高等学校教材

材料科学与工程
专业英语

大学英语专业阅读教材编委会组织编写

匡少平　张永恒　李旭东　主编

张书圣　主审

化学工业出版社
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前　言

出版系列的专业英语教材，是许多院校多年来共同的愿望。在高等教育面向21世纪的改革中，学生的基本素质、知识面及实际工作能力的培养受到空前重视，其中专业英语水平是衡量大学生素质能力的重要指标之一。在此背景下，教育部（原国家教委）多次组织会议研究加强外语教学问题，制定有关规范，使外语教学更加受到重视。教材是教学的基本要素之一，与基础英语相比，专业英语教学的教材问题显得尤为突出。

国家主管部门的重视和广大院校的呼吁引起了化学工业出版社的关注，他们及时地与原化工部教育主管部门和全国化工类专业教学指导委员会请示协商后，组织全国十余所院校成立了大学英语专业阅读教材编委会。在经过必要的调研后，根据学校需求，编委会优先从各校教学（交流）讲义中确定选题，同时组织力量开展编审工作。本套教材涉及的专业主要包括：化学工程与工艺、石油化工、机械工程、信息工程、工业过程自动化、应用化学、生物工程、环境工程、精细化工及制药工程、材料科学与工程、化工商贸等。

根据“全国部分高校化工类及相关专业大学英语专业阅读教材编审委员会”的要求和安排编写的《材料科学与工程专业英语》教材，具有以下特点。(1) 知识面宽：该书囊括了目前与材料科学相关专业的各类知识，涉及陶瓷材料、高分子材料、复合材料、纳米材料、金属材料及生物材料等内容；覆盖范围宽，学科全面。(2) 内容新颖：教材读物均选自国外最新出版的相关学科教材、专著或期刊论文；内容新颖，学科前沿知识丰富，学生和教师都可从中了解材料科学的最新发展趋势。(3) 趣味性强：教材读物在保证学科知识基础性、全面性的前提下，有相当一部分具有很强的趣味性。我们在材料科学类专业英语的教学过程中发现，学生对学科专业以外的知识，如教材中生物材料和纳米材料的功能、应用及其制备表现出极大的兴趣，这样有利于学生拓宽知识面、开拓视野。(4) 读者面宽：《材料科学与工程专业英语》教材适应于各类材料专业的学生使用，也可作为研究生、教师及相关领域研究人员的学习参考书。

教材分为7部分（PART），每个部分含3～5个单元（UNIT），共27个单元，每个单元由一篇课文和一篇阅读材料组成。阅读材料提供与课文相应的背景知识或是课文的续篇，以进一步拓展课文的内容。根据课文与阅读材料的内容，配有相应的练习题、注释和词汇表。课文与阅读材料共计54篇，均选自1999年以来出版的原版英文教科书、科技报告、著作及专业期刊等。其中：PARTⅠ为材料科学与工程概论，包括材料科学与工程的历史、材料的分类、材料的特性、材料与化学的关系以及材料科学的研究进展和发展趋势；PARTⅡ～PARTⅦ，分别介绍金属材料（包括合金）、陶瓷材料、高分子材料、复合材料、纳米材料和生物医学材料的化学组成、性质、种类、制造技术和用途等；教材的最后为附录部分，主要包括自然元素（附录1）、与材料科学和工程相关的主要国际学术期刊（附录2）、材料科学和工程的研究团体和协会（附录3）、常用的聚合材料名称（附录4）和词汇表。

本教材在编写过程中得到化学工业出版社的大力支持，同时得到青岛科技大学教务处、化学与分子工程学院、环境与材料科学学院和高分子科学与工程学院等领导的大力支持；另外，教材中许多阅读材料得到 Seeram Ramakrishna，J. R. Jones，F. H. (Sam) Froes 等的

