field when exposed to a mechanical response in the same material. Such materials may be used to sense and reduce undesirable vibrations of a component through their actuator response. Once a vibration is detected, a current is applied to produce a mechanical response that counters the effect of **vibration**.

Now let us consider the design and development of systems at micrometer size scale that use smart materials and devices to sense, communicate, and actuate: such is the world of microelectromechanical system (MEMS). Originally, MEMS were devices that integrated technology, electronic materials, and smart materials on a semiconductor chip to produce what were commonly known as a micromachine. The original MEMS devices had the microscopic mechanical elements fabricated on silicon chips using **integrated circuits** technology; MEMS were used as sensors or actuators. But today the term "MEMS" is extended to any miniaturized device. The applications of MEMS are also numerous, including but not limited to micropumps, **locking systems**, motors, mirrors, and sensors. For instance, MEMS are used in automobile **airbags** to sense both deceleration and the size of person sitting in the car and to deploy the airbag at a proper speed.

Nanomaterials

Nanomaterials are generally defined as those materials that have a characteristic length scale (that is particle diameter, grain size, layer thickness, etc.) smaller than 100 nm ($1\text{nm} = 10^{-9}\text{m}$). Nanomaterials can be metallic, polymeric, ceramic, electronic, or composite. In this respect, ceramic powder **aggregates** of less than 100nm in size, bulk metals with grain size less than 100nm, thin polymeric films with thickness less than 100nm, and electronic wires with diameter less than 100nm are all considered nanomaterials or nanostructured materials. At the nanoscale, the properties of the material are neither that of the molecular or atomic level nor that of the bulk material. Although a tremendous amount of research and development activities has been devoted to this topic in the past decade, early research on nanomaterials dated back to the 1960s when chemical flame furnaces were used to produce particles smaller than one micron ($1\text{micron} = 10^{-6}\text{m} = 10^{3}\text{nm}$) in size. The early applications of nanomaterials were as chemical catalysts and pigments. Metallurgists have always been aware that by refining the grain structure of a metal to **ultrafine** (submicron) levels, its strength and hardness increases significantly in comparison to the **coarse**-grained (micron-size) bulk metal. For example, nanostructured pure copper has a yield strength six times that of coarse-grained copper.

The reasons for the recent extraordinary attention to these materials may be due to the development of (1) new tools that make the observation and characterization of these materials possible and (2) new methods of processing and synthesizing nanostructured materials that enable researchers to produce these materials more easily and at a higher yield rate.

The future applications of nanomaterials are only limited to the **imagination**, and one of the major **obstacle** in **fulfilling** this potential is the ability to efficiently and inexpensively produce these materials. Consider the manufacturing of **orthopaedic** and dental implants from nanomaterials with

better biocompatibility characteristics, better strength, and better wear characteristics than metals. One such material is nanocrystalline zirconia (zirconium oxide), a hard and wear resistant ceramic that is chemically stable and biocompatible[②]. This material can be processed in a porous form, and when it is used as implant material, it allows for bone to grow into its pores, resulting in a more stable fixation. The metal alloys that are currently used for this application do not allow for such interaction and often loosen over time, requiring further **surgery**. Nanomaterials may also be used in producing paint or coating materials that are significantly more resistant to **scratching** and environmental damage. Also, electronic devices such as transistors, diodes and even lasers may be developed on a **nanowire**. Such materials science advancements will have both technological and economical impact on all areas of engineering and industries.

Welcome to the **fascinating** and **exceedingly** interesting world of materials science and engineering!

(Selected from *Foundation of Materials Science and Technology*, by W. F. Smith and J. Hashemi, 2004)

Questions

1. What materials will critically affect all major industries?
2. What are smart materials?
3. What are shape-memory alloys?
4. Please describe MEMS by using your own words.
5. What are the reasons for the recent extraordinary attention to nanomaterials?

New Words and Expressions

1. smart material 智能材料，机敏材料
2. humidity *n.* 湿度，潮湿
3. generically *adv.* 一般地
4. actuator *n.* 致动器，传动装置
5. sensory *adj.* 传感的，感觉的，感官的
6. shape-memory alloy 形状记忆合金
7. piezoelectric *n.* 压电的
8. revert *v.* 还原，回复
9. critical transformation temperature 临界转变温度
10. stent *n.* 血管内支架；*adj.* 扩张的
11. strainless *adj.* 无张力的，无应变的
12. conversely *adv.* 相反地
13. vibration *n.* 振动，颤动
14. integrated circuit 集成电路
15. locking system 锁闭系统，锁定装置

16. airbag *n.* 安全气囊，气袋
17. aggregate *n.* 总计，集合体；*adj.* 集合的，聚合的；*v.* 集合，聚合
18. ultrafine *adj.* 超细的，极其细小的
19. coarse *adj.* 粗的，粗糙的
20. imagination *n.* 想象，空想，想象力
21. obstacle *n.* 障碍，干扰
22. fulfill *v.* 履行，实现，完成
23. orthopaedic *adj.* 整形外科的
24. surgery *n.* 外科，手术室，诊疗室
25. scratch *n.* 擦伤，抓痕；*v.* 擦，刮
26. nanowire *n.* 纳米线
27. fascinating *adj.* 迷人的，令人着魔的
28. exceedingly *adv.* 非常地，极度地

Notes

① One biomedical application of a shape-memory alloy is a stent for supporting weakened artery walls or for expanding narrow arteries.

参考译文：形状记忆合金在生物医学中的一种应用，是用来制作支撑变弱的动脉壁或扩张狭窄动脉的支架。

② One such material is nanocrystalline zirconia (zirconium oxide), a hard and wear resistant ceramic that is chemically stable and biocompatible.

参考译文：一种这样的材料是纳米氧化锆（氧化锆），它是一种坚硬又耐磨的陶瓷，其化学成分稳定并具有生物相容性。

8.2 Trends in Materials Science and Technology(I)

Fabrication at the micro- and nanoscale level will yield a number of new devices and products, ranging from **exquisite** sensors to tiny walking robots and automated labs-on-a-chip. Key to such advances is understanding how to control the materials used and the development of new molecular manipulation and micromachining tools. Advancements in **photonics** will help meet the demand for greater **bandwidth** for communications, and **innovations** in photonic-integrated systems will expand their use for signal processing. Both high- and low-temperature superconductors pose challenges and promise commercial applications over the next decade, including in the distribution of electric power and as ships' engines①. Creation of new materials will have effects throughout society, and the versatility of polymers makes them a particularly attractive target for research. Self-assembly, by which molecules form into structures on their own, also has gained increasing attention.

Microscale and Nanoscale Fabrication

Emerging micro- and **nanominiaturization** techniques promise to transform the typically

planar world of these scales into three dimensions and to enable new devices and technologies of scientific, industrial, economic, and security import, including a host of new sensors, walking **microrobots**, **nanomotors**, and new polymers. Understanding how to control the chemical composition, physical properties, and configuration of materials at the molecular level is a key element in devising nanoscale building blocks for assembly into working devices and machines[②]. Achieving this knowledge and integrating it into products requires an interdisciplinary effort by chemists, physicists, materials scientists, and engineers.

MEMS

Microelectromechanical system (MEMS) devices have gone from relatively simple accelerometers to devices that enabled the successful flight of twin tethered experimental communications satellites, each of which is only 12 cubic inches and weighs 0.55 lb. The challenge now is to improve MEMS techniques and develop new ways to do three-dimensional **microfabrication** of things such as metallic coils. MEMS devices—already in commercial use as sensors and actuators—are being developed as micromachines and microrobots. Especially promising to the MEMS field is the advent of laser-based micromachining and other innovations to supplement the photolithography-chemical etching process used originally. Laser techniques now in laboratory development can micromachine metals and fabricate devices of smaller dimensions—a few micrometers today and, perhaps, nanoscale devices tomorrow. Swedish researchers have fabricated a walking silicon microrobot, as well as a microrobotic arm that uses conjugated-polymer activators to pick up, move, and place micrometer-size objects.

At the nanoscale level, the ability to manipulate atoms, molecules, and molecular clusters has revealed often unexpected and potentially useful properties. Now scientists are seeking to exploit these findings to create nanowires, nanomotors, macromolecule machines, and other devices. Nanomotors, for example, will be needed to power many **envisioned nanodevices**, including switches, actuators, and pumps. The challenge is to devise ways to convert chemical energy into power that enables nanodevices to perform useful tasks and to find ways to control and refuel the tiny motors.

Nanotubes

Carbon-based nanotubes continue to attract interest because of the potential of their physical and electrical properties. They are stronger and tougher than steel, can carry higher current densities than copper, and can be either metals or semiconductors. Uses envisioned for them range from tiny switches to new composite materials capable of stopping high-velocity bullets. Bringing such nanometer applications to fruition, however, especially for electronics, will require new methods to reliably and economically mass-produce nanotubes and control their characteristics, as well as ways to structure and organize them.

Without scanning probe microscopy, nanotechnology would remain largely a concept. Nevertheless, there exists the need for faster techniques to control, image, and manipulate materials and for new ways to make molecular-scale measurements. One approach to greater specificity would harness

the **spatial** resolution of scanning probe microscopy with the chemical specificity of molecular **spectroscopy**.

Sensors

Microfabrication and MEMS devices will play increasingly greater roles in the development and manufacture of high-tech sensors. The increased potential for **terrorist** attacks and the threat of chemical or germ warfare has spurred efforts by the civilian and military sectors to detect explosives, deadly chemicals, and biological agents. A single lab-on-a-chip can detect and identify a number of different substances, a capability useful to medical and environmental monitoring as well as national security. Beyond today's technology, researchers funded by the Defense Advanced Research Projects Agency (DARPA) are developing small, lightweight, easy-to-use MEMS-based **biofluidic microprocessors** capable of monitoring a person's blood and **interstitial fluid** and comparing readings with an **assay** reference chip. Such devices could not only give early warning of exposure to chemicals or biological agents but also monitor general health, medication usage, and psychological stress.

The coming decade should see other significant advances in medical microsensors. For example, English scientists are developing a camera-in-a-pill that can be swallowed to examine the **gastrointestinal tract**. The device, currently 11 × 30 millimeters, contains an image sensor, a light-emitting diode, telemetry transmitter, and battery. Several improvements are needed before it can complement or replace current endoscopy tools, including orientation control and a more powerful battery that will enable it to image the entire gastrointestinal tract, from **ingestion** to elimination. And a Michigan company, a winner in the 2000 Advanced Technology Program competition, is trying to commercialize technologies developed at the University of Michigan. It hopes to create implantable wireless, **batteryless** pressure sensors to continuously monitor fluids in the body. Potential beneficiaries include patients with glaucoma, hydrocephalus, chronic heart disease, or urinary incontinence.

Artificial or **electronic noses** are starting to find a home in industry. These devices typically consist of an array of polymers that react with specific odors and a pattern-recognition system to identify an **odor** by the change it produces in a polymer. To date, artificial noses have been used mainly in the food industry to augment or replace existing means of quality control, but potential uses include quality control in the pharmaceutical, cosmetic, and **fragrance** industries. Expanding the uses of electronic noses will require sensors with greater sensitivity and specificity and more advanced **algorithms** to improve performance.

Photonics

Photonics **underpins** optical communications. Because photons are more effective carriers of information than electrons, the demand for new ways to **harness** light to communicate and store data will intensify[3], driven by the worldwide need for greater bandwidth. The development of wavelength division multiplexing has opened a progressive revolution in data transmission, storage, and processing that could match that of electronics in the 20th century. Although most photonic circuits today

are analog, the development of low-cost photonic integrated systems will enable uses beyond communications, including signal processing and exquisite sensors.

Photons travel at the speed of light and do not interact with one another, which all but eliminates cross talk and inference. However, logic functions require some interaction, and researchers have sought ways to process information electronically and transmit it optically. One promising approach to integration is the use of smart **pixel** devices, which combine electronic processing circuitry with optical inputs and/or outputs and can be integrated into two-dimensional arrays. Researchers are investigating several approaches to applying smart pixels in high-speed switching, as interconnects, and in flat-panel display applications.

Electro-optical Polymers

The increase in optical-fiber capacity also creates the need to speed information in and out of the fibers. One new approach to speeding this information flow uses polymers containing organic **chromophores**, which are molecules involved in color. Evidence suggests that embedding chromophores can yield electro-optical polymers that have higher speeds—as high as 100 gigahertz—and require lower voltages than present-day electronic modulators. However, chromophores tend to **align** in ways that reduce the effect of an applied field, a problem that needs resolution.

Researchers are also exploring **holography** to create three-dimensional photonic crystals for use in ultrasmall **waveguides** and other optical-communications uses. So far, however, the thickness of the crystal layers is limited to about 30 micrometers, and more advances in processing will be needed to obtain the larger photonic crystals needed for communications applications.

Significant improvements in key photonic devices seem a certainty in the next decade, including in-fiber optical filters (known as fiber Bragg gratings), in-fiber amplifiers, and fiber lasers④. Fiber **Bragg gratings**, for example, are the building blocks of wavelength division multiplexing and essential elements for the next generation of all-optical switches and networks. In-fiber amplifiers depend on doping the core of optical fibers with rare-earth ions, and refining the doping process should optimize various amplifier designs. Fiber lasers can sustain high power densities and can currently generate pulses of 100 **femtoseconds**. The development of polymer lasers holds significant potential for speeding communications.

One challenge to developing new photonic devices is that models currently used to characterize materials require unrealistic computer time. As a result, prototype devices often must be built for testing. A great need exists for new algorithms to address issues such as simulation, analysis, alignment tolerance, and increasing the yields of photonic components.

