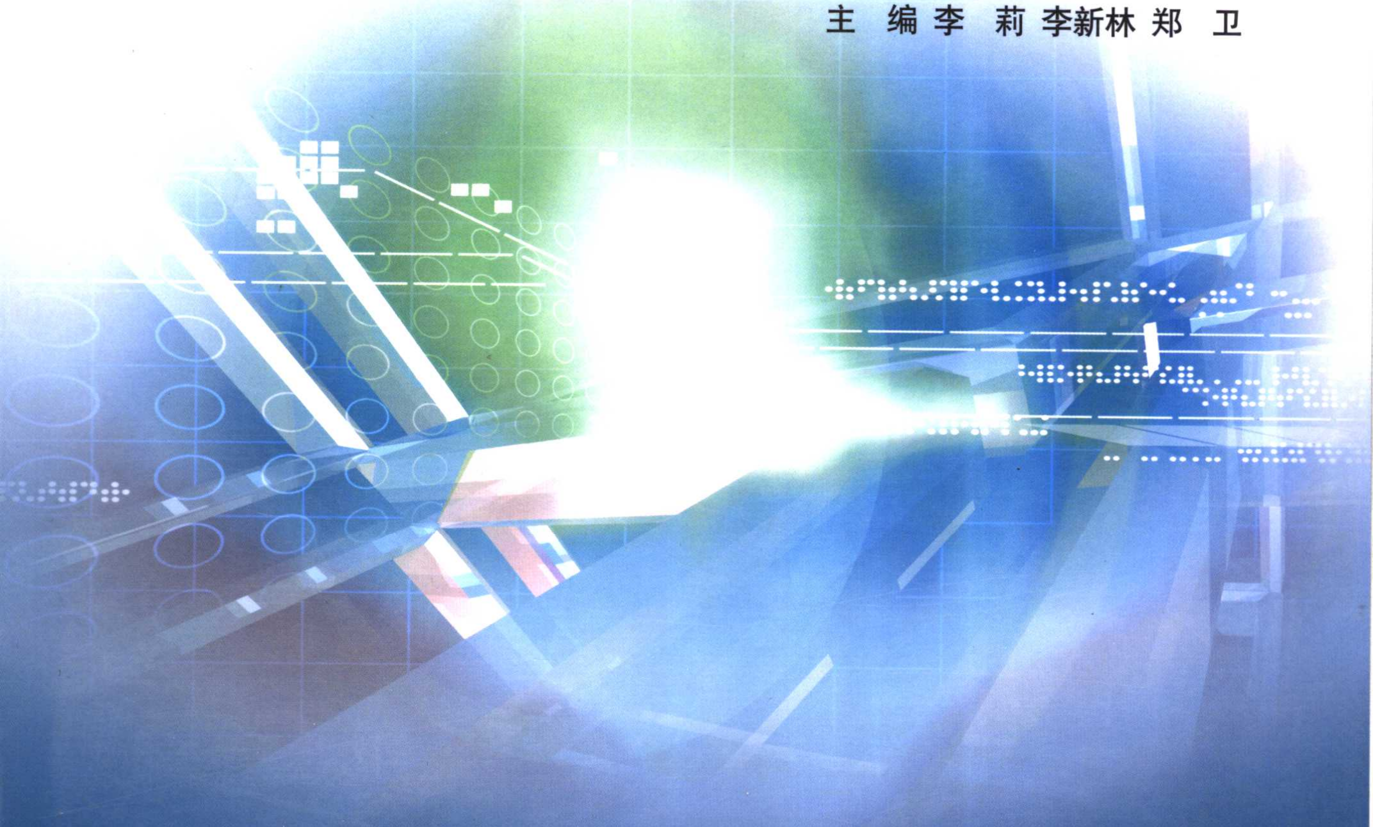
材料科学与工程
专业英语

English for Materials Science and Engineering

主　编　李　莉　李新林　郑　卫



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内容简介

本书由六部分构成,第一部分概述材料科学与工程学科发展,第二部分讲述材料科学的物理冶金基础内容,第三部分讲述材料的物理性能,如电、热、磁及光性能,第四部分介绍材料的力学性能,第五部分介绍材料的加工过程,最后一部分内容分别介绍了各类材料,如金属合金、陶瓷、高分子及复合材料,以及材料的选材及设计标准。

