高等院校专业英语系列教材

材料物理科技英语

毛祥武　主编

English for Materials Physics

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全国百佳图书出版单位

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内容提要

本书为高等院校材料物理专业英语教材，包括：材料科学基础、等离子体、真空技术、薄膜沉积、器件制备工艺、专业文献阅读（科技论文、专利、设备操作说明书）、科技论文写作。

本书适合作为普通高校材料物理、微电子技术及应用等专业的专业英语教材，也可供微电子和光电行业从业者参考。

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材料物理科技英语

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前言 Foreword

材料物理是物理学与材料科学的一个交叉学科，是材料科学的重要分支，主要通过各种物理技术和物理效应，实现材料的合成、制备、加工、修饰与应用。由于不同高校材料物理专业的人才培养方向有所不同，因此，目前市场上还未出现针对材料物理专业英语的教材。本校根据自身的学科优势和人才优势，将材料物理专业人才培养特色定位于等离子体技术及应用和功能薄膜材料的开发，学生就业主要面向光电及微电子等行业。由于该行业技术革新迅速，因此通过英文论文和专利等了解该行业的最新进展等较为必要，另外，很多进口镀膜设备的操作说明和界面等均为英文。在此背景下，我们教研室组织编写了面向微电子及光电等行业的材料物理专业英语。

本书由武汉工程大学材料学院从事专业英语以及材料物理专业教学的教师共同编写完成。具体内容如下，Unit 1：Basis of Materials Science（毛样武，邓泉荣），Unit 2：Plasmas（刘繁，熊礼威），Unit 3：Vacuum Technology（毛样武），Unit 4：Thin Film Deposition（陈喆），Unit 5：Devices Fabrication Process（付秋明），Unit

6：Reading Practice（毛样武），Unit 7：Writing Practice（毛样武）。该书在编写过程中，马志斌教授在章节布置和内容选取等方面给了很多建议和帮助，另外，还得到了王升高教授、王传新教授、满卫东教授、林志东教授、徐军教授、付萍副教授、许传波老师等的建议和支持，在此表示衷心感谢！另外，教材内容参考了国外的教材、科技论文、授权专利及设备的操作说明书等，对此表示衷心感谢！

本书适合作为普通高校材料物理、微电子技术及应用等专业的专业英语教材，也可供微电子和光电行业从业者参考。

由于作者水平有限，书中疏漏在所难免，恳请读者批评指正。

编者

2015年6月

目录 Contents

Unit 1
Basis of Materials Science

1.1 Introduction

Materials science is an interdisciplinary field applying the properties of matter to various areas of science and engineering. This scientific field investigates the relationship between the structure of materials at atomic or molecular scales and their macroscopic properties.

It is no surprise that every quantum leap in our civilization is identified with a material: stone age, bronze age, iron age, etc. Even though the current era is labeled as the information age, its more apt designation would be the materials age. This is so because without some of the crucial developments in the synthesis and processing of semiconductors and related materials, the information age might not have materialized.

The understanding of the underlying science of a given materials technology could have substantial impact on further enhancing that technology. For example, many ancient civilizations knew that gold and silver pieces could be beaten into extremely thin foils without knowledge of the governing process. This behavior could now be rationalized in terms of the hypothesis, first proposed in 1934, which plastic deformation in crystalline solids occurs by the motion of dislocations. Experimental observations by transmission electron microscopy in the early 1950s confirmed the presence of dislocations. Following this confirmation, a number of increasingly sophisticated approaches were developed to strengthen solids by incorporating obstacles into them to block the glide of dislocations.

We have known about the existence of semiconductors since the time of Michael Faraday, i.e., the middle of the nineteenth century. However, we could not test the concept of semiconductor because of the lack of availability of high-purity materials. With the advent of zone refining in the late 1940s, it was possible to purify germanium and silicon to very high levels. This enabled scientists from Bell Laboratories to demonstrate the transistor action in 1948 for which they received a Nobel Prize.

Most current technologies impose stringent performance requirements on materials. For example, those used for the manufacture of supersonic aircraft and space vehicles must be lightweight and must tolerate extremely high temperatures, in many cases up to 90% of their melting points. At the same time, they must display excellent strength, a very demanding requirement!

In the electronics industry, the principal driving forces for ultra large-scale integration technology are higher device speeds and reduced cost per chip. These objectives can be satisfied by reducing device dimensions and by increasing the diameter of wafers so that the yield of chips per wafer is increased. Since macroscopically dislocation-free silicon crystals are required for high-performance devices and circuits, large diameter crystals must be grown under precisely tailored thermal gradients to avoid the introduction of dislocations. This objective has been successfully achieved, and crystals as large as 30 cm in diameter have been grown using the Czochralski process. This has produced the most nearly perfect of synthesized materials, a crowning achievement of materials engineering!