(Selected from *Future R & D Environments: A Report for the National Institute of Standards and Technology*, American National Research Council, 2002)

Questions

1. What kinds of products will yield if fabrication at the micro- and nanoscale levels?

2. What are nanotubes?
3. What is a sensor?
4. Why does photonics underpining optical communications?
5. Give some examples of electro-optical polymers.

New Words and Expressions

1. exquisite *adj.* 精致的，敏锐的，异常的，优雅的
2. photonics *n.* 光子学，纤维光学
3. bandwidth *n.* 带宽
4. innovation *n.* 革新，改革
5. nanominiaturization *n.* 纳米微型化
6. planar *adj.* 平面的，平坦的
7. microrobot *n.* 微型机器人
8. nanomotor *n.* 纳米电机
9. microfabrication 微型制作（装配）
10. envision *v.* 想象，预想
11. nanodevice *n.* 纳米器件（元件）
12. nanotube *n.* 纳米管
13. spatial *adj.* 空间的
14. spectroscopy *n.* 光谱学，波谱学，分光术
15. terrorist *n.* 恐怖分子
16. biofluidic *adj.* 生物体液的，生物流体的
17. microprocessor *n.* 微处理器，微处理机
18. interstitial fluid 细胞间液，间质流体
19. assay *n.* & *v.* 化验，检定
20. gastrointestinal *adj.* 胃肠的
21. tract *n.* （解剖）管道，地方
22. ingestion *n.* 摄取
23. batteryless *adj.* 无电池的
24. electronic nose 电子鼻（用于测气体）
25. odor *n.* 气味，名声
26. fragrance *n.* 芬芳，香味
27. algorithm *n.* 算法，运算法则
28. underpin *v.* 巩固，支撑，加强……的基础
29. harness *n.* 导线，装备；*v.* 利用
30. pixel *n.* 像素，像元
31. chromophore *n.* 发色团，载色体
32. align *v.* 排列，对齐，定位
33. holography *n.* 全息摄像术

34. waveguide　*n.* 波导

35. Bragg grating　布拉格光栅

36. femtosecond　*n.* 飞秒，毫微微秒（10^{-15}s）

Notes

① Both high- and low-temperature superconductors pose challenges and promise commercial applications over the next decade, including in the distribution of electric power and as ships' engines.

参考译文：高温和低温超导体面临着挑战和在未来 10 年在商业上应用的承诺，包括电力配送和用于船舶发动机。

② Understanding how to control the chemical composition, physical properties, and configuration of materials at the molecular level is a key element in devising nanoscale building blocks for assembly into working devices and machines.

参考译文：对设计可装配成工作器件和设备的纳米级构件来说，了解如何在分子水平上控制材料的化学成分、物理性质和结构是一个关键因素。

③ Because photons are more effective carriers of information than electrons, the demand for new ways to harness light to communicate and store data will intensify, ...

参考译文：由于光子是比电子更有效的信息载体，新的利用光来通信和进行数据存储的需求非常大，……

④ Significant improvements in key photonic devices seem a certainty in the next decade, including in-fiber optical filters (known as fiber Bragg gratings), in-fiber amplifiers, and fiber lasers.

参考译文：在未来 10 年，关键的光子器件会有显著的改进，包括光纤光学过滤器（称为布拉格光纤光栅）、光纤放大器和光纤激光器。

8.3 Trends in Materials Science and Technology(Ⅱ)

Superconductors

In recent years, applications of high-temperature superconductors have moved beyond the realm of laboratory sensors[①]. The U. S. **Navy**, for example, has awarded a contract for the design of a 25,000-**horsepower** superconductor motor to power its next generation of **destroyers**. The ability of these superconductors to transmit electricity with essentially zero resistance will in and of itself guarantee continued efforts to understand the phenomenon, develop new superconducting materials, and apply them.

Opening up applications and a large commercial market for superconductor wires and cables will require increasing the current-carrying capacity of high temperature superconductors, and the coming years will witness further efforts to resolve this challenge. German researchers have achieved a six-fold increase in current-carrying capacity at 77 K by **manipulating** the make-up of a **yttrium-barium**-copper oxide superconductor. The researchers replaced some yttrium ions at grain boundaries

with calcium ions. 77 K is the boiling point of **nitrogen** and the point above which many believe superconductors can be widely commercialized. This discovery suggests similar chemical tinkering may raise the current carrying capacity of other high-temperature superconductor compounds.

Superconducting Plastics

Electrically conducting plastics were discovered a quarter-century ago, but only now have superconductor plastics come to the fore. Superconductor polymers have been **problematic** because plastics carry current as the result of doping them with impurities, but superconductivity requires an ordered structure that does not disrupt electron flow. An international team that included **Bell Labs** researchers reported earlier this year that it had observed superconductivity in the polymer **poly (hexythiophene)**. The researchers placed the polymer inside a field-effect transistor, injected it with **holes**, and achieved superconductivity at 2.35 K. The new discovery should pave the way for a new approach to developing and applying superconductor polymers.

The discovery of an intermetallic superconductor with a critical temperature of 39 K, announced earlier this year, opens another area of opportunity. Although low in operating temperature compared with today's high-temperature superconductors, the **magnesium boride** compound can carry three times as much current, weight for weight, because it is a lighter material, and it can be cooled by **closed-cycle** refrigeration instead of **liquid helium coolants**[②].

Nanotubes

Low-temperature superconductors continue to demonstrate **resilience** and the potential for significant development. An ongoing Department of Energy program supports efforts to move these materials into commercial use. In one demonstration project, a consortium of companies is readying superconductor cable to serve 14,000 inner-city Detroit customers with electricity. Experimentally, nanotubes—which at room temperatures can be insulators, semiconductors, or metals—have added to their reputation as physical chameleons with the discovery that they can become superconductors. European researchers suspended a number of single-wall nanotubes between two superconductor electrodes and found they became superconductors and ultrasmall **Josephson junctions** at between 0.3 and 1.0 K, depending on the sample.

New Materials and Self-Assembly

Materials science underpinned much of the technological advancement of the 20th century and will continue to do so in this decade. The discipline involves understanding the structure and physical properties of materials and finding ways to alter them for useful purposes. The coming years will accelerate the design of materials with specific performance capabilities dictated by a specific need. The applications of materials science range across modern life, from new structural materials, to sensing devices, to implantable biocompatible replacement parts for humans. As they have in recent decades, innovations in materials will enable a spectrum of new products and technologies.

1. Polymers

These long-chain molecules have made important contributions to technology and will continue to do so (see **flat displays** and **printed circuits**). Polymers, depending on their composition, can be as rigid and strong as steel, as floppy and stretchable as rubber bands, or somewhere in between. Synthesizing polymers with specific properties, sizes, and shapes, however, remains a significant challenge. Despite substantial progress in controlling the architecture and functions of polymers, considerably more needs to be accomplished in understanding these materials and in developing ways to easily tailor their configurations and properties to meet specific needs—whether as new materials for an old product or a new material for an envisioned use. Japanese researchers, for example, have used the **probe tip** of a scanning tunneling microscope to fashion conjugated polymers into nanowires. Researchers at the Massachusetts Institute of Technology are developing a shape-memory polymer with properties and applications superior to those of the shape-memory metal alloys now available.

2. Composite materials

By chance, **guesswork**, and science, humans have created alloys for more than 4,000 years. Composite materials, in the form of straw-based bricks, go back roughly 7,000 years. As scientists develop a deeper understanding of how to structure and process molecules in ways that fine-tune their physical properties, new alloys and composite materials will emerge. In **Earth-orbit** experiments, researchers have developed a **nanocomposite** in which magnetic nanoparticles move freely inside cavities that form within the material. Potential applications include tiny compasses, gyroscopes, switches, and, perhaps, microtransformers. Today's alchemists rely on computers—for modeling, computational chemistry, and computational physics—sensitive imaging studies, and nondestructive testing. Even better tools are needed as the science surges forward.

3. Self-assembly

One area likely to progress rapidly over the next decade is that of molecular self-assembly to inexpensively produce atomically precise materials and devices[3]. Harnessing this phenomenon will provide a critical element in fabricating new materials, nanomachines, and electronic devices. Some examples of self-assembling materials in development include smart plastics that assemble themselves into photonic crystals, spinach-based **opto-electronic** circuits for possible use in logic devices and ultrafast switches, and inorganics and organics that self-assemble between two electrodes to form transistors. Earlier this year, English scientists reported what they called the equivalent of catalytic antibodies for synthetic chemists—a dynamic solution that enables molecules to arrange themselves into the best combination to bind to a specific target. Self-assembly has important applications in the biomedical sciences. One technique, for example, uses a system in which molecules assemble into **countless** combinations that are quickly tested for their ability to bind to receptors.

A great deal remains unknown about the process of molecular self-assembly or how to utilize it for producing new materials or new applications. Even more challenging is the creation of materials that self-assemble from two or more types of molecules.

(Selected from *Future R & D Environments: A report for the National Institute of Standards and Technology*, American National Research Council, 2002)

Questions

1. What is a superconductor?
2. Can nanotubes become superconductors?
3. What does self-assembly mean?
4. Tell something about composite materials.

New Words and Expressions

1. navy *n.* 海军，深蓝色
2. horsepower *n.* 马力
3. destroyer *n.* 驱逐舰，破坏者
4. manipulate *v.* 操作，操纵，利用，使用
5. yttrium *n.* 钇
6. barium *n.* 钡
7. boiling point 沸点
8. nitrogen *n.* 氮
9. problematic *adj.* 成问题的，有疑问的
10. Bell Labs 贝尔实验室
11. poly（hexythiophene） *n.* 聚己基噻吩
12. hole *n.* 空穴，孔
13. magnesium boride 硼化镁
14. closed-cycle 闭合循环
15. liquid helium 液氦
16. coolant *n.* 冷却剂，散热剂
17. resilience *n.* 回弹力，弹性，恢复力
18. Josephson junction 约瑟夫森结
19. self-assembly 自装配，自组装
20. flat display 平板显示器
21. printed circuit 印制电路
22. probe tip 探针头
23. guesswork *n.* 猜测，猜想
24. Earth-orbit 环地球轨道
25. nanocomposite *n.* 纳米复合物，纳米复合材料
26. opto-electronic 光电的
27. countless *adj.* 无数的，数不尽的

Notes

① In recent years, applications of high-temperature superconductors have moved beyond the realm of laboratory sensors.

参考译文：近年来，高温超导体的应用已经超出了实验室的范围。

② Although low in operating temperature compared with today's high-temperature superconductors, the magnesium boride compound can carry three times as much current, weight for weight, because it is a lighter material, and it can be cooled by closed-cycle refrigeration instead of liquid helium coolants.

参考译文：尽管镁硼化合物的工作温度与现在的高温超导体相比较低，但在重量相同的情况下，它可以传输后者3倍的电流，它更轻，并且可以靠闭路循环制冷来冷却，而不用液态氦制冷剂。

weight for weight 在此可译成“在重量相同的情况下”。

③ One area likely to progress rapidly over the next decade is that of molecular self-assembly to inexpensively produce atomically precise materials and devices.

参考译文：一个可能在未来10年内迅速发展的领域是分子自组装，它可以低成本地生产原子精密材料和器件。

科技英语写作技巧

科技英语论文的写作，对于提高研究水平和推动科学技术发展起着不可低估的作用。好的思路和好的实验结果，要想完善地描述出来，就需要对科技英语的专业词汇以及专业表达具有很准确的把握，即需要有很强的写作能力，这就需要有一些基本的写作技巧。

1. 科技英语摘要书写要点

（1）摘要描述研究目的与意义的一般句式：

We aim to investigate the effect of high current density electropulsing on the corrosion resistance of X70 pipeline steel.

This paper focuses on cutting performance for HSS twist drills with CrTiN coating.

The purpose of this paper is to investigate the effect of Er on the mechanical properties of Al-Zn-Mg alloy.

（2）摘要描述研究方法的一般句式：

The effect of Er on microstructures was studied by OM, RD, SEM and TEM.

XRD and TEM were used to study the structural evolution of the powder during ball milling.

The effect of sodium molybdate concentration on the surface morphology was analyzed by EDS, SEM and XRD.

（3）摘要描述结果和结论的一般句式：

The results show that the addition of Er on Al-6Zn-2Mg alloy is capable of refining grains obviously.

The paper concludes that the corrosion resistance of the composite coating heat-treated at 500℃ is better than as deposited and Re-Ni-W-SiC composite coating heat-treated at 400℃.

2. 科技英语引言书写要点

一篇好的科技文章，引言至关重要。引言中要写的内容包括：研究的理由、目的和背景，包括问题的提出，前人对这一问题做了哪些工作，存在哪些不足；希望解决什么问题，该问题的解决有什么作用和意义。

（1）通常在叙述了前人成果之后，用 however 或 but 等词引导不足，比如：

Several studies on the synthesis of TiB_2 have been reported, however the formation mechanism of TiB_2 is not clear till now because of the insufficient analysis methods.

There are references on friction, wear and oxidation performance of the composite coating, but the reports on corrosion resistance are few.

So it is hardly to utilize the advantages of the surface micro- or nano-crystallization on pack aluminizing.

（2）指出当前研究的不足，从而有目的地阐述自己的研究的重要性：

The purpose of this paper is to study the effect of heat treatment on the structure and thermal stability of the mechanically alloyed powder.

In addition, we will also discuss the reaction mechanism of the formation of TiB_2 via MA technique.

Further studies are still necessary to develop a new processing technique.

The purpose of the paper was to provide feasible conditions of using and reduce the corrosion rate of $NiFe_2O_4$ based cermets.