本书适合作高等院校材料专业及相关专业高年级学生的专业英语教材,也可作为该类专业的研究生以及从事相关领域的教学、科研和工程技术人员的自学用书。

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前　言

高等教育的改革十分重视学生科技创新能力和实际工作能力的培养。学好英语，尤其是专业英语，是学生获取科研信息、掌握学科发展动态、参加国际学术交流的基本前提。材料学科涉及的研究领域十分广泛，具有很强的学科交叉性，同时新材料的发展日新月异，这使得材料学科的专业英语教学显得尤为重要。为提高高校学生、专业科技人员熟练运用英语获得科学与工程的科研信息、进行科技交流的能力和素质，我们编写了这本书，期望能对读者专业英语水平的提高有所帮助。

本书充分考虑了专业英语教学的特点，注重专业术语的准确性。内容设置反映了材料研究的基本理论，适合材料科学与工程一级学科宽口径的专业培养。

本书由六部分构成，第一部分简要介绍了材料科学与工程学科发展，第二部分选择性地介绍了材料科学的物理冶金基础的各个方面内容，第三部分全面地讲述材料的物理性能，如电、热、磁及光性能，第四部分重点论述了材料的力学性能，第五部分为材料的加工过程，最后一部分内容分别为各类材料，如金属合金、陶瓷、高分子及复合材料，并且介绍了材料的选材及设计标准。

本书的编写分工如下：第4、5、6、7章由李莉编写；第1、2、3、15、16、17章由李新林编写；第8、9、10、11章由陈枫编写；第12、13、14章由金国编写；第18、19、20、21章由郑卫编写。最终由李莉、李新林、郑卫统稿。本书在选材及编写过程中得到哈尔滨工程大学刘二宝、胡玲、孙广伟、訾方涛等研究生的无私帮助，编者对他们的工作表示衷心的感谢。

感谢哈尔滨工程大学教材建设资金的资助，感谢哈尔滨工程大学出版社的大力支持和辛勤工作才使得本书得以高质量出版。我们深感才疏学浅，书中有不正确之处，敬请读者指出。

编者

2006年8月

Catalog

Part 1 Introduction to Materials Science and Engineering

Part 2 Physical Foundations of Materials Science

Part 3 Physical Properties of Materials

Part 4 Mechanical Properties of Materials

Part 5 Processing

Part 6 Materials and Design

Part 1
Introduction to Materials Science and Engineering

Chapter 1 Introduction

1.1 Historical Perspective

Materials are at the core of all technological advances and they are **evolving**① today faster than at any time in history. Industrial nations regard the development of new and improved materials as an "**underpinning**② technology". Materials are probably more **deep-seated**③ in our culture than most of our realization. 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' ability 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 had access to only a very limited number of materials, those which 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, **ceramics**④, and composite and so on. 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 characteristics. 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; these include metals,

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① evolving *adj*. 进化的，展开的
② underpinning *n*. 基础，支柱，支撑
③ deep-seated *adj*. 根深蒂固的，深层的
④ ceramics *n*. 陶瓷

plastics, glasses, and fibers.

Materials science and engineering plays a vital role in this modem age of science and technology. The development of many technologies that make our existence so comfortable has been intimately associated with the accessibility of suitable materials. A progress in the understanding of a material type is often the **forerunner**① 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 substitute. In our contemporary era, sophisticated electronic devices rely on components that are made from what are called **semiconducting**② materials.

1.2 Importance of Materials Science and Engineering

Why do we study materials? Many an applied scientist or engineer, whether mechanical, civil, chemical, or electrical, will at one time or another be exposed to a design problem involving materials. 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 one of selecting the right material from the many thousands that are available. There are several criteria on which the final decision is normally based. First of all, the in-service conditions must be characterized, for these will dictate the properties required of the material. On only rare occasions 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**③; 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**④ consideration is that of economics. What will the finished product cost? A material may be found that it 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 to produce the desired shape.

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① forerunner *n*. 先驱(者),预兆
② semiconducting *adj*. [物]半导体的,有半导体特性的
③ ductility *n*. 展延性,柔软性
④ overriding *adj*. 最重要的;高于一切的

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**① materials choices based on these criteria.