大力帮助，有的阅读材料是他们将即将出版的相关教材通过网络发给我们的。在此，我们向他们表示衷心的感谢。

教材由匡少平、张永恒、李旭东三位教师主编（张永恒和李旭东为并列第二主编）。其中，Unit1、2、3、4、6、8、17、23、24、25、26、27和Append.1、3由匡少平同志编写；Unit7、9、10、11、12、20、21、22由张永恒同志编写；Unit5、13、14、15、16、18、19和Append.4由李旭东同志编写；Append.2由匡少平同志和张永恒同志完成；教材最后的词汇表（Glossary）由匡少平同志统一编撰、汇总。全书由匡少平同志统稿。张书圣同志审稿。

由于时间所限，教材涉及的内容较广泛，可能出现错漏，希望广大读者不吝指正，使本书在使用过程中不断改进和完善。

编　者

2002年12月

全国部分高校化工类及相关专业大学英语专业阅读教材编审委员会

内容提要

《材料科学与工程专业英语》是根据《大学英语教学大纲》专业阅读部分的要求编写的。全书共分7部分，27个单元，每个单元由一篇课文和一篇阅读材料组成。阅读材料提供与课文相应的背景知识或是课文的续篇；根据课文与阅读材料的内容，配有相应的练习题、注释和词汇表。课文与阅读材料共计54篇，均选自1999年以来出版的原版英文教科书、科技报告、著作及专业期刊等。其中，第Ⅰ部分为材料科学与工程概论，主要介绍材料科学与工程的历史、材料的分类、材料的特性、材料与化学的关系、以及材料科学的研究进展和发展趋势；第Ⅱ～Ⅶ部分，分别介绍金属材料（包括合金）、陶瓷材料、高分子材料、复合材料、纳米材料和生物医学材料的化学组成、性质、种类、制造技术和用途等。

本教材内容丰富、新颖，知识面宽，趣味性强。适应于各类材料专业的学生使用，也可作为研究生、教师及相关领域研究人员的学习参考书。

Contents

PART Ⅰ INTRODUCTION TO MATERIALS SCIENCE AND ENGINEERING

PART Ⅱ METALLIC MATERIALS AND ALLOYS

PART Ⅲ CERAMICS

PART Ⅳ POLYMERS

PART Ⅴ COMPOSITES

PART Ⅵ NANOMATERIALS

PART Ⅶ BIOMATERIALS

APPENDIXES

PART Ⅰ INTRODUCTION TO MATERIALS SCIENCE AND ENGINEERING

Unit 1 Materials Science and Engineering

Materials are properly more deep-seated in our culture than most of us realize. Transportation, housing, clothing, communication, recreation and food production——virtually every segment of our everyday lives is influenced to one degree or another by materials. Historically, the development and advancement of societies have been intimately tied to the members' abilities to produce and manipulate materials to fill their needs. In fact, early civilizations have been designated by the level of their materials development (i. e. Stone Age, Bronze Age).

The earliest humans has access to only a very limited number of materials, those that occur naturally stone, wood, clay, skins, and so on. With time they discovered techniques for producing materials that had properties superior to those of the natural ones; these new materials included pottery and various metals. Furthermore, it was discovered that the properties of a material could be altered by heat treatments and by the addition of other substances. At this point, materials utilization was totally a selection process, that is, deciding from a given, rather limited set of materials the one that was best suited for an application by virtue of its characteristic. It was not until relatively recent times that scientists came to understand the relationships between the structural elements of materials and their properties. This knowledge, acquired in the past 60 years or so, has empowered them to fashion, to a large degree, the characteristics of materials. Thus, tens of thousands of different materials have evolved with rather specialized characteristics that meet the needs of our modern and complex society.

The development of many technologies that make our existence so comfortable has been intimately associated with the accessibility of suitable materials. Advancement in the understanding of a material type is often the forerunner to the stepwise progression of a technology. For example, automobiles would not have been possible without the availability of inexpensive steel or some other comparable substitutes. In our contemporary era, sophisticated electronic devices rely on components that are made from what are called semiconducting materials.