3. 科技英语结论书写要点

科技英语结论是整篇论文最终的、总体的概括和总结，一般包括以下三个方面的内容：本次实验的研究结果；与前人所做工作的不同，即创新点；有时候也包括下一步的研究计划或建议。

（1）从上面的研究中引出结论：

The results indicated that increasing Zn content makes the grains of the as-deposited alloys refines.

The following conclusions can be made from this study.

The results obtained are summarized as follows.

From the present study, the following conclusions can be established.

（2）结论有些不足，从而为下一步研究提出建议：

There are several issues deserving further study.

However, a full explanation for link between the soft made theory in Raman spectra and ferroelectric phase transition at microscopic level is still difficult and waits for a further exploration.

Any further investigation in this area must focus on larger additions of ternary elements.

A more extensive investigation of the Ti-Al-Ag system will be required to allow exact definition of an optimum alloy composition range.

From the study the following recommendation should be made.

Appendixes

Appendix A Chemical Elements

原子序数	元素符号	中文名称	拉丁文名	英文名
1	H	氢	Hydrogenium	Hydrogen
2	He	氦	Helium	Helium
3	Li	锂	Lithum	Lithium
4	Be	铍	Beryllium	Beryllium
5	B	硼	Borium	Boron
6	C	碳	Carbonium	Carbon
7	N	氮	Nitrogenium	Nitrogen
8	O	氧	Oxygenium	Oxygen
9	F	氟	Fluorum	Fluorine
10	Ne	氖	Neonum	Neon
11	Na	钠	Natrium	Sodium
12	Mg	镁	Magnesium	Magnesium
13	Al	铝	Aluminium	Aluminium
14	Si	硅	Silicium	Silicon
15	P	磷	Phosphyorum	Phosphorus
16	S	硫	Sulphu	Sulfur
17	Cl	氯	Chlorum	Chlorine
18	Ar	氩	Argonum	Argon
19	K	钾	Kalium	Potassium
20	Ca	钙	Calcium	Calcium
21	Sc	钪	Scandium	Scandium
22	Ti	钛	Titanium	Titanium
23	V	钒	Vanadium	Vanadium

（续）

原子序数	元素符号	中文名称	拉丁文名	英文名
24	Cr	铬	Chromium	Chromium
25	Mn	锰	Manganum	Manganese
26	Fe	铁	Ferrum	Iron
27	Co	钴	Cobaltum	Cobalt
28	Ni	镍	Niccolum	Nickel
29	Cu	铜	Cuprum	Copper
30	Zn	锌	Zincum	Zinc
31	Ga	镓	Gallium	Gallium
32	Ge	锗	Germanium	Germanium
33	As	砷	Arsenium	Arsenic
34	Se	硒	Selenium	Selenium
35	Br	溴	Bromium	Bromine
36	Kr	氪	Kryptomum	Krypton
37	Rb	铷	Rubidium	Rubidium
38	Sr	锶	Strontium	Strontium
39	Y	钇	Yttrium	Yttrium
40	Zr	锆	Zirconium	Zirconium
41	Nb	铌	Niobium	Niobium
42	Mo	钼	Molybdanium	Molybdenum
43	Tc	锝	Technetium	Technetium
44	Ru	钌	Ruthenium	Ruthenium
45	Rh	铑	Rhodium	Rhodium
46	Pd	钯	Palladium	Palladium
47	Ag	银	Argentum	Silver
48	Cd	镉	Cadmium	Cadmium
49	In	铟	Inlium	Indium
50	Sn	锡	Stannum	Tin
51	Sb	锑	Stibium	Antimony
52	Te	碲	Tellurum	Tellurium
53	I	碘	Iodium	Iodine
54	Xe	氙	Xenonum	Xenon
55	Cs	铯	Caesium	Caesium

（续）

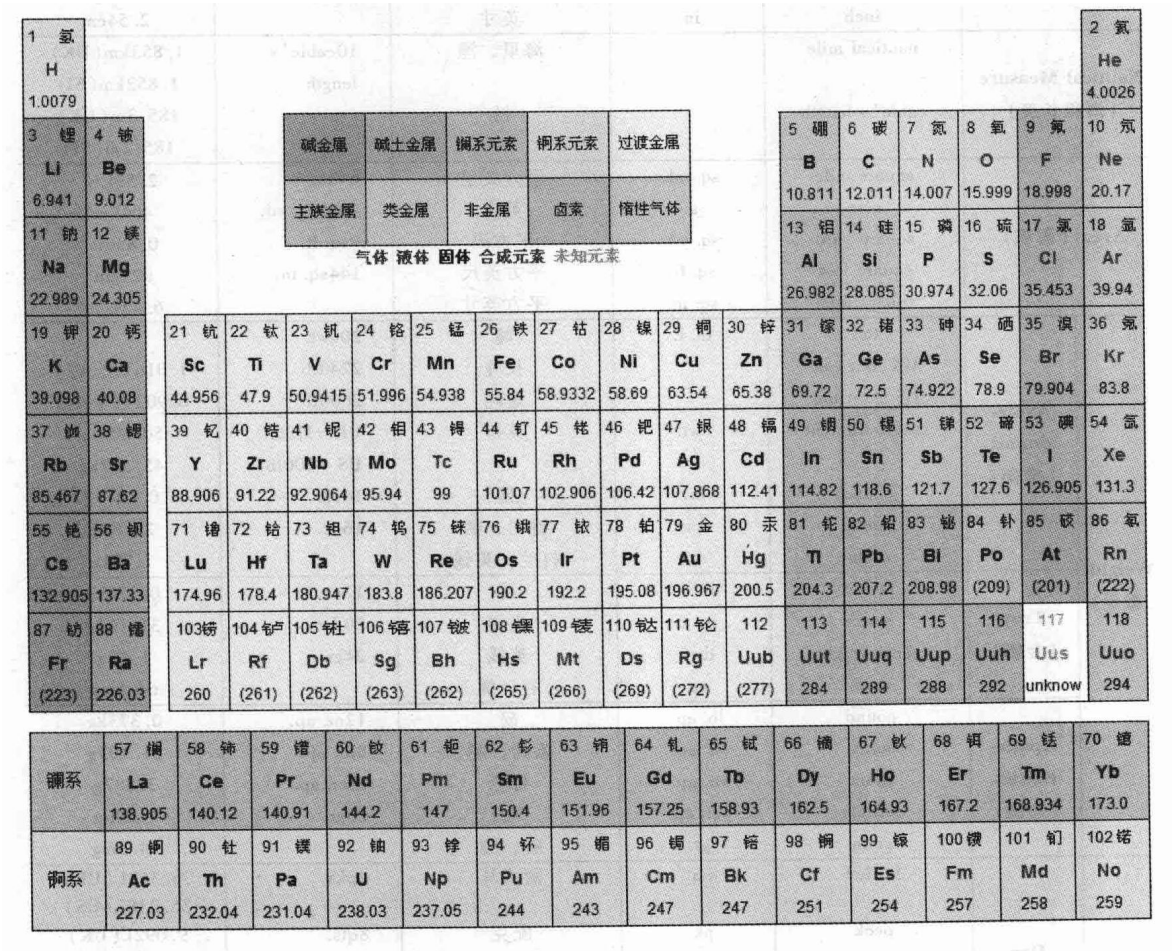
原子序数	元素符号	中文名称	拉丁文名	英文名
56	Ba	钡	Baryum	Barium
57	La	镧	Lanthanum	Lanthanum
58	Ce	铈	Cerium	Cerium
59	Pr	镨	Praseodymium	Praseodymium
60	Nd	钕	Neodymium	Neodymium
61	Pm	钷	Promethium	Promethium
62	Sm	钐	Samarium	Samarium
63	Eu	铕	Europinu	Europium
64	Gd	钆	Gadolinium	Gadolinium
65	Tb	铽	Terbium	Terbium
66	Dy	镝	Dysprosium	Dysprosium
67	Ho	钬	Holmium	Holmium
68	Er	铒	Erbium	Erbium
69	Tm	铥	Thulium	Thulium
70	Yb	镱	Ytterbium	Ytterbium
71	Lu	镥	Lrtetium	Lutetium
72	Hf	铪	Hafnium	Hafnium
73	Ta	钽	Tanatalum	Tantalum
74	W	钨	Wolfram	Tungsten
75	Re	铼	Rhenium	Rhenium
76	Os	锇	Osmium	Osmium
77	Ir	铱	Iridium	Iridium
78	Pt	铂	Platinum	Platinum
79	Au	金	Aurum	Gold
80	Hg	汞	Hydrargyrum	Mercury
81	Tl	铊	Thallium	Thallium
82	Pb	铅	Plumbum	Lead
83	Bi	铋	Bismuthum	Bismuth
84	Po	钋	Polonium	Polonium
85	At	砹	Astatium	Astatine
86	Rn	氡	Radon	Radon
87	Fr	钫	Franium	Francium

（续）

原子序数	元素符号	中文名称	拉丁文名	英文名
88	Ra	镭	Radium	Radium
89	Ac	锕	Actinium	Actinium
90	Th	钍	Thorium	Thorium
91	Pa	镤	Protactinium	Protactinium
92	U	铀	Uranium	Uranium
93	Np	镎	Neptunium	Neptunium
94	Pu	钚	Plutonium	Plutonium
95	Am	镅	Americium	Americium
96	Cm	锔	Curkelium	Curium
97	Bk	锫	Berkelium	Berkelium
98	Cf	锎	Californium	Californium
99	Es	锿	Einsteinium	Einsteinium
100	Fm	镄	Fermim	Fermium
101	Md	钔	Mendelevium	Mendelevium
102	No	锘	Nobelium	Nobelium
103	Lr	铹	Lawrencium	Lawrencium
104	Rf	𬬭	Ruthorfordium	Ruthorfordium
105	Db	𬭊	Dubnium	Dubnium
106	Sg	𬭳	Seaborgium	Seaborgium
107	Bh	𬭛	Bohrium	Bohrium
108	Hs	𬭶	Hassium	Hassium
109	Mt	鿏	Meitnerium	Meitnerium
110	Ds	𫟼	Darmstadtium	Darmstadtium
111	Rg	𬬻	Roentgenium	Roentgenium
112	Uub			
113	Uut			
114	Uuq			
115	Uup			
116	Uuh			
117	Uus			
118	Uuo			

Appendix B Periodic Table of Elements

元素周期表（Periodic table of (chemical) clements）



1 氢 H 1.0079																2 氦 He 4.0026
3 锂 Li 6.941	4 铍 Be 9.012											5 硼 B 10.811	6 碳 C 12.011	7 氮 N 14.007	8 氧 O 15.999	9 氟 F 18.998	10 氖 Ne 20.17
11 钠 Na 22.989	12 镁 Mg 24.305											13 铝 Al 26.982	14 硅 Si 28.085	15 磷 P 30.974	16 硫 S 32.06	17 氯 Cl 35.453	18 氩 Ar 39.94
19 钾 K 39.098	20 钙 Ca 40.08	21 钪 Sc 44.956	22 钛 Ti 47.9	23 钒 V 50.9415	24 铬 Cr 51.996	25 锰 Mn 54.938	26 铁 Fe 55.84	27 钴 Co 58.9332	28 镍 Ni 58.69	29 铜 Cu 63.54	30 锌 Zn 65.38	31 镓 Ga 69.72	32 锗 Ge 72.5	33 砷 As 74.922	34 硒 Se 78.9	35 溴 Br 79.904	36 氪 Kr 83.8
37 铷 Rb 85.467	38 锶 Sr 87.62	39 钇 Y 88.906	40 锆 Zr 91.22	41 铌 Nb 92.9064	42 钼 Mo 95.94	43 锝 Tc 99	44 钌 Ru 101.07	45 铑 Rh 102.906	46 钯 Pd 106.42	47 银 Ag 107.868	48 镉 Cd 112.41	49 铟 In 114.82	50 锡 Sn 118.6	51 锑 Sb 121.7	52 碲 Te 127.6	53 碘 I 126.905	54 氙 Xe 131.3
55 铯 Cs 132.905	56 钡 Ba 137.33	71 镥 Lu 174.96	72 铪 Hf 178.4	73 钽 Ta 180.947	74 钨 W 183.8	75 铼 Re 186.207	76 锇 Os 190.2	77 铱 Ir 192.2	78 铂 Pt 195.08	79 金 Au 196.967	80 汞 Hg 200.5	81 铊 Tl 204.3	82 铅 Pb 207.2	83 铋 Bi 208.98	84 钋 Po (209)	85 砹 At (201)	86 氡 Rn (222)
87 钫 Fr (223)	88 镭 Ra 226.03	103铹 Lr 260	104 𨧀 Rf (261)	105 𨧄 Db (262)	106 𨨏 Sg (263)	107 𨭆 Bh (262)	108 𨨫 Hs (265)	109 鿏 Mt (266)	110 𫟷 Ds (269)	111 𬬭 Rg (272)	112 Uub (277)	113 Uut 284	114 Uuq 289	115 Uup 288	116 Uuh 292	117 Uus unknow	118 Uuo 294

镧系	57 镧 La 138.905	58 铈 Ce 140.12	59 镨 Pr 140.91	60 钕 Nd 144.2	61 钷 Pm 147	62 钐 Sm 150.4	63 铕 Eu 151.96	64 钆 Gd 157.25	65 铽 Tb 158.93	66 镝 Dy 162.5	67 钬 Ho 164.93	68 铒 Er 167.2	69 铥 Tm 168.934	70 镱 Yb 173.0
锕系	89 锕 Ac 227.03	90 钍 Th 232.04	91 镤 Pa 231.04	92 铀 U 238.03	93 镎 Np 237.05	94 钚 Pu 244	95 镅 Am 243	96 锔 Cm 247	97 锫 Bk 247	98 锎 Cf 251	99 锿 Es 254	100 镄 Fm 257	101 钔 Md 258	102 锘 No 259