1.3 Advanced Materials

Advanced materials are critical to the national quality of life, security, and economic strength. Meanwhile, advanced materials are the building blocks of advanced technologies. Everything people use is composed of materials, from semiconductor chips to flexible concrete skyscrapers, from plastic bags to a ballerina's artificial hip, or the composite structures on spacecraft. The impact of materials is in all aspects. Materials that are utilized in high-technology (or high-tech) applications are sometimes termed advanced materials. By high technology we mean a device or product that operates or functions using relatively intricate and sophisticated principles; examples include electronic equipment (VCRs, CD players, etc.), computers, fiber optic systems, spacecraft, aircraft, and military rocketry. These advanced materials are typically either traditional materials whose properties have been enhanced or newly developed, high-performance materials. Furthermore, they may be of all material types (*e.g.*, metals, ceramics, polymers), and are normally relatively expensive.

1.4 Modern Materials Needs

In spite of the tremendous progress that has been made in the understanding and development of materials within the past few years, there remain technological challenges requiring even more sophisticated and specialized materials. Some is appropriate in this regard to round out the materials perspective.

Energy is a current concern. There is a recognized need to find new economical sources of energy and, in addition, to use the present resources more efficiently. Materials will undoubtedly play a significant role in these developments. For example, the direct conversion of **solar**② into electrical energy has been demonstrated. Solar cells employ some rather complex and expensive materials. To ensure a viable technology, materials that are highly efficient in this conversion process yet loss costly must be developed.

Nuclear energy holds some promise, but the solutions to the many problems that remain will necessarily involve materials, from fuels to containment structures to facilities for the disposal of radioactive waste.

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① judicious *adj*. 明智的，合理的
② solar *adj*. 太阳的，日光的

Furthermore, environmental quality depends on our ability to control air and water pollution. Pollution control techniques employ various materials. In addition, materials processing and refinement methods need to be improved so that they produce less environmental **degradation**①, that is, less pollution and less despoilment of the landscape from the mining of raw materials.

Significant quantities of energy are involved in transportation. Reducing the weight of transportation vehicles (automobiles. aircraft, trains, etc.), as well as increasing engine operating temperatures, will enhance fuel efficiency. New high-strength, low-density structural materials remain to be developed, as well as materials that have higher temperature capabilities, for use in engine components.

Many materials that we use are derived from resources that are non-renewable, that is, not capable of being regenerated. These include polymers, for which the prime raw material is oil, and some metals. These unrenewable resources are gradually becoming **depleted**②, which necessitates either the discovery of additional reserves or the development of new materials having comparable properties and less adverse environmental impact. The latter alternative is a major challenge for the material scientist and engineer.

Vocabulary

evolving	*adj*.进化的,展开的
underpinning	*n*.基础, 支柱,支撑
deep-seated	*adj*.根深蒂固的,深层的
ceramic	*n*.陶瓷
forerunner	*n*.先驱(者),预兆
semiconducting	*adj*.[物]半导体的,有半导体特性的
ductility	*n*.展延性, 柔软性
overriding	*adj*.最重要的;高于一切的
judicious	*adj*.明智的,合理的
solar	*adj*.太阳的,日光的
degradation	*n*.降级,降格,退化
deplete	*vt*.耗尽,使衰竭

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① degradation *n*.降级,降格,退化
② deplete *vt*.耗尽,使衰竭

Part 2
Physical Foundations of Materials Science

Chapter 2 Atomic Structure and Interatomic① Bonding

2.1 Introduction

Some of the important properties of solid materials depend on geometrical atomic arrangements, and also the interactions that exist among constituent atoms or molecules. We often take for granted the **intrinsic②** properties of engineering materials. If we are to alter the structure of materials to enhance their properties, however, it becomes necessary to develop a thorough understanding of why materials behave the way they do. This chapter, by way of preparation for subsequent discussions, considers several fundamental and important concepts, namely: atomic structure, electron configurations in atoms and the periodic table, and the various types of primary and secondary interatomic bonds that hold together the atoms comprising a solid. These topics are reviewed briefly, under the assumption that some of the materials are familiar to the readers.