Materials Science and Engineering

Materials science is an interdisciplinary study that combines chemistry, physics, metallurgy, engineering and very recently life sciences. One aspect of materials science involves studying and designing materials to make them useful and reliable in the service of humankind. It strives for basic understanding of how structures and processes on the atomic scale result in the properties and functions familiar at the engineering level. Materials scientists are interested in physical and chemical phenomena acting across large magnitudes of space and time scales. In this regard it differs from physics or chemistry where the emphasis is more on explaining the properties of pure substances. In materials science there is also an emphasis on developing and using knowledge to understand how the properties of materials can be controllably designed by varying the compositions, structures, and the way in which the bulk and surfaces phase materials are processed.

In contrast, materials engineering is, on the basis of those structure properties correlations, designing or engineering the structure of a material to produce a predetermined set of properties. In other words, materials engineering mainly deals with the use of materials in design and how materials are manufactured.

"Structure" is a nebulous term that deserves some explanation. In brief, the structure of a material usually relates to the arrangement of its internal components. Subatomic structure involves electrons within the individual atoms and interactions with their nuclei. On an atomic level, structure encompasses the organization of atoms or molecules relative to one another. The next large structural realm, which contains large groups of atoms that are normally agglomerated together, is termed "microscopic" meaning that which is subject to direct observation using some type of microscope. Finally, structural elements that may be viewed with the naked eye are termed "macroscopic".

The notion of "property" deserves elaboration. While in service use, all materials are exposed to external stimuli that evoke some type of response. For example, a specimen subject to forces will experience deformation; or a polished metal surface will reflect light. Property is a material trait in terms of the kind and magnitude of response to a specific imposed stimulus. Generally, definitions of properties are made independent of material shape and size.

Virtually all important properties of solid materials may be grouped into six different categories: mechanical, electrical, thermal, magnetic, optical, and deteriorative. For each there is a characteristic type of stimulus capable of provoking different responses. Mechanical properties relate deformation to an applied load or force: examples include elastic modulus and strength. For electrical properties, such as electrical conductivity and dielectric constant, the stimulus is an electric filed. The thermal behavior of solids can be represented in terms of heat capacity and thermal conductivity. Magnetic properties demonstrate the response of a material to the application of a magnetic field. For optical properties, the stimulus is electromagnetic or light radiation: index of refraction and reflectivity are representative optical properties. Finally, deteriorative characteristics indicate the chemical reactivity of materials.

In addition to structure and properties, two other important components are involved in the science and engineering of materials, namely "processing" and "performance". With regard to the relationships of these four components, the structure of a material will depend on how it is processed. Furthermore, a material's performance will be a function of its properties. Thus, the interrelationship between processing, structure, properties, and performance is linear as follows:

Processing→Structure→Properties→Performance

Why Study Materials Science and Engineering?

Why do we study materials? Many an applied scientists or engineers, whether mechanical, civil, chemical, or electrical, will be exposed to a design problem involving materials at one time or another. Examples might include a transmission gear, the superstructure for a building, an oil refinery component, or an integrated circuit chip. Of course, materials scientists and engineers are specialists who are totally involved in the investigation and design of materials.

Many times, a materials problem is to select the right material from many thousands available ones. There are several criteria on which the final decision is normally based. First of all, the in-service conditions must be characterized. On only rare occasion does a material possess the maximum or ideal combination of properties. Thus, it may be necessary to trade off one characteristic for another. The classic example involves strength and ductility: normally, a material having a high strength will have only a limited ductility. In such cases a reasonable compromise between two or more properties may be necessary.

A second selection consideration is any deterioration of material properties that may occur during service operation. For example, significant reductions in mechanical strength may result from exposure to elevated temperatures or corrosive environments.

Finally, probably the overriding consideration is economics. What will the finished product cost? A material may be found that has the ideal set of properties, but is prohibitively expensive. Here again, some compromise is inevitable. The cost of a finished piece also includes any expense incurred during fabrication.

The more familiar an engineer or scientist is with the various characteristics and structure-property relationships, as well as processing techniques of materials, the more proficient and confident he or she will be to make judicious materials choices based on these criteria.