Appendix C The Metric, British and U. S. Systems

Classfications		Name	Abbr.	Chinese Translation	Equivalent	Metric Value
Length（长度）		mile	ml.	英里	1760yd.	1.609km
		yard	yd.	码	3ft.	0.914m
		foot	ft.	英尺	12in.	30.48cm
		inch	in.	英寸		2.54cm
Nautical Measure（海程长度）		nautical mile		海里，浬	10cable's length	1.853km(UK) 1.852km(SI)
		cable's length		链		185.3m(UK) 185.2m(SI)
Area（面积）		square mile	sq. ml.	平方英里	640a.	2.59km^2
		acre	a.	英亩	4840sq. yd.	4047m^2
		square yard	sq. yd.	平方码	9sq. ft.	0.836m^2
		square foot	sq. ft.	平方英尺	144sq. in.	929cm^2
		square inch	sq. in.	平方英寸		6.451cm^2
Weight（重量）	Avoirdupois（常衡）	ton	tn. t.	吨	20cwt.	
		UK long ton		长吨	2240lb.	1.016T(公吨)
		US short ton		短吨	2000lb.	0.907T(公吨)
		hundredweight	cwt.	英担	UK=112lb.	50.802kg
					US=100lb.	45.359kg
		pound	lb.	磅	16oz.	0.454kg
		ounce	oz	盎司，啊	16dr.	28.35g
		dram	dr.	打兰，英钱		1.771g
	Troy（金衡）	pound	lb. t.	磅	12oz. t.	0.373kg
		ounce	oz. t.	盎司	20dwt.	31.103g
		pennyweight	dwt.	英钱	24gr.	1.55g
		grain	gr.	谷，喱		64.8mg
	Apothecaries（药衡）	pound	lb. ap.	磅	12oz. ap.	0.373kg
		ounce	oz. ap.	盎司，啊	8dr. ap.	31.103g
		dram	dr. ap.	打兰	3scr. ap.	3.887g
		scruple	scr. ap.	吩	20gr.	1.296g
		grain	gr.	谷，喱		64.8mg
Capacity（容量）	Dry Measure（干量）	bushel	bu.	蒲式耳	4pks.	36.368L(UK) 35.238L(US)
		peck	pk.	配克	8qts.	9.092L(UK) 8.809L(US)
		gallion①	gal.	加仑	4qts.	4.546L(UK)
		quart	qt.	夸脱	2pts.	1.136L(UK) 1.101L(US)
		pint	pt.	品脱		0.568L(UK) 0.55L(US)
	Liquid Measure（液量）	gallion	gal.	加仑	4qts.	4.546L(UK) 3.785L(US)
		quart	qt.	夸脱	2pts.	1.136L(UK) 0.946L(US)
		pint	pt.	品脱	4gi.	0.568L(UK) 0.473L(US)
		gill	gi.	及耳		0.142L(UK) 0.118L(US)

① gallion 在干量单位中仅用于英制。

Appendix D Glossary

A

a minimum of 最低
abrasion *n.* 擦伤，磨损
abrasion resistance 耐磨性
abrasive *adj.* 有磨蚀作用的；*n.* 磨料，金刚砂，研磨剂
accentuation *n.* 强调，重读
accessibility *n.* 可及性，可达性，可接近性，可亲性，渗入性
accomplish *v.* 完成，实现，做成功
accrue *v.* 增加，增长
acetic acid 乙酸
acrylamide *n.* 丙烯酰胺
activation energy 活化能
active site 活性点，活性中心
actuator *n.* 致动器，传动装置［机构］，执行器，加载器
acyl chloride 酰氯
additive *n.* 添加剂
adhesives *n.* 粘合剂
adjacent *adj.* 邻近的
adobe *n.* 砖坯，土坯
adoption *n.* 采纳，采用；收养
advent *n.* 出现，到来
aerodynamic *adj.* 空气动力学的
aerogel *n.* 气凝胶
aerospace *n.* 航空和宇宙航行空间
affinity *n.* 亲合力，密切关系，相似（性）
agar *n.* 琼脂，石花菜
agglomerate *v.* 成团，凝聚；*n.* 大团，大块；*adj.* 成块的
aggravate *vt.* 使恶化，使更严重
aggregate *n.* 总计，集合体；*adj.* 集合的，聚合的；*v.* 集合，聚合
aggressive *adj.* 进取的，主动的，好斗的，有闯劲的，侵略性的
airbag *n.* 安全气囊，气袋
albeit *conj.* 尽管，即使
alchemy *n.* 炼金术，魔力
aldehyde *n.* 醛，乙醛
algorithm *n.* 算法，运算法则

align *v.* 排列，对齐，定位
alignment *n.* 排成直线
aliphatic *adj.* 脂肪族的
alkaline *adj.* 碱的，碱性的
alkoxide *n.* 醇盐
alkylbenzene *n.* 烷基苯
allotropic *adj.* 同素异形的
alter *v.* 改变，变更
alternating-copolymer 交替共聚物
alumina *n.* 矾土，铝氧土，氧化铝
alumina silica 硅铝矾土硅石
aluminosilicate *n.* 铝硅酸盐
aluminum *n.* 铝
amateur *n.* 业余爱好者，业余艺术家
ambient *adj.* 周围的，外界的
ambient temperature 环境温度
ambulatory *adj.* 流行的，非固定的
amenable *adj.* 柔顺的，顺从的，符合的
amine *n.* 胺
amorphous *adj.* 无定形的，非结晶的
amorphous polymer 非晶态聚合物
amputate *v.* 切除（手臂、腿等）
analog（=analogue） *n.* 相似物，类似物，类比
anecdotally *adv.* 趣闻地，多轶事地
angiogenesis *n.* 血管再生术，血管新生
anhydride *n.* 酐
anionic polymerization 阴离子聚合
anisotropic *adj.* 非均质的，各向异性的
anode *n.* 阳极
anodic *adj.* 阳极的
anorthite *n.* 钙长石
antibacterial *n.* 抗菌药；*adj.* 抗菌的
antibiotic *n.* 抗生素；*adj.* 抗生的
antiquity *n.* 古代，古物
antistatic *adj.* 抗静电的
apart from 远离，除……之外
appearance *n.* 外观，外貌，外表
appliance *n.* 器具，器械，装置
application temperature 适用温度

approach *v.* 靠近，接近，临近
approval *n.* 承认，赞成，正式批准
aquaculture *n.* 水产业
aqueous *adj.* 水的，含水的
aramid *n.* 芳族聚酰胺，芳纶
arbitrary *adj.* 随意的，主观的
arc *n.* 弧，弧线；电弧
arc welding 电弧焊，弧焊
archeologist *n.* 考古学家
architecture *n.* 体系结构，（总体、层次）结构，建筑学，建筑式样，建筑设计
armour *n.* 盔甲，装甲
aromatic *adj.* 芳香的，有香味的
aromatization *n.* 芳构化
array *n.* 排列，编队；*v.* 部署，排列
artificial hip 人工髋关节
artificial muscle 人造肌肉
asbestos *n.* 石棉
aspect *n.* 方面；方位，朝向；面貌，模样，神态
assay *n.* & *v.* 化验，分析，检定
assert *v.* 断言，声称
asset *n.* 资产，财产；有价值的人或物；优点，长处
associate with 与……交往，联系
atomistic *adj.* 原子论的
atrophy *n.* 萎缩，衰退；*v.* 萎缩，引起萎缩
attack *v.* 攻击
attain *v.* 实现，达到，得到
attribute *n.* 性能，特性
attrition *n.* 消耗；消磨，磨损
augment *v.* 增加，提高，扩大
autoclave *n.* 高压釜，压热器
auxiliary *adj.* 辅助的；*n.* 辅助剂，次要，从属
availability *n.* 可用性，有效性，实用性
average value 平均值
aviation *n.* 航空，航空工业
axisymmetric *adj.* 轴对称的

B

backbone *n.* 主架
ball mill 球磨机

bandage *n.* 绷带
bandwidth *n.* 带宽
bare wire 光焊丝，裸焊丝，裸线
barium *n.* 〈化〉钡（元素符号 Ba）
base material 基体金属，母材，母体金属
battery *n.* 电池
batteryless *adj.* 无电池的
BCC 体心立方的（Body Centered Cubic）
be applied to 适用于，应用于
be composed of 由……组成
be resistant to 能抗，耐
Bell Labs 贝尔实验室
bell *n.* 钟，钟形物
bell kiln 钟罩式窑
bent *n.* 倾向，爱好
benzoyl peroxide 过氧化苯甲酰
beryllium *n.* 〈化〉铍（元素符号 Be）
beverage *n.* 饮料
bezel *n.* 表框
bifunctionality *n.* 双官能度
billboard *n.* 广告牌，布告板
bimetallic *adj.* 双金属的
bimorph *n.* 双压电晶片，双晶
binde *n.* 粘合剂，粘合料
biocompatibility *n.* 生物适应性
biodegradable *adj.* 生物降解的，生物能分解的
biofluidic *adj.* 生物体液的，生物流体的
biomedical *adj.* 生物医学的
biomedical application 生物医学应用
bioMEM 生物微电子机械的（biological Microelectromechanical）
biomimetics *n.* 仿生学
bioreaction *n.* 生化反应
bismaleimide *n.* 双马来酰亚胺
bladder *n.* 膀胱，球胆
blast furnace 鼓风炉，高炉
blend with 与……混和
block copolymer 嵌段共聚物
blocking *n.* 模块化
blood clot 血块

blunt *adj.* 率直的，直言不讳的，钝的；*v.* 把……弄钝，减弱
bobbin *n.* 线轴，绕线筒
boiling point 沸点
bonding *n.* 连接，结合，键合
bone china 骨灰瓷（用瓷土与磷酸钙烧成的半透明瓷器）
bony tissue 骨组织
borderland *n.* 边界地，边陲
boride *n.* 硼化物
boron n.〈化〉硼（元素符号 B）
boundary *n.* 边界，边界线
box *n.* 匣钵，盒，箱；*vt.* 把……装入匣钵中
Bragg grating 布拉格光栅
braiding *n.*（总称）各种编织带；编织物
brass *n.* 黄铜；黄铜色；铜器；铜管乐器
brewing *n.* 酿造
bridge decks 桥面
brittle *adj.* 易碎的，易损坏的
brittle waxes 脆性蜡
broadcloth *n.*（毛、棉、丝织成的）细平布
bronze *n.* 青铜（铜和锡的合金），青铜制品；青铜色；青铜色的颜料；青铜器
bumper *n.*（汽车上的）保险杠，缓冲器
bumpy *adj.* 颠簸的，不稳定的
buoy *n.* 浮标，航标，救生圈；*vt.* 使浮起，鼓励
buttress *n.* 支撑物；*v.* 支持，扶住
butylene terephthalate 对苯二甲酸丁二醇酯
butyl-rubber 丁基橡胶，异丁橡胶
by contrast 对比起来，与之相比，相反地
by virtue of 凭借……的力量，由于……

C

calcination *n.* 煅烧，焙烧，煅烧产物
calcine *v.* 烧成石灰，煅烧，焙烧
calendaring *n.* 压延
candidate *n.* 选择物，候选者
canopy *n.*（飞行器上的）座舱罩
capacitor *n.* 电容器；电容
carbide *n.* 碳化物，碳化钙，电石，硬质合金
carbon black 黑烟末，碳黑，炭黑
carbon monoxide 一氧化碳

carbonitride *n.* 碳氮化物
carbonize *v.* 使成碳，碳化，使与碳化合
carboxyl *n.* 羧基
cardiovascular stent 心血管支架
carried out 完成，实现；进行；执行，贯彻
castable *adj.* 浇注的，铸块的，可浇铸材料的
catalysis *n.* 催化作用
catalysts *n.* 催化剂，促进因素
catalytic *adj.* 接触反应的
cataract *n.* 白内障
cataractous *adj.* 白内障的
categorize *v.* 把……归类，把……列为
catheter *n.* 导管，导尿管
cathode ray 阴极射线
cathodic *adj.* 阴极的，负极的
caul *n.* 胎膜，大网膜
cavity *n.* 空洞，空腔，空穴，模槽
cellulose *n.* 纤维素
cellulose acetate 醋酸纤维素
celsian *n.* 钡长石
cement *n.* 水泥，胶泥；*v.* 结合，用水泥涂，粘牢
cementite *n.* 渗碳体，碳化铁
chain polymerization 链式聚合反应
chairlift *n.* （运送滑雪者或游客上，下的）升降机，高空缆车
Chalocolithic *adj.* 铜石并用时代的
chamber *n.* 室，房间，枪膛
combustion chamber 燃烧室
chemical activity 化学活性
chemical bond 化学键
chitin *n.* 甲壳素
chromophore *n.* 发色团，载色体
circuit *n.* 电路，环形
circumferential *adj.* 圆周的
circumvent *v.* 设法克服或避免（某事物）；回避
cladding *n.* 覆层
classical *adj.* 经典的，古典的，正统的
clay *n.* 黏土，泥土
closed-cycle 闭合循环
CNC 电脑数值控制（Computerized Numerical Control），计算机数控