2.2 Atomic Structure

All matter is composed of atoms. The atoms, in turn, consist of electrons, protons, and neutrons. Each atom consists of a very small nucleus composed of protons and neutrons, which is encircled by moving electrons. Both electrons and protons are electrically charged, the charge magnitude being 1.60×10^{-19} C, which is negative in sign for electrons and positive for protons, and neutrons are electrically neutral. Masses for those subatomic particles are **infinitesimally③** small; protons and neutrons have approximately the same mass, 1.67×10^{-27} kg, which is significantly larger than that of an electron, 9.11×10^{-31} kg.

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① interatomic *adj*.[核](同一分子中的)原子间的
② intrinsic *adj*.固有的,内在的,本质的
③ infinitesimally *adv*.无穷小地,极小地,无限小地

Each chemical element is characterized by the number of protons in the nucleus, or the atomic number (Z). For an electrically neutral or complete atom, the atomic number also equals the number of electrons. This atomic number ranges in **integral**① units from 1 for hydrogen to 94 for **plutonium**②, the highest of the naturally occurring elements.

The atomic mass (A) of a specific atom may be expressed as the sum of the masses of protons and neutrons within the nucleus. Although the number of protons is the same for all atoms of a given element, the number of neutrons (N) may be variable. Thus atoms of some elements have two or more different atomic masses, which are called **isotopes**③. The atomic **weight**④ of an element corresponds to the weighted average of the atomic masses of the atomic naturally occurring isotopes. The atomic mass unit (amu) may be used for computations of atomic weight. A scale has been established whereby 1 amu is defined as $\frac{1}{12}$ of the atomic mass of the most common isotope of carbon, carbon 12 (^{12}C) ($A = 12.000\,00$). Within this scheme, the masses of protons and neutrons are slightly greater than unity, and

$$A = Z + N \qquad (2-1)$$

The atomic weight of an element or the molecular weight of a compound may be specified on the basis of amu per atom (molecule) or mass per mole of materials. In one mole of a substance there are 6.023×10^{23} (Avogadro's number) atoms or molecules. These two atomic weight schemes are related through the following equation:

$$1\ \text{amu} \cdot \text{atom}^{-1} (\text{or molecule}^{-1}) = 1\ \text{g} \cdot \text{mol}^{-1}$$

For example, the atomic weight of iron is $55.85\ \text{amu} \cdot \text{atom}^{-1}$, or $55.85\ \text{g} \cdot \text{mol}^{-1}$. Sometimes use of amu per atom or molecule is convenient; on other occasion's g (or kg)/mol is preferred.

2.3 Electrons in Atoms

2.3.1 Atomic Models

During the latter part of the nineteenth century it was realized that many phenomena involving electrons in solids could not be explained in terms of classical mechanics. What followed was the establishment of a set of principles and laws that govern systems of atomic and subatomic entities that

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① integral *adj*.整数的,整体的,[数学]积分的;*n*.[数学]积分,完整,部分

② plutonium *n*.[化]钚

③ isotopes *n*.同位素

④ The term "atomic mass" is really more accurate than "atomic weight" inasmuch as, in this context, we are dealing with masses and not weights. However, atomic weight is, by convention, the preferred terminology, and will be used throughout this book. The reader should note that it is not necessary to divide molecular weight by the gravitational constant.

came to be known as **quantum mechanics**①. An understanding of the behavior of electrons in atoms and crystalline solids necessarily involves the discussion of quantum-mechanical concepts. However, a detailed exploration of these principles is beyond the scope of this book, and only a very superficial and simplified treatment is given.

One early outgrowth of quantum mechanics was the simplified Bohr atomic model, in which electrons are assumed to revolve around the atomic nucleus in discrete orbital, and the position of any particular electron is more or less well defined in terms of its orbital. This model of the atom is represented in Figure 2.1.