(Selected from *Materials Science and Engineering: An Introduction*,
by William D Callister, 2002)

New Words and Expressions

pottery ['pɔtəri] *n.* 陶瓷
by virtue of 依靠（……力量），凭借，由于，因为
empower [im'pauə] *vt.* 授权，准许；使能够
empower sb. to do sth. 授权某人做某事

forerunner	['fɔːˌrʌnə]	*n.* 先驱（者），传令官，预兆
stepwise	['stepwaiz]	*a.* 逐步地，分阶段地
interdisciplinary	[ˌintə'disiplinəri]	*a.* 交叉学科的
metallurgy	[me'tælədʒi]	*n.* 冶金学
nebulous	['nebjuləs]	*a.* 星云的，云雾状的，模糊的，朦胧的
agglomerate	[ə'glɔməreit]	*n.* 大团，大块；*a.* 成块的，凝聚的
elaboration	[iˌlæbə'reiʃən]	*n.* 详尽的细节，解释，阐述
electrical conductivity		电导性，电导率
dielectric constant		介电常数
thermal conductivity		热导性，热导率
heat capacity		热容
refraction	[ri'frækʃən]	*n.* 衍射
reflectivity	[ˌriflek'tiviti]	*n.* 反射
ductility	[dʌk'tiliti]	*n.* 延展性
corrosive	[kə'rəusiv]	*a.* 腐蚀的，蚀坏的，腐蚀性的；*n.* 腐蚀物，腐蚀剂
overriding	[ˌəuvə'raidiŋ]	*a.* 最重要的；高于一切的
prohibitive	[prə'hibitiv]	*a.* 禁止的，抑制的
judicious	[dʒuː'diʃəs]	*a.* 明智的
criterion	[krai'tiəriən]	*n.* （*pl.* criteria）标准，准则，尺度

Notes

① It was not until relatively recent times that scientists came to understand the relationships between the structural elements of materials and their properties. 这是一个强调句，强调时间。came to＋不定式，译为“终于……”，“开始……”。参考译文：直到最近，科学家才终于了解材料的结构要素与其特性之间的关系。

② The notion of “property” deserves elaboration. deserve，应受，值得；elaboration，详尽阐述。参考译文：“property”一词的概念值得详细阐述。

③ Many an applied scientist or engineer, . . . , will at one time or another be exposed to a design problem involving materials. many a (an, another)＋单数名词，许多的，多的，一个接一个的，例如：many a person，许多人。be exposed to，暴露，面临，处于……境地。参考译文：许多应用科学家或工程师，……，在某个时候都将面临着涉及材料的设计问题。

④ On only rare occasion does a material possess the maximum or ideal combination of properties. 这是一个倒装强调句，其原句为：A material possesses the maximum or ideal combination of properties on only rare occasion. 句中的 possess 是“具有”的意思。

Exercises

1. Question for discussion

  (1) What is materials science? What is materials engineering?

  (2) Why do we study materials science and engineering?

(3) Give the important properties of solid materials.

2. Translate the following into Chinese

materials science
naked eye
optical property
mechanical strength
Stone Age
Bronze age
integrated circuit
thermal conductivity

- Materials science is an interdisciplinary study that combines chemistry, physics, metallurgy, engineering and very recently life sciences. One aspect of materials science involves studying and designing materials to make them useful and reliable in the service of human kind.
- Virtually all important properties of solid materials may be grouped into six different categories: mechanical, electrical, thermal, magnetic, optical, and deteriorative.
- In addition to structure and properties, two other important components are involved in the science and engineering of materials, namely "processing" and "performance".
- The more familiar an engineer or scientist is with the various characteristics and structure-property relationships, as well as processing techniques of materials, the more proficient and confident he or she will be to make judicious materials choices based on these criteria.

3. Translate the following into English

交叉学科
固体材料
力学性质
材料加工
介电常数
热容
电磁辐射
弹性系数（模数）

Reading Material

Chemical Banding and Solid Materials

Solid materials are distinguished from the other states of matter (liquids and gases) by the fact that their constituent atoms are held together by strong interatomic forces. The electric and atomic structures, and almost all the physical properties, of solids depend on the nature and strength of primary interatomic bonds. Three difference types of strong of primary interatomic bonds are recognized: ionic, covalent, and metallic.