coalesce *v.* 合并
coarse *adj.* 粗的，粗糙的
coating *n.* 涂料，涂层，覆盖层
coaxial *adj.* 同轴的
cobalt *n.* 〈化〉钴（元素符号 Co）
coefficient of the thermal expansion 温度膨胀系数，热膨胀系数
coercivity *n.* 矫顽力，矫顽性
coexist *v.* 共存
colloidal *adj.* 胶状的，胶质的
combination *n.* 结合
combine *v.* 联合，结合；*n.* 联合企业，联合收割机
comb-like 梳状
combust *v.* 燃烧，消耗
combustion *n.* 燃烧，（有机体内营养料的）氧化
come out of 由……产生，从……出来
commercialized *vt.* 使商业化，使商品化
commingle *v.* 混合，掺和，合并
commit to 交付，把……投入
commonplace *adj.* 普通的，平庸的；*n.* 陈词滥调，寻常的事物
compactibility *n.* 压塑性，成型性，紧密性
compacting *n.* 压实，压制，（加）压（模）塑
compared to 与……相比
compatibility *n.* 兼容性
compatible *adj.* 可以并存的，相容的，协调的
complementary *adj.* 补充的，补足的
component *n.* 成分，组成部分，部件，元件
composite *n.* 复合材料，合成物；*adj.* 合成的，复合的
compound *n.* 化合物，混合物；*adj.* 复合的；*v.* 混合，配合
computer modelling 计算机模拟
conceivable *adj.* 可想到的，可相信的，可想象的
concrete *adj.* 实体的，有形的；*n.* 凝结物，混凝土
condensation yeaction 缩合反应，缩聚反应
cone *n.* 圆锥形，锥形物，尖圆体
confer *v.* 授予，赠与，协商，交换意见
configuration *n.* 构造，形状，外貌，轮廓
confinement *n.* （被）限制，（被）禁闭，分娩
conflicting *adj.* 相冲突的，不一致的，相矛盾的
congenital heart anomalies 先天心脏异常
congressman *n.* 国会议员，众议员

consciousness *n.* 意识，知觉，觉悟
consensus *n.* 一致同意，舆论，同感
considerably *adv.* 相当地
consist of 组成，由……构成
consistency *n.* 坚实度
consolidation *n.* 固化
consortium *n.* （数家公司或银行联合组成的）财团，联营企业
consumable electrode 熔化电极，自耗电极
contend with 与（某事物）抗争，苦于应付；与（某人）竞争
continuous phase 连续相
conventional *adj.* 依照惯例的，约定俗成的，常规的
convergence *n.* 集中，收敛
converging *adj.* 收敛的，趋同的
conversely *adv.* 相反地
conversely *adv.* 相反地，颠倒地
convey *v.* 传送，传达，搬运，转让
coolant *n.* 冷却剂，散热剂
copolymer *n.* 共聚物
co-precipitation 共沉淀
cordierite *n.* 堇青石
corneal *adj.* 角膜的
corpuscle *n.* 微粒，粒子，血球
corrosion *n.* 腐蚀；受腐蚀的部位
cosmetic *n.* 化妆品；*adj.* 化妆用的
cost effectiveness 成本效率
counterpart *n.* 相对应的人或物，副本
countless *adj.* 无数的，数不尽的
couple *v.* 连接，联结，联系
coupling agent 耦合剂
covalent *adj.* 共有原子价的，共价的
crack *n.* 裂纹；*v.* 开裂
creep *v.* 蠕变
criterion *n.* （批评、判断等的）标准，准则（复数形式为 criteria）
critical transformation temperature 临界转变温度
cross-linking 交联
crossover *n.* 转型，转向
cross-sectional *adj.* 横断面的，截面的，代表性的
crucial *adj.* 至关紧要的
crystalline *adj.* 结晶的

crystalline *adj.* 结晶质的；*n.* 结晶质，结晶体，晶态

crystalline polymer 晶态聚合物

crystallite *n.* 微晶

crystallographic *adj.* 晶体的，晶体学的

crystallography *n.* 结晶学

CSIRO （澳大利亚）联邦科学与工业研究组织（Commonwealth Scientific and Industrial Research Organization）

cure *v.* 硬化，固化

curiosity *n.* 奇物，珍品

curvature *n.* 弯曲；弯曲部分；曲率，曲度

cyanate *n.* 氰酸盐

cyanate ester 氰酸酯

cyclic *adj.* 循环的，周期的

cyclization *n.* 环化（作用）

cylindrical *adj.* 圆柱的

Czechoslovakia *n.* （原）捷克斯洛伐克

D

dacron *n.* 涤纶，的确良

dampen *v.* 减震

damping *n.* 阻尼，减幅，衰减

debit *n.* 借方，借入；*v.* 记入借方

decompose *v.* 分解

decomposition *n.* 分解

decoration *n.* 装饰，装饰品

decorative *adj.* （物体或建筑）装饰性的，作装饰用的

deflect *v.* （使）偏斜，（使）偏离，（使）转向

deformation *n.* 变形，畸变

degenerative *adj.* 变质的，退化的

degradation *n.* 退化，裂化，降解，降解作用，剥蚀

degree of crystallinity 结晶度

de-ice *v.* 除去（某物上的）冰，防止（某物的表面）结冰

deliberation *n.* 熟思，商议，考虑，从容

delocalized *v.* 使离开原位

dendrimer *n.* 纳米树形分子

dendritic *adj.* 树枝状的，树状的

densification *n.* 增浓作用，稠化（作用）；密封，封严；压实，夯实

density *n.* 浓度，密度

dent *n.* 凹坑

deplete *v.* 使大大地减少；损耗
deploy *v.* （尤指军事行动）使展开；施展；部署
deployment *n.* 展开，部署，调度
description *n.* 叙述，描写，说明；种类，类型
destroyer *n.* 驱逐舰，破坏者
detrimental *adj.* 有害的，不利的
developmental *adj.* 发展的；试验性的；开发的
deviation *n.* 偏差，误差；偏斜
diagnostic *adj.* 诊断的
diagnostics *n.* 诊断，诊断学
dialysis *n.* 透析，分离
diamine *n.* 二胺
diamond cutting 金刚石切割
diaphragm *n.* 横膈膜，膜片，振动膜
diatomic *adj.* 二原子的，二价的
dicarboxylic acid 二羧酸
dictate *v.* 指示，指定，指令
didactic *adj.* 说教的，教诲的
die *n.* 模具
dielectric *n.* 电介质，绝缘体；*adj.* 非传导性的
diffusion *n.* 扩散，传播
digital signage 数字标牌
diisocyanate *n.* 二异氰酸盐（脂）
dimmers *n.* 二聚体
DIMOX 直接金属氧化法（Directed Metal Oxidation）
dinnerware *n.* 整套的餐具
dipole *n.* 偶极子
direction *n.* 方向，趋向，趋势，动向
disastrous *adj.* 灾难性的；极坏的，很糟的
disintegrate *v.* （使）破裂（分裂，粉碎）；（使）崩溃
dislocation *n.* 混乱，紊乱；位错
disperse *v.* 分散，弥散，切碎，粉碎
dispersion *n.* 分散（体，相，体系，作用，系统），散布，驱散
disproportionation *n.* 歧化（终止），不均匀
dissipation *n.* 消散，消耗
distinct *adj.* 截然不同的，完全分开的；清晰的，明显的
distributed computing 分布式计算（技术）
diverse *adj.* 不同的，变化多的，多种多样的
dome *n.* 拱顶

domestic *adj.* 本国的，国内的
donate *v.* 捐赠，赠送
dramatically *adv.* 戏剧地
drawdown *n.* 牵伸
drilling *n.* 钻孔；钻井
duality *n.* 二元性，对偶性
ductile *adj.* 可延展的，有韧性的
ductility *n.* 展延性，柔软性
ductility *n.* 延展性，塑性，粘性，可塑性，韧性
due to 由于；欠下债（账），应给予
durability *n.* 耐久性，耐用性；坚固
dust *n.* 粉尘
dynamic *adj.* 动力的，动力学的；力学（上）的；动态的，电动的，冲击的

E

earthen element 陶土成分
earthenware *n.* 陶器
Earth-orbit 环地球轨道
ECM 细胞外基质（Extra Cellular Matrix）
ecological *adj.* 生态的，生态学的
edge dislocation 边缘位错，刃形位错
effluent *adj.* 发出的，流出的
elaborate *adj.* 精心制作的，详细阐述的；*n.* 精心制作，详细描述
elastic fiber 弹性纤维
elasticity *n.* 弹力，弹性
elastomer *n.* 弹性体，人造橡胶
electrochemical corrosion 电化学腐蚀
electrochromic *adj.* 电致变色的
electrode *n.* 电极
electroluminescent *adj.* 场致发光的，电致发光的
electrolysis *v.* 电解，电蚀
electromagnetic *adj.* 电磁的
electronic nose 电子鼻（用于测气体）
electrophoresis *n.* 电泳现象
elemental analysis 元素分析
elevated temperature 高温
elicit *v.* 得出，引出，引起
eliminate *v.* 消除，排除；忽略；淘汰
elongate *v.* 延长，加长；*adj.* 延长［伸］的

eluting *v.* 洗提
embark *v.* 着手
embed *v.* 把……嵌入，埋入
embedded *adj.* 装入的，压入的，嵌入的，内含的，植入的
embedded system 嵌入式系统
empirical *adj.* 实验的，经验的，经验主义的
enamel coating 搪瓷涂层
encapsulate *v.* 装入胶囊，形成包封，压缩
enclosure *n.* 围绕，圈占
encompass *v.* 包围，环绕，包含或包括某事物
end group analysis 端基分析法
endow *v.* 捐赠，捐钱，资助
energetic *adj.* 积极的，精力充沛的
energy dissipation 能量损耗
energy storage 能量储存
enhance *v.* 提高，增加，加强
entropy *n.* 熵（热力学函数）
envision *v.* 想象，预想
enzyme *n.* 酶
epoxide *n.* 环氧化物
epoxy *n.* 环氧树脂；*adj.* 环氧的
equiaxial *adj.* 等轴的
equilibrium *n.* 平衡，均衡
essentially *adv.* 实质上，本质上
esteem *v.* 把……看作，尊重，认为；*n.* 尊敬，尊重
ethical *adj.* 与伦理有关的，民族的，民族特有的
ethyl alcohol *n.* 乙醇
ethylene diamine 乙二胺
ethylene-butylene 乙烯-丁烯
eutectic *n.* 共晶；*adj.* 共熔的
eutectoid *n.* 类低共熔体；*adj.* 共析的
evacuate *v.* 疏散，撤出，排泄
exceedingly *adv.* 非常地，极度地
exhaust *v.* 弄空，耗尽
exothermic *adj.* 发热的，放出热量的
exotic *adj.* 外来的，奇异的
expel *v.* 驱逐，赶走，放逐
exploit *v.* 开采，开发，剥削；*n.* 功绩［勋］，业绩，英勇的行为，辉煌的成就
expose to 暴露；面临

exquisite *adj.* 精致的，敏锐的，异常的，优雅的
extensive *adj.* 广阔［大］的，广博的；大量的
extract *n.* 榨出物，摘录，选粹；*v.* 拔出，榨取，提取，开方
extreme *adj.* 极度的，极端的；尽头的，末端的
extrusion molding 挤压成型
extrusion *n.* 挤压，挤压成型；热［模］压；挤出

F

fabric *n.* 织物，布
fabrication *n.* 制作，构成
fabrics *n.* 织物，组织
fairing *n.* 整流罩
fascinating *adj.* 迷人的，着魔的
fatigue *n.* 疲劳，劳累
fatigue strength 疲劳强度
FCC 面心立方的（Face Centered Cubic）
feedstock *n.* 给料（指供送入机器或加工厂的原料）
feldspar *n.* 长石
femtosecond *n.* 飞秒，毫微微秒（10^{-15}s）
femurs *n.* 大腿骨，腿节，股节
ferrite *n.* 纯铁体；铁素体，铁氧体
fertility *n.* 繁殖能力，生育力，生产力
fiber *n.* 纤维
fiberglass *n.* 玻璃纤维，玻璃丝
fibrillar *adj.* 纤丝状的，纤维状的
field emission 场发射
fighter pilot *n.* 战斗机飞行员
filament *n.* 灯丝，长丝，长纤维，单丝，细丝
filler metal 填充金属，填料金属
filler *n.* 填充物，漏斗
filter *n.* 过滤，过滤器
filtration *n.* 过滤，筛选
fingernail *n.* 手指甲
finite element analysis 有限元分析
firing *n.* 烧成，烧制
fishing pole *n.* 钓鱼竿
fixed *adj.* 固定的，确定的
flashlight *n.* 手电筒
flat display 平板显示器

flesh *n.* 肉，肉体，人体；*v.* 用肉喂，长胖
flexibility *n.* 弹性，适应性，机动性，挠性
flexible *adj.* 易弯的，挠性的，有弹性的，柔韧的，灵活的，可塑造的
flexing *n.* 挠曲，可挠性
flexural *adj.* 曲折的，弯曲的
flexure *n.* 屈曲，褶曲，弯曲（部）；曲线；曲率
flint pebble 燧石
flourish *v.* 繁荣，兴旺发达
fluid *n.* 液体，流体，流动性；*adj.* 流动的，不固定的，流畅的
fluorescent *adj.* 荧光性的，发荧光的
flux cored arc welding（FCAW） 管状电弧焊
flux *v.* 熔化，使熔解，用助熔剂处理；*n.* 焊剂，熔剂
fluxing agent 助熔剂
foam *n.* 泡沫材料
forebear *n.* 祖先，祖宗
foreign object 异物
foreknowledge *n.* 预知，先见之明
formability *n.* 可成形性
formulation *n.* 用公式表示，明确地表达，作简洁陈述
foundry *n.* 铸造，翻砂，玻璃厂，铸造厂
fracture toughness 断裂韧度
fragment *n.* 碎片，片断
fragrance *n.* 芬芳，香味
free radical polymerization 自由基聚合
fuel *v.* （给……）加燃料，（给船等）上煤，（给……）加油；刺激，推动
fulfill *v.* 履行，实现，完成
fullerene *n.* 富勒烯
functional *adj.* 有用的，实用的
functional group 官能团
furfuryl *n.* 糠基
furnace *n.* 炉子，熔炉，高炉；窑，燃烧室
fusion *n.* 熔合，聚变，核合成