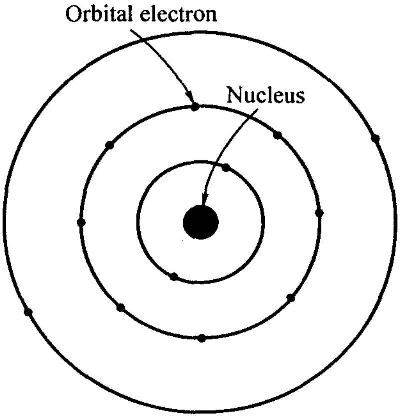

Figure 2.1 Schematic representation of the Bohr atom

Another important quantum-mechanical principle **stipulates**② that the energies of electrons are quantized; that is, electrons are permitted to have only specific values of energy. An electron may change energy, but in doing so it must make a quantum jump either to an allowed higher energy (with absorption of energy) or to a lower energy (with emission of energy). Often, it is convenient to think of these allowed electron energies as being associated with energy levels or states. These states do not vary continuously with energy; that is, **adjacent**③ states are separated by finite energies. For instance, allowed states for the Bohr hydrogen atom are represented. These energies are taken to be negative, whereas the zero reference is the unbound or free electron. Of course, the single electron associated with the hydrogen atom will fill only one of these states.

Thus, the Bohr model represents an early attempt to describe electrons in atoms, in terms of both position (electron orbital) and energy (quantized energy levels).

2.3.2 Wave-Mechanical Atomic Model

This Bohr model was eventually found to have some significant limitations because of its inability to explain several phenomena involving electrons. A resolution was reached with a wave-mechanical model, in which the electron is considered to exhibit both wavelike and particlelike characteristics and the motion of an electron is described by mathematics that govern wave motion. With this model, an electron is no longer treated as a particle moving in a discrete orbital; but rather, position is considered to be the probability of

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① quantum mechanics *n*.[物]量子力学
② stipulate *v*.规定,保证
③ adjacent *adj*.邻近的,接近的

an electronic being at various locations around the nucleus. In other words, position is described by a probability distribution or electron cloud. In Figure 2.2 compares Bohr and wave-mechanical models for hydrogen atom.

2.3.3 Quantum Numbers

Using wave mechanics, every electron in an atom is characterized by four parameters called quantum numbers. The size, shape, and spatial orientation of an electronic probability density are specified by three of these quantum numbers. Furthermore, Bohr energy levels separate into electron **subshells**①, and quantum numbers dictate the number of states within each subshell. Shells are specified by a principal quantum number n, which may take on integral values beginning with unity; sometimes these shells are designated by the letters K, L, M, N, O, and so on, which correspond, respectively, to n = 1, 2, 3, 4, 5, ⋯. It should also be noted that this quantum number and it only, is also associated with the Bohr model. This quantum number is related to the distance of an electron from the nucleus, or its position.

2.3.4 Electron Configurations

The preceding discussion has dealt primarily with electron states—values of energy that are permitted for electrons. To determine the manner in which these states are filled with electrons, we use the Pauli Exclusion Principle, another quantum-mechanical concept. This principle stipulates that each electron state can hold no more than two electrons, which must have opposite **spins**②. Thus, *s*, *p*, *d*, and *f* subshells may each accommodate, respectively, a total of 2, 6, 10, and 14 electrons; the maximum number of electrons that may occupy each of the first four shells.

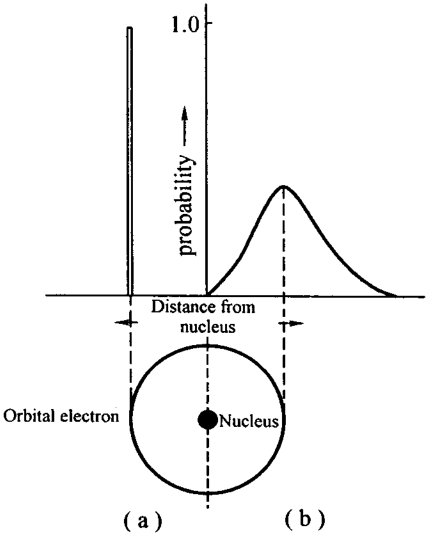

Figure 2.2 Comparison of the (a) Bohr and (b) wave-mechanical atom models in terms of electron distribution

Of course, not all possible states in an atom are filled with electrons. For most atoms, the electrons fill up the lowest possible energy states in the electron shells and subshells, two electrons (having opposite

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① subshell *n*.[核]支壳层，亚壳层
② spin *v*.旋转，纺，纺纱；*n*.旋转