Ionic bonding: In the ionic bond, electron donor (metallic) atoms transfer one or more electrons to an electron acceptor (nonmetallic) atom. The two atoms then become a cation (e. g. ,metal) and an anion (e. g. ,nonmetal), which are strongly attracted by the electrostatic effect. This attraction of cations and anions constitutes the ionic bond.

In ionic solids composed of many ions, the ions are arranged so that each cation is surrounded by as many anions as possible to reduce the strong mutual repulsion of cations. This packing further reduces the overall energy of the assembly and leads to a highly ordered arrangements called a crystal structure. The loosely bound electrons at the atoms are now tightly held in the locality of the ionic bond. Thus, the electron structure of the atom is changed by the creation of the ionic bond. In addition, the bound electrons are not available to serve as charge carriers and ionic solids are normally poor electrical conductors. Finally, the low overall energy state of these substances endows them with relatively low chemical reactivity. Sodium fluoride (NaF) and magnesium chloride ($MgCl_2$) are examples of ionic solids.

Covalent Bonding: Elements that fall along the boundary between metals and nonmetals, such as carbon and silicon, have atoms with four valence electrons and about equal tendencies to donate and accept electrons. For this reason, they do not form strong ionic bonds. Rather, stable electron structures are achieved by sharing valence electrons. For example, two carbon atoms can each contribute an electron to a shared pair. This shared pair of electrons constitutes the covalent bond.

If a central carbon atom participates in four of these covalent bonds (two electrons per bond), it has achieved a stable outer shell of right valence electrons. More carbon atoms can be added to the growing aggregate so that every atom has four nearest neighbors with which it shares one bond each. Thus, in a large grouping, every atom has a stable electron structure and four nearest neighbors. These neighbors often form a tetrahedron, and the tetrahedra in turn are assembled in an orderly repeating pattern (i. e. a crystal). This is the structure of both diamond and silicon. Diamond is the hardest of all materials, which shows that covalent bonds can be very strong. Once again, the bonding process results in a particular electronic structure (all electrons in pairs localized at the covalent bonds) and a particular atomic arrangement or crystal structure. As with ionic solids, localization of the valence electrons in the covalent bond renders these materials poor electrical conductors.

Metallic Bonding: The third and least understood of the strong bonds is the metallic bond. Metal atoms, being strong electron donors, do not bond by either ionic or covalent processes. Nevertheless, many metals are very strong (e. g. cobalt) and have high melting points (e. g. tungsten), suggesting that very strong interatomic bonds are at work here, too. The model that accounts for this bonding envisions the atoms arranged in an orderly, repeating three-dimensional pattern, with the valence electrons migrating between the atoms like a gas.

It is helpful to imagine a metal crystal composed of positive ion cores, atoms without their valence electron, about which the negative electrons circulate. On the average, all the electrical charges are neutralized throughout the crystal and bonding arises because the negative electrons act like a glue between the positive ion cores. This construct is called the free electron model of metallic bonding. Obviously, the bond strength increases as the ion cores and electron "gas" becomes more tightly packed (until the inner electron orbits of the ions begin to overlap). This leads to a condition of lowest energy when the ion cores are as close together as possible.

Once again, the bonding leads to a closely packed (atomic) crystal structure and a unique electronic configuration. In particular, the non-localized bonds within metal crystals permit plastic deformation (which strictly speaking does not occur in any nonmetals), and the electron gas accounts for the chemical reactivity and high electrical and thermal conductivity of metallic systems.

Weak Bonding: In addition to the three strong bonds, there are several weak secondary bonds that significantly influence the properties of some solid materials, especially polymers. The most important of these are van der Waals bonding and hydrogen bonding, which have strengths $3\% \sim 10\%$ that of the primary C—C covalent bond.