G

galvanic *adj.* 电流的，由电流引起的
galvanic couple 电耦合
galvanized *adj.* 电镀的，镀锌的
gamma ray 伽马射线
garbage cans 垃圾桶，垃圾箱

gas tungsten arc welding（GTAW） 钨极气体保护焊
gasket *n.* 垫圈
gastrointestinal *adj.* 胃肠的
gate *n.* 内浇道，浇口
gelatin *n.* 凝胶，明胶
generically *adv.* 一般地
genome *n.* 基因组，染色体组
geologic *adj.* 地质（学）的，地质（学）上的
gettering *n.* 收气，吸气，吸附；吸气法（真空技术）
glaze *n.* 上釉的表面，釉面；*vt.* 给……上釉
glucose *n.* 葡萄糖
glycolic acid 乙醇酸，羟基乙酸
GPS 全球定位系统（Global Position System）
grading *n.* 筛分
graft *v.* & *n.* （皮肤等）移植，嫁接
graft-copolymer 接枝共聚物
grain boundary 晶界，晶粒边界，晶粒间界
graniten *n.* 花岗岩，花岗石
granular *adj.* 粒的，含颗粒的，粒状的，粗面的
graphene *n.* 石墨的单原子层
graphite fiber 石墨纤维
graphite *n.* 石墨，石墨粉，炭精，铅粉
graphitization *n.* 石墨化
Greek *n.* 希腊人，希腊语；*adj.* 希腊的，希腊语的
grind *v.* 研磨，磨光［碎］；制粉
guardrail *n.* 扶栏
guesswork *n.* 猜测，猜想
guinea pig *n.* 豚鼠；（动物实验用）小鼠

H

hamper *v.* 妨碍，牵制
hand lay-up 手工制造增强塑料膜；手糊成形
handcraft *n.* 手工，手艺
harness *n.* 导线，装备； *v.* 利用
hazard *n.* & *v.* 危险，冒风险
healing *n.* 康复，复原；*adj.* 有疗效的
heart valve 心脏瓣膜
heat barrier 热障
heat sink 吸热设备，冷源；散热片；（半导体）热沉

heat treatment 热处理
helical *adj.* 螺旋状的
hemodialysis *n.* 血液透析
hemodialyzer *n.* 人造肾脏
hemoglobin *n.* 血色素
heterogeneity *n.* 异种，异质，不同成分，异质性，不均匀性
heterogeneous *adj.* 异质的，非均质的，多相的
highlight *n.* 提示区，加亮区，最显著（重要）部分；*v.* 加亮，标出，增加亮度
HIP 热等静压［烧结］(Hot Isostatic Pressing)
hip-joint 髋关节
hitherto *adv.* 迄今，至今
hole *n.* 空穴，孔
holistic *adj.* 整体的，全盘的
hollow *adj.* 空的，空心的
holographic *adj.* 全息的
holography *n.* 全息摄像术
homing beacon 归航（无线电）信标
homogeneous *adj.* 同类的，均相的，均匀的，均质的，均一的
homopolymer *n.* 均聚物
horsepower *n.* 马力
hot melt adhesive 热熔胶
HP 热压［烧结］(Hot Pressing)
hull *n.* 船体，船身
humidity *n.* 湿度，潮湿
hybrid composite 复合材料
hydrated *adj.* 含水的
hydride *n.* 氢化物
hydrocarbon *n.* 碳氢化合物，烃
hydrochloric acid 盐酸
hydrogel *n.* 水凝胶
hydrogen *n.* 〈化〉氢（元素符号 H）
hydrolyse *v.* 水解
hydrolysis *n.* 水解
hydrothermal *adj.* 热液的，热水（作用）的
hydroxyapatite *n.* 羟基磷灰石
hydroxyl *n.* 羟（基），氢氧基
hygiene *n.* 卫生，保健
hypereutectoid *adj.* 过共析的
hypoeutectoid *adj.* 亚共析的

hypothesis *n.* 假设

I

identical *adj.* 同一的，完全相同的
IEEE （美）电气和电子工程师学会（Institute for Electrical and Electronic Engineers）
igneous *adj.* 火的，（尤指岩石）火成的
igneous rock 火成岩
ignition *n.* 点火，着火，引燃；灼热
ilmenite *n.* 钛铁矿
imagination *n.* 想象，空想，想象力
immunologic *adj.* 免疫学的
impact resistance 冲击［撞击］阻力
impact strength 冲击强度
impart *v.* 给予，传授
impedance *n.* 阻抗，全电阻
imperative *adj.* 必要的，紧急的，极重要的
impetus *n.* 推动，促进，刺激
implementation *n.* 执行，实现，工具，设备
impregnation *n.* 注入，浸渍
impure *adj.* 不纯的
in agreement with 符合……，和……一致
in aqueous environments 水环境
in general 一般而言，总的来说，大体上
in regard to 关于……，对于，就……而论
in series or parallel 串联或并联
in the case of 至于……，就……来说
in this regard 关于此事，在这点上
in turn 反过来
incendiary bomb 燃烧弹
inclusion *n.* 包含，内含物；夹杂，夹杂物，夹渣
incorporate *v.* 把……合并，使并入
incredibly *adv.* 不能相信地
increment *n.* 增加，增量
inductance heating 感应加热炉
inductance *n.* 电感，感应，感应系数［现象］；（发动机）进气
induction *n.* （电或磁的）感应
inert *adj.* 惰［惯］性的，不活泼的，钝的，不起化学作用的，中和（性）的
infiltration *n.* 渗透
inflammation *n.* 发炎，发火，燃烧

inflammatory *adj.* 炎性的，发炎的，煽动的
influence *n.* 影响；*vt.* 影响，感化
infrared measurement 红外测量
infrastructure *n.* 基础；基础结构［设施］
ingestion *n.* 摄取
inhale *v.* 吸入
inherent *adj.* 固有的；内在的
initiate *v.* 引发
initiate *v.* 开始，着手
initiator *n.* 引发剂
injection molding 注射成型
inlet *n.* 供料口，进料口，嵌入
innovation *n.* 革新，改革
innovative *adj.* 创新的，革新的
inorganic *adj.* 无机的；无机物的
insertion *n.* 插入，插入物
insulating *n.* & *adj.* 绝缘（的）；保温（的）；绝热（的）
insulator *n.* 绝缘、隔热或隔音等的物质或装置
insulin-releasing system 胰岛素释放系统
intact *adj.* 完整无缺的
integral *adj.* 构成整体所必需的
integrated circuit 集成电路
intelligent sensor 智能传感器
interconnect *v.* 互相连接；互相联系
interface *n.* 界面，分界面
interlaminar *adj.* 层间的
interlock *n.* 连锁，互锁
intermetallic *adj.* 金属间（化合）的
intermix *v.* （使）混和，（使）混杂
internal stress 内应力
interstitial *adj.* 间隙的，填隙的，中间的
interstitial fluid 细胞间液，间质流体
intimate *adj.* 亲密的，密切的
intraocular *adj.* 眼内的
intrinsic *adj.* 固有的，内在的
Invar *n.* 热膨胀系数较小的材料，也叫因瓦合金
inventory *n.* 详细目录，存货清单
investigate *v.* 调查
invitro *n.* & *adj.* 活体外部（的）

invivo *n.* & *adj.* 活体内（的），生物体内（的）
ionic *adj.* 离子的
IR 红外线（infrared）
irrespective *adj.* 不考虑的，不问的，不顾的
isostatic pressing 等静压成型
isostatically *adv.* 均衡地
isotropic *adj.* 各向同性的
iterative *adj.* 重复的，反复的，迭代的

J

jet *n.* 喷射，射流；喷注，气流
Josephson junction 约瑟夫森结

K

kaolinite *n.* 高岭石
kiln *n.* 窑
kinetic *adj.* 动力学的
kinking *n.* 弯纱；纽结（纱线疵点）
knitting *n.* 编织品，针织

L

lactic acid 乳酸
lactide *n.* 丙交脂，交脂
ladle *n.* （铸，盛钢）桶，罐，铁［钢］水包
lamella *n.* 薄层，薄片，薄片层
laminate *v.* （将薄片砌合在一起）制成（材料）；*n.* 层压材
laminating *n.* 层压（法），层合（法）
latex paint 乳胶漆
lay-up *n.* 铺叠成型
leach *v.* （将化学品、矿物质等）过滤，（液体）过滤；滤去
leachable *adj.* 可滤去的，可滤取的
leaching *n.* 浸出［滤，提］；沥滤（法），淋溶（作用）
leakproof *adj.* 不会漏的，防漏的
LED 发光二级管（light-emitting diode）
lever rule 杠杆原理
leverage *n.* 杠杆机构，杠杆作用，扭转力矩；*vt.* 促使……改变
ligament *n.* 韧带
lightweight *adj.* 轻量的
lignin *n.* 木质素

likewise *adv.* 同样地，照样地
limb *n.* 肢，翼，分支
lime-mortar 石灰砂浆
linear polymer 线性聚合物
linger *v.* 拖延，逗留，游移
lining *n.* 衬里，里子，衬料，内衬
liquid helium 液氦
LCD 液晶显示屏（器）（liquid-crystal display）
liquidus line 液相线
literature *n.* 文献，著作，文学（作品）
lithium *n.* 〈化〉锂（元素符号 Li）
locking system 锁闭系统，锁定装置
loess *n.* 黄土
longer-lasting 更耐用的，更耐久的
longitudinal *adj.* 经度的，纵向的
loom *n.* 织布机
low-leakage 低泄漏，低漏电
Lycra *n.* 莱卡

M

machinabilty *n.* 可加工性，可切削性
macroscopic *adj.* 宏观的，肉眼可见的
macroscopic world 宏观世界
macroscopical *adj.* 肉眼可见的，宏观的
magnesium boride 硼化镁
magnesium *n.* 〈化〉镁（元素符号 Mg）
magnet *n.* 磁体，磁铁
magnetic resonance 磁共振
malleable *adj.* 可锻的
mandrel *n.* 心轴；芯模
maneuver *v.* & *n.* 机动
manifest *v.* 出现，表明，证明；*adj.* 显然的，明白的；*n.* 旅客名单，载货单
manipulate *v.* 使用，利用，熟练控制
manufacture *v.* 制造
martensitic *adj.* 马氏体的
MASH （美）陆军流动外科医院（Mobile Army Surgical Hospital）
mast *n.* 船桅，桅杆；旗杆
mastery *n.* 掌握
matched to 使和……相等，匹配

matrices *n.* 母体，基体（matrix 的复数形式）
matrix *n.* 基体，母体
mechanical coupling 机械轴节
Melbourne *n.* 墨尔本（澳大利亚港市）
melt viscosity 熔体粘度
melting point 熔点
membrane *n.* 膜，隔膜
Mendeléev 门捷列夫（1834—1907），发现化学元素周期律的俄国科学家
Mesolithic *adj.* 中石器时代的
mesophase *n.* 中间期，中间相
mesoscopic *adj.* 介观的，准微观的
metallic bond 金属键
metaphorical *adj.* 比喻性的
metastable *adj.* 亚稳态的
methacylate *n.* 甲基丙烯酸酯
methanol *n.* 甲醇
methodology *n.* 方法学，方法论
metric *adj.* 公制的
microcrack *v.* （使）产生微裂纹
microelectronic *n.* 微电子
microfabrication *n.* 微型制作（装配）
microprocessor *n.* 微处理器，微处理机
microrobot *n.* 微型机器人
microscope *n.* 显微镜
microwave *n.* 微波
military *adj.* 军用的，军事的
millimeter *n.* 毫米
milling *n.* 混炼；研磨
minera *n.* 矿物；矿石；矿物质
miniature *adj.* 小型的
miniaturisation *n.* 小型化，微型化
misshapen *adj.* 奇形怪状的，畸形的
MIT 麻省理工学院（Massachusetts Institute of Technology）
mitigate *v.* 减轻，缓和
modification *n.* 缓和，限制，减轻；更改，改变
modify *v.* 修改，修饰
modul *n.* 模量
modulus *n.* 系数，模数
moist *adj.* 潮湿的，润湿的

moisture resistance 防潮性；抗湿性
mold *n.* 模子，模型；*v.* 浇铸，塑造
molded object 模塑对象
molecular *adj.* 分子的
molecularly *adv.* 分子地
molecule *n.* 分子
monitoring *n.* 监视，控制，监测，追踪
monodisperse *adj.* 单分散的
monoatomic *adj.* 单原子的
monoclinic *adj.* 单斜晶［系］的
monocrystalline *n.* 单晶，单晶质
monofilament *n.* 单（根长）丝，单纤（维）丝
monomer *n.* 单体
monometal *n.* 单金属
morphing *n.* 变形
motif *n.* 图形，图案，主题，动机
mullite *n.* 莫来石，高铝红柱石
multidisciplinary *n.* 包括各种学科的
multi-discipline 多学科
multitude *n.* 大量，许多

N

nacre *n.* 珠母贝
nagging *adj.* 唠叨不休的，责备的，挑剔的；恼人的
nanocomposite *n.* 纳米复合物，纳米复合材料
nanocrystalline *adj.* 纳米晶的
nanodevice *n.* 纳米器件（元件）
nanomaterial *n.* 纳米材料
nanometric *adj.* 纳米的
nanominiaturization *n.* 纳米微型化
nanomotor *n.* 纳米电机
nanoparticle *n.* 纳米颗粒
nanophotonic *adj.* 纳米光电的，纳米光子的
nanoscale *n.* 纳米尺度，纳米等级
nanosphere *n.* 纳米球
nanostructure *n.* 纳米结构
nanotechnology *n.* 纳米技术
nanotextural *adj.* 纳米组织上的
nanotube *n.* 纳米管

nano-watts 毫微瓦（特），10^{-9}瓦
nanowire *n.* 纳米线
nascent *adj.* 开始形成的，发生中的，初期的；初生的，新生的
natural *adj.* 天然的
navy *n.* 海军，深蓝色
Neolithic *adj.* 新石器时代的
Neolithic Period 新石器时代
nitride *n.* 氮化物
nitrogen *n.* 〈化〉氮（元素符号 N）
node *n.* 节，结，瘤；节点，波节（振动体的静止点）
non-covalent bond 非共价
nonferrous alloy 有色合金
nonfouling *adj.* 未污染的，未弄脏的
nonmagnetic *adj.* 无磁性的
nonmetallic *adj.* 非金属的；*n.* 非金属物质
nonviable *adj.* 无法生活的，不能存活的
notch-sensitivity 切口效应
novel *adj.* 新颖的，异常的；*n.* 小说
noxious *adj.* 有害的
nuclei nucleus 的复数形式
nucleic acid 核酸
nylon *n.* 尼龙

O

obstacle *n.* 障碍，干扰
obviate *v.* 消除；排除（障碍、危险等）；预防，避免
odor *n.* 气味，名声
offset *v.* 抵消，补偿，偏移，偏转；*n.* 错位，错移，位置偏移
opaque *adj.* 不透明的，不传热的
operational cost 经营成本
oph-thalmologist *n.* 眼科医生，眼科专家
optical bench 光具座
optical rotation 旋光
optimize *v.* 使最优化
opto-electronic 光电的
orbit *n.* 轨道，势力范围；*v.* 绕……轨道而行，沿轨道飞行，进入轨道
organic *adj.* 有机体的，生物的
organism *n.* 生物体，有机体
organometallic catalyst 有机金属催化剂

orthopaedic *adj.* 整形外科的，骨科的
orthotropic *adj.* 各向异性的
oscillation *n.* 振动，振荡，摆动
osseointegration 骨结合
ostensible *adj.* （指理由等）假装的，表面的
osumilite *n.* 大隅石
outgrowth *n.* 结果
outpatient *n.* 门诊病人
overemphasize *v.* 过分强调
overlap *v.* 部分重叠
oxidation *n.* 氧化
oxygen *n.* 〈化〉氧（元素符号 O），氧气
oyster *n.* 牡蛎，蚝

P

pace *v.* 踱步于，走动以步测量；步测，为……定步速
Paleolithic *adj.* 旧石器时代的
paradigm *n.* 典范，范例，示例；聚合体
partial *adj.* 部分的，局部的，偏爱的
pathophysiological *adj.* 病理生理的
pathway *n.* 路径
pattern *n.* 样本，样品，格式，形式；款式，图案，图形，图型；模子，模具
pearlite *n.* 珠光体
pellet *n.* 球［条形，丸形］团矿
penetrate *v.* 渗透，渗入
penetrate *v.* 穿过，渗透，了解
perfection *n.* 完美；完善
perforate *vt.* 穿孔于，在……上打眼、打齿孔
performance product 高性能产品
pericardial *adj.* 心包的
periodic *adj.* 周期的，定期的
periodicity *n.* 周期，周期性，间歇性
permeable *adj.* 可渗透的，具渗透性的
permeate *v.* 充满，渗透，透过，弥漫
peroxide *n.* 过氧化氢，过氧化物
perpendicular *adj.* 垂直的，成直角的
perspective *n.* 观察，看法，远景，前途，透视图
pertain *v.* 属于，适合
petrochemical *adj.* 石化的，石化制品的，岩石化学的；*n.* 石化产品

petroleum *n.* 石油
pewter 铅锡锑合金
pharmaceutical *n.* 药物；*adj.* 制药的，药学的
phase *n.* 相
phase separation 相分离
phenolic *adj.* 酚的，石碳酸的
phenomenology *n.* 现象学
phosphate *n.* 磷酸盐
photonics *n.* 光子学，纤维光学
physiological *adj.* 生理学的，生理学上的
piezoelectric *adj.* 压电的
pitch *n.* 球场，沥青
pitting *n.* 蚀损斑，氢气泡
pixel *n.* 像素，像元
planar *adj.* 平面的，平坦的
plant trial 工厂条件下试用；生产上试用
plasma *n.* 等离子体
plastic glazing 有机玻璃
plasticiser *n.* 增塑剂
plasticizer *n.* 增塑剂
plastics 整形外科
platinum *n.* 白金，铂（元素符号 Pt）
platy *n.* 板状的，扁平状的
ply *v.* 使用（工具），固定往来；*n.* （夹板的）层片
poly(ethyl acrylate) 聚（丙烯酸乙酯）
poly(ethylene oxide) 聚（环氧乙烷）
Poly(ethylene terephthalate) 聚（对苯二甲酸乙二醇酯）
poly(hexythiophene) *n.* 聚己基噻吩
polyacrylonitrile *n.* 聚丙烯腈
polyamide *n.* 聚酰胺
polyamides *n.* 聚酰胺
polyatomic *adj.* 多原子的
polybutadiene *n.* 聚丁二烯
polycarbonate *n.* 聚碳酸酯
polycrystalline *adj.* 多晶的；*n.* 多晶体
polycrystalline phase 晶相
polyester *n.* 聚酯；涤纶
polyether *n.* 聚醚
polyetheretherketone *n.* 聚醚醚酮

polyetherimide *n.* 聚醚酰亚胺
polyethersulfone *n.* 聚醚砜
polyethylene *n.* 聚乙烯
polyimide *n.* 聚酰亚胺
polyimide *n.* 聚酰亚胺
polyisoprene *n.* 聚异戊二烯
polylactic acid 聚乳酸
polymer *n.* 聚合物（体）
polymeric *adj.* 聚合的，聚合体的
polymerization *n.* 聚合
polypeptide *n.* 多肽
polyphenylene sulfide 聚苯硫醚
polyphosphazene *n.* 聚磷腈
polysaccharide *n.* 多糖
polysilanes *n.* 聚硅烷
polysiloxane *n.* 聚硅氧烷
polystyrene *n.* 聚苯乙烯
polyurethane *n.* 聚亚胺脂
polyvinyl alcohol 聚乙烯醇
ponder *v.* 沉思，考虑
porcelain *n.* 瓷，瓷器
porous *adj.* 多孔的；有气孔的；疏松的
Portland cement 波特兰水泥，普通水泥，硅酸盐水泥
pose *v.* 摆姿势，提出
posterior *adj.* 后端的，后面的，较晚的
pottery *n.* 陶器，陶器器皿
precursor *n.* 先驱，先行者；先兆，前驱体
predominantly *adj.* 支配的，主要的，突出的
preform *v.* 预先形成； *n.* 粗加工的成品，预成型坯
preforming *n.* 预成型，压片
preliminary *adj.* 初步的，预备的，开端的
preponderance *n.* 优势，占优势
prepreg *n.* （塑料或其他合成材料在模塑之前用树脂浸饱的）预浸料坯
pre-preg 含有化学增稠剂的模（型）垫；预浸渍
pressing 压制成型
pressing molding 模压成型
pretreat *v.* 预先处理，预处理
prevaile *v.* 流行，盛行，获胜，成功
prevailing *adj.* 占优势的，主要的，流行的

preventative *adj.* 预防性的
primary structure 一级结构；主（要）结构
primitive *adj.* 原始的，初期的；简单的；粗糙的
printed circuit 印制电路
probe tip 探针头
problematic *adj.* 问题的，有疑问的
procurement *n.* 获得
prognosticate *v.* 预言
prominent *adj.* 显著的，突出的
promulgate *v.* 发布，公布，传播
prone *adj.* 有……倾向的，易于……的
propagate *v.* 传播，增殖
propagation *n.* 传播，扩展，增长
propensity *n.* 倾向
proprietary *adj.* 私有的
prosthesis *n.* 假体（如假肢、假眼或假牙等），人体修复（术）
prosthetics *n.* 弥补术
protein *n.* 蛋白质；*adj.* 蛋白质的
protocol *n.* （条约等的）草案；（外交的）议定书；会谈记录；礼仪，礼节
prototype *n.* 原型；样板
proven *adj.* 经过验证或证实的
pseudo bond 假键
puddle *n.* 熔池
pultrusion *n.* 拉挤成型
pyrolysis *n.* 高温热解
pyrolytic *adj.* 热解的

Q

quantum dot 量子圆点
quantum *n.* 量子，量子论，量
Quantum Science 量子科学
quartz tuning fork 石英音叉
quasicrystalline *adj.* 准结晶的；*n.* 准结晶体
quenching *n.* 淬火

R

radiation *n.* 辐射，放射线，放射物
radii *n.* 半径
radioactive *adj.* 放射性的

random copolymer 无规共聚物
rapid prototype 快速成型，快速原型
rare-earth 稀土
raw materials 原材料
rayon *n.* 人造丝，人造纤维，人造丝织物，粘胶纤维
react *v.* 反应
reactant *n.* 反应物
reagent *n.* 试剂，反应力，反应物
real-time 即时处理的，实时的
rechargeable *adj.* 可再充电的
rechargeable battery 充电电池
recipient *n.* 接受者，容器；*adj.* 容易接受的，感受性强的
reconcile *v.* 使和谐，使和解，协调
recreate *v.* 得到休养，得到娱乐
recreation *n.* 娱乐（方式）；消遣（方式）
rectangle *n.* 长方形，矩形
rectangular *adj.* 长方形的，矩形的
redundant *adj.* 多余的，过剩的
re-entrant *adj.* 凹（角）的
refine *v.* 精炼，提炼，提纯，提去（杂质等）
reflector *n.* 反射器；反射光［热、声音］的物体
refractive index 折射率
refractory *adj.* 耐熔的，难熔炼的
refractory lining 耐火衬砌，耐火炉衬，耐火（材料）衬里
refrigerator *n.* 电冰箱，制冷器，冷藏库
regenerative *adj.* 再生的，更生的
regulated power 稳压电源
rehabilitation *n.* 复原，修复
reinforcement *n.* 增强，加固；钢筋，构［支］架，护炉设备
reinforce *v.* 增强
remarkably *adv.* 非常地，显著地，引人注目地
remediation *n.* 补习，辅导
renewable energy source 可再生能源
renewable resource 可再生资源
repeating unit 重复单元
repellent *adj.* 排斥的，令人厌恶的
resemblance *n.* 类同之处
resemble *vt.* 像，类似
residual *adj.* 剩余的，残留的

residue *n.* 剩余物，残余，留数
resilience *n.* 回弹力，弹性，恢复力
resin *n.* 树脂
resistance heating 电阻加热
resistant *adj.* 抵抗的，有抵抗力的
resolution *n.* 分辨率，清晰度，决心，决议
resonance *n.* （波长的）调谐；共鸣，共振；回声，反响
respective *adj.* 分别的，各自的
restenosis *n.* （心瓣手术后的）再狭窄
resurgence *n.* 苏醒
retention *n.* 保持，保留
reversible properties 可逆性质
revert *v.* 还原，回复
RF 射频（Radio Frequency），无线电频率
rheology *n.* 流变学，流变能力
rheumatological *adj.* 风湿病的
rigid *adj.* 刚硬的，不弯曲的
riser *n.* 冒口，气口，气门，升降器
robotics *n.* 机器人学，机器人技术
robust *adj.* 健康的，要用力气的，坚定的，粗野的
roller *n.* 滚压机；滚杠，滚柱，定形卷夹
routinely *adv.* 例行公事地
roving *n.* 粗纱
royal *adj.* 王室的，第一流的
runner *n.* 流道，横浇道
rust *n.* 铁锈，锈