Atomic Structure: The three-dimensional arrangement of atoms or ions in solid materials is one of the most important structural features that derive from the nature of the solid-state bond. In the majority of solid materials, this arrangement constitutes a crystal. A crystal is a solid whose atoms or ions are arranged in an orderly repeating patterns in three dimensions. These patterns allow the atoms to be closely packed (i. e. ,have the maximum possible number of near or contacting neighbors) so that the number of primary bonds is maximized and the energy of the aggregate is minimized.

Crystal structures are often represented by repeating electrons or subdivisions of the crystal called unit cells. Unit cells have all the geometric properties of the whole crystal. A model of the whole crystal can be generated by simply stacking up unit cells like blocks or hexagonal tiles.

Materials

The technical materials used to build most structures are divided into three classes, metals, ceramics (including glasses), and polymers. These classes may be identified only roughly with the three types of interatomic bonding.

Metals: Materials that exhibit metallic bonding in the solid state are metals. Mixtures or solutions of different metals are alloys.

About 85% of all metals have a crystal structure. In both face-centered cubic (FCC) and hexagonal close-packed (HCP) structures, every atom or ion is surrounded by twelve touching neighbors, which is the closest packing possible for spheres of uniform size. In any enclosure filled with close-packed spheres, 74% of the volume will be occupied by the spheres. In the body-centered cubic (BCC) structure, each atom or ion has eight touching neighbors or eightfold coordination. 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.

Ceramics: Ceramic materials are usually solid inorganic compounds with various combination of ionic or covalent bonding. They also have tightly packed structure, but with special requirements for bonding such as fourfold coordination for covalent solids and charge neutrality for ionic solids (i. e. ,each unit cell must be electrically neutral). As might be expected, these additional requirement lead to more open and complex crystal structures.

Carbon is often included with ceramics because of its much ceramic like properties, even though it is not a compound and conducts electrons in its graphitic form. Carbon is an interesting material since it occurs with two different crystal structures. In the diamond form, the four valence electrons of carbon lead to four nearest neighbors in tetrahedral coordination. This gives rise to the diamond cubic structure. An interesting variant on this structure occurs when the tetrahedral arrangement is distorted into a nearly flat sheet. The carbon atoms in the sheet have a hexagonal arrangement and stacking of the sheets gives rise to the graphite form of carbon. The (covalent) bonding within the sheets is much stronger than the bonding between sheets.

The existence of an element with two different crystal structures provides a striking opportunity to see how physical properties depend on atomic and electronic structure.

Inorganic Glasses: Some ceramic materials can be melted and upon cooling do not develop a crystal structure. The individual atoms have nearly the ideal number of nearest neighbors, but an orderly repeating arrangement is not maintained over long distances throughout the three-dimensional aggregates of atoms. Such noncrystals are called glasses or, more accurately, inorganic glasses and are said to be in the amorphous state. Silicates and phosphates, the two most common glass formers, have random three-dimensional network structures.

Polymers: The third category of solid materials includes all the polymers. The constituent atoms of classic polymers are usually carbon and are joined in a linear chairlike structure by covalent bonds. The bonds within the chain require two of the valence electrons of each atom, leaving the other two bonds available for adding a great variety of atoms (e. g. , hydrogen), molecules, functional groups, and so on.

Based on the organization of these chains, there are two classes of polymers. In the first, the basic chains have little or no branching. Such "straight" chain polymers can be melted and remelted without a basic change in structure (an advantage in fabrication) and are called thermoplastic polymers. If side chains are present and actually form (covalent) links between chains, a three-dimensional network structure is formed. Such structures are often strong, but once formed by heating will not melt uniformly on reheating. These are thermosetting polymers.

Usually both thermoplastic and thermosetting polymers have intertwined chains so that the resulting structures are quite random and are also said to be amorphous like glass, although only the thermoset polymers have sufficient cross linking to form a three-dimensional network with covalent bonds. In amorphous thermoplastic polymers, many atoms in a chain are in close proximity to the atoms of adjacent chains, and van der Waals and hydrogen bonding holds the chains together. It is these interchain bonds that are responsible for binding the substance together as a solid. Since these bonds are relatively weak, the resulting solid is relatively weak. Thermoplastic polymers generally have lower strengths and melting points than thermosetting polymers.

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