S

sacrifice *n.* & *v.* 牺牲
safety-of-flight 安全飞行
salient *adj.* 显著的，重要的，主要的，（指角）凸出的
sandstone *n.* 砂岩
sandwich *v.* 夹入
sapphire *n.* 蓝宝石，刚玉
saturated *adj.* 饱和的
saturation magnetization 饱和磁化，磁饱和
scaffold *n.* 脚手架；搭架
scalable *adj.* 可（用磅称等）称的；可攀登的；可升级的
scalpel *n.* 解剖刀，外科手术刀

scarcity *n.* 缺乏，不足
scatter *n.* 离散
scavenging *n.* 除气，除气法；净化，清除
scission *n.* 切断，分开，分离，分裂
scratch *n.* 擦伤，刮伤，抓痕，刮痕；*v.* 擦，刮
screw dislocation 螺形位错，螺线位错
seamlessly *adv.* 无缝地，无伤痕地
segment *n.* 部分，片段
self-assembly 自装配，自组装
self-replicating 自我复制的
semicrystalline *adj.* 半晶质的；*n.* 半结晶体
sensor *n.* 传感器，灵敏元件
sensory *adj.* 传感的，感觉的，感官的
shape-memory alloy 记忆合金
shard *n.* 碎片，破片
shear *n.* 切变
shear force 切变应力
shielding composites 防护复合材料
shrinkage *n.* 收缩，皱缩，缩水
signal conditioner 信号调节器
signaling *n.* 打信号，发信号
silica *n.* 硅石，硅土，二氧化硅，无水硅酸
silicate *n.* 硅酸盐
silicide *n.* 硅化物
silicon *n.* 〈化〉硅（元素符号 Si）
silicon carbide *n.* 碳化硅，金刚砂
similar *adj.* 相像的，相仿的，类似的
simultaneously *adv.* 同时地
sizing *n.* 胶料
skeletal *adj.* 骨骼的，骨架的，纲要的
skeleton *n.* 骨干，框架，骨架
slab *n.* 厚板，平板，厚片
sliding friction 滑动摩擦
slip casting 浇铸成型，注浆成型
slip *v.* 滑，滑动，滑接，滑致畸变，滑脱
smart material 智能材料，机敏材料
snow sky 雪照云光
socioeconomic *adj.* 社会经济学的；*n.* 社会经济学
softball bat 垒球棒

solar energy 太阳能
solder *n.* 锡，钎料
sol-gel 溶胶-凝胶
solubility *n.* 溶解度
solution *n.* 溶液
solvent *n.* 溶剂，溶解，基本成分
solvus line 固相线
sophistication *n.* 复杂，久经世故
space shuttle （往返于地球和太空站之间运载人和物资的）航天飞机
spandex *n.* 氨纶
sparingly *adv.* 节俭地，保守地
spark plug 火花塞
spatial *adj.* 空间的
specific *adj.* 确切的，详尽的，特有的，特定的，仅限于……的
specimen *n.* 样品，样本
spectroscopy *n.* 光谱学，波谱学，分光术
speculate *v.* 推测，思索
spherical *adj.* 球形的，球的
spider *n.* 蜘蛛
spinning *n.* 纺，精纺；旋转，自转，旋压；*adj.* 纺纱的，旋转的
sponge *n.* 海绵，（外科用）棉球，纱布；*v.* 用海绵等擦拭、吸收（液体）
spool *n.* （绕线、铁线、照相软片等的）管、筒、线轴
sprue *n.* 浇铸道，铸口，注料口，流道，直浇道
spun spin 的过去式和过去分词；*adj.* 纺成的
stable *adj.* 稳定的，牢固的；平稳的
stack *n.* 烟道，（高炉）炉身，烟囱
stack *v.* 堆积
stainless *adj.* 不锈的，无瑕疵的，纯洁的
stain-resistant 耐污的
standpoint *n.* 立场，观点
starch *n.* 淀粉
star-like 星形
static *adj.* 不变化的，不发展的，静止的，静态的
statistical *adj.* 统计学的，以数据表示的
statistic-copolymer 无规共聚物
stealth *n.* 秘密行动
steel making 炼钢
stent *n.* 血管内支架；*adj.* 扩张的
sterilization *n.* 杀菌，绝育

stiff *adj.* 不易弯曲的，硬的；稠的
stiffen *v.* （使）变硬；变坚强，加强
stiffness *n.* 刚度，劲度
stifle *v.* 抑制，窒息
stimulus *n.* 刺激，促进因素，刺激物
stitching *n.* 用U字钉钉箱，缝纫
stoichiometric *adj.* 化学当量的，化学计算的
store *v.* 储藏，存放
strainless *adj.* 无张力的，无应变的
strand *n.* 线，绳；*v.* 搓
straw *n.* 稻草，麦秸
strength *n.* 强度
stress concentration 应力集中
stretch *v.* & *n.* 伸长，伸展
strike *v.* 打，击，敲响
styrene *n.* 苯乙烯
Styrofoam 聚苯乙烯泡沫塑料
subcontract *n.* 转包合同
submarine *n.* 潜水艇；*adj.* 水下的，海底的
submerged arc welding（SAW） 埋弧焊
substantially *adv.* 充分地
substitutional *adj.* 替代的，置换的
substrate *n.* 衬［基］底，基片，垫托物
substructure *n.* 亚结构，基础
sulfuric *adj.* 硫磺的，含大量硫磺的
sun-block cream 防晒霜，紫外线防护霜
sunscreen *n.* （防晒油中的）遮光剂
super transducer 超级传感器
superalloy *n.* 超合金，超耐热合金
supercapacitor 超级电容器
superconductor n. 超导体
superplastic *adj.* 超塑性的
Surface Plasmons 表面等离子激元
surgeon *n.* 外科医生
surgery *n.* 外科，手术室，诊疗室
surveillance *n.* 监视，监督，侦测
susceptibility *n.* 易受影响或损害的状态
suspend *v.* 悬，吊，使悬浮
suspension *n.* 吊，悬浮，悬浮液，暂停

sustained *adj.* 持续不变的，相同的
sustaining *adj.* 持续的，支持的
swap *n.* & *v.* 交换，调动
swell *v.* 膨胀
switch *n.* 开关，改变
swollen *adj.* 肿胀的，肿的
symmetry *n.* 对称，对称现象，对称性，相称，不变性
synchronize *v.* （使）同步；（使）同速进行
synergy *n.* 协同，配合，企业合并后的协力优势或协合作用
synthetic *adj.* 合成的，人造的

T

tailor *n.* 裁缝；*v.* 裁制，调整使适应
tailorability *n.* （衣料等）可裁剪性
tailorable *adj.* （衣料等）可裁制的
tailored *adj.* 裁剪的，剪裁得体的
take full advantage of 充分利用
tantalum *n.* 〈化〉钽（元素符号 Ta）
tape casting 流延成型
T_c 居里温度
technical ceramics 工业陶瓷，技术陶瓷
Teflon *n.* 特氟龙，聚四氟乙烯
telemetry *n.* 遥测学；遥测技术［装置］，测距术
tempering *n.* 回火，退火
tendon *n.* 腱
tensile *adj.* 拉力的，张力的，可拉长的
tensile modulus 拉伸模量
tensile strength *n.* 抗张强度，拉伸强度
termination *n.* 终止
terrorist *n.* 恐怖分子
tetragonal *adj.* 四方晶系的，四角形的，四边形的
textile coating 纺织涂层
texture *n.* 手感，质感，质地
T_g = glass transition temperature 玻璃化转变温度
the degree of polymerization 聚合度
the molecular weight 分子量
therapeutic *n.* 治疗剂；*adj.* 治疗的，治疗学的
therapeutics *n.* 疗法，治疗学
thermal conductivity 导热性［系数］，热导率

thermal expansion coefficient 热膨胀系数
thermal stability 热稳定性
thermit *n.* 铝热剂，灼热剂
thermoplastic *adj.* 热塑性的；*n.* 热塑性塑料
thermoplastic elastomers 热塑性弹性体
thermoset *n.* 热固树脂，热固塑料；*adj.* 热固的
three-dimensional 三维的
threefold *adv.* 三倍
threshold *n.* 阈；阈值
threshold voltage 阈值电压
thruster *n.* 推进器
ticker board （股票交易、机场、火车站等处随时变化的）信息栏，信息显示板
tinplate *n.* 白铁皮，镀锡铁皮
tissue engineering （生物）组织工程学
titanium *n.*〈化〉钛（元素符号 Ti）
titanium dioxide 二氧化钛
toll transponder 收费器
tooling *v.* 加工
toughen *v.* 使（变）强韧
toughness *n.* 韧性，韧度，刚性，粘稠性
toxic *adj.* 有毒的，中毒的
toxicity *n.* 毒性
toxicological *adj.* 毒物学的
tracking *n.* 跟踪，探测
tract *n.*（解剖）管道，地方
trade-off 交换，协定，交易，平衡
trajectory *n.* 轨道，轨迹，弹道
transceiver *n.* 无线电收发机，收发器
transducer *n.* 转换器，变流器，换频器，发送器；传感器；转录程序
transduction efficiency 换能效率
transfer *n.* & *v.* 过渡，传递，转换
transistor *n.* 晶体管
transition *n.* 过渡；转变；变迁
transmission electron microscope 透射电子显微镜
transmitter *n.* 变送［传感、发送、传递］器；发射［报、信、话］机
transparency *n.* 透明（性）
transparent *adj.* 透明的，显然的，明晰的
traverse *v.* 横越，穿越，横贯
tremendous *adj.* 极大的，巨大的，惊人的；绝妙的，极棒的

trimers *n*. 三聚体
tube *n*. 管，软管
tubular *adj*. 管的；管状的，管子形的
tundish *n*. 漏斗
tungsten *n*. 〈化〉钨（元素符号 W）
tungstic acid 钨酸
tunnel *n*. 隧道，坑道，地道；烟道，烟囱；风洞；管道
turbine blade 涡轮叶片
twist *v*. 扭，搓，缠绕

U

ubiquitous *adj*. 到处存在的，普遍存在的
ultimate *adj*. 最后的，终极的；基本的，首要的
ultrafine *adj*. 超细的，极其细小的
unary *adj*. 一元的
unauthorized *adj*. 未被授权的
underpin *v*. 巩固，支撑，加强……的基础
unidirectional *adj*. 单向的，单向性的
uniform state 统一状态
unique *adj*. 异常的，特有的，少见的；独一无二的，仅有的，惟一的
unmanned aerial vehicles 无人驾驶飞行器
unpaired *adj*. 未配对的
unsaturated *adj*. 没有饱和的，不饱和的
unsuitable *adj*. 不合适的
upheaval *n*. 突然的巨变；大动荡；大变动
user-defined 自定义
utensils *n*. 器具
utilitarian *adj*. 有效用的，实用的
utmost *n*. 极限，最大可能性；*adj*. 极度的，极端的

V

vacancy *n*. 空，空格点，空位，缺额
vacuum *n*. 真空
vague *adj*. 模糊的
Van der Waals 范德华
vanguard *n*. 先锋，先驱
vapor grown carbon fibers 气相生长碳纤维
variation *n*. 变化，变动（的程度），变异，变量
varnish *n*. 清漆，光泽面；*v*. 修饰

vascular *adj.* 脉管的，血管的
vascular graft 血管移植
vectoring nozzle 向量喷嘴，变向喷嘴
vessel *n.* 器皿，容器
viable *adj.* 切实可行的；可实施的
vibration *n.* 振动，颤动
vibration damping 减振
vinylester *n.* 乙烯酯树脂
virtually *adv.* 事实上，实质上
viscoelastic *adj.* 粘弹性的
viscosity *n.* 粘度，粘性
viscous *adj.* 黏性的；半流体的，黏滞流体的
viscous suspension spinning process 粘性悬浮纺丝工艺
volatile *adj.* （液体或油）易挥发的
volcanic *adj.* 火山的，暴烈的
Vp-p（=Peak-to-peak voltage）峰-峰电压值

W

wafer *n.* 薄片，晶片，基片
walled off （用墙）隔开
warp *v.* 弄弯，变歪；*n.* 弯曲
warp knitting 经编
water jet 喷射，射流；喷注，气流
waterproof *adj.* 不透水的，防水的；*vt.* 使防水，使不透水
wavefront *n.* 波阵面；波前
waveguide *n.* 波导
wear *v.* 磨损，耐穿
wear-resistant *adj.* 耐磨的，抗磨的
weathering *n.* 侵蚀，风化
weft knitting 纬编
weft *n.* 织物
weld seam 焊缝
well-established 已享有盛誉的，久负盛名的
wettability *n.* 润湿性
whisker *n.* 须，须晶
whiteware *n.* ［总称］白色陶瓷（器），卫生陶瓷（器）（如抽水马桶、餐具和绝缘陶瓷）
windmill *n.* 风车，风车房；风力发动机，螺旋桨
wireless sensor networks 无线传感器网络

Woven Fabrics　梭织布，编织布
wrinkle-free　不皱的

X

X-ray diffraction　X 射线衍射

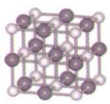
Y

yarn　*n.* 纱，纱线，纺线
yield strength　屈服强度
yttria　*n.* 氧化钇，三氧化二钇
yttrium　*n.* 〈化〉钇（元素符号 Y）

Z

ZigBee standard　紫蜂短距离无线传输标准
zirconia　*n.* 氧化锆，锆土

ISBN 978-7-111-30261-2
策划编辑：何月秋
封面设计：马精明



CAILIAO ZHUANYE YINGYU

本书特色

- 知识面广，趣味性强。涉及材料科学相关专业的各类知识，论述的概念清楚、准确、简练。
- 内容丰富、新颖。55篇文章全部选自近年来出版的原版英文教科书、科技报告、专业期刊和著作。内容新颖，学科前沿知识丰富，特别突出在纳米技术和生物医学材料方面的进展。
- 为便于理解和学习原文，每篇文章都带有问题及难点注释。
- 为了提高读者的科技英语翻译和写作水平，每一章都附有有关科技英语翻译及写作技巧的内容。
- 词汇量大，词汇表实用。词汇总表中列出了有关专业词汇、术语和词组1300多条。
- 本书既可作为高等院校材料类专业的英语教科书，也可供材料科学与工程有关的研究人员、工程技术人员学习和参考。

上架指导：工业技术/材料工程

ISBN 978-7-111-30261-2

9 787111 302612 >

地址：北京市百万庄大街22号
电话服务
社服务中心：(010)88361066
销售一部：(010)68326294
销售二部：(010)88379649
读者服务部：(010)68993821

邮政编码：100037
网络服务
门户网：http://www.cmpbook.com
教材网：http://www.cmpedu.com
封面无防伪标均为盗版

定价：35.00元