1.2 Materials Science and Engineering

Sometimes it is useful to subdivide the discipline of materials science and engineering into materials science and materials engineering subdisciplines. Strictly speaking, materials science involves investigating the relationships that exist between the structures and properties of materials. In contrast, materials engineering is, on the basis of these structure-property correlations, designing or engineering the structure of a material to produce a predetermined set of properties. From a functional perspective, the role of a materials scientist is to develop or synthesize new materials, whereas a materials engineer is called upon to create new products or systems using existing materials, and/or to develop techniques for processing materials. Most graduates in materials programs are trained to be both materials scientists and materials engineers.

Structure is at this point 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 larger 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 subjected to forces will experience deformation, or a polished metal surface will reflect light. A 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 (stiffness), strength, and toughness. For electrical properties, such as electrical conductivity and dielectric constant, the stimulus is an electric field. 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 relate to 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 as depicted in the schematic illustration shown in Figure 1.1.

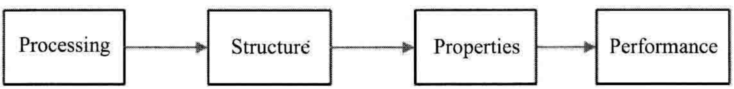

Figure 1.1 The four components of the discipline of materials science and engineering and their interrelationship

We now present an example of these processing-structure-properties-performance principles. Three thin disk specimens of aluminum oxide were placed over a printed page in order to demonstrate their differences in light-transmittance characteristics. One disk is transparent (i.e., virtually all light that is reflected from the page passes through it), whereas another one is translucent (meaning that some of this reflected light is transmitted through the disk). The last one is opaque——that is, none of the light passes through it.

It is obvious that the optical properties of each of the three materials are different. All of these specimens are of the same material, aluminum oxide, but the transparent one is what we call a single crystal——that is, has a high degree of perfection， which gives rise to its transparency. The translucent one is composed of numerous and very small single crystals that are all connected; the boundaries between these small crystals scatter a portion of the light reflected from the printed page, which makes this material optically translucent. Finally, the opaque one is composed not only of many small, interconnected crystals, but also of a large number of very small pores or void spaces. These pores also effectively scatter the reflected light and render this material opaque.

Thus, the structures of these three specimens are different in terms of crystal boundaries and pores, which affect the optical transmittance properties. Furthermore, each material was produced using a different processing technique. And, of course, if optical transmittance is an important parameter relative to the ultimate in-service application, the performance of each material will be different.

1.3 Classification of Materials

Materials science encompasses various classes of materials, each of which may constitute a separate field. There are several ways to classify materials. For instance, the traditional groups are ceramics, metals and polymers based on atomic structure and chemical composition. In addition, there are the composites, which are engineered combinations of two or more different materials. Another category is advanced materials——those used in high-technology applications, such as semiconductors, biomaterials, smart materials, and nanoengineered materials.

1.3.1 Metals

Metals and alloys are composed of one or more metallic elements (e.g., iron, aluminum, copper, titanium, gold, and nickel), and often also nonmetallic elements (e.g., carbon, nitrogen, and oxygen) in relatively small amounts. Atoms in metals and their alloys are arranged in a very orderly manner. Alloys have the same fundamental structure as metals; however, pure metals solidify at one temperature (the melting point) whilst alloys solidify over a temperature range. Metals and alloys have a number of properties that make them very useful as engineering materials.

They are generally strong in both tension and compression, usually having a high strength: weight ratio. Metallic materials have large numbers of nonlocalized electrons; that is, these electrons are not bound to particular atoms. Many properties of metals are directly attributable to these electrons. For example, metals are extremely good conductors of electricity and heat, and are not transparent to visible light.

Metals may be readily fabricated, namely, they can be readily worked and shaped, and they retain this new shape permanently. They may be stiffened by corrugating, curving or by making the metal into right angled pieces which increase the mechanical properties of the formed metallic product. In this form they resist buckling and bending. Using this method of stiffening, thin sheet steel can be made to have mechanical properties equivalent to a much thicker planar section. This arises because metals have the same mechanical properties in compression as they do in tension. Metals and alloys generally keep their formed shape up to fairly high temperatures, whereas other materials (such as thermoplastics) will revert to their original preformed shape. Metals acquire their "new" shape under high stresses but with little "spring-back", a beneficial characteristic when forming complex panel shapes.

They can be used in tension and undergo a strengthening process when deformed. Metals and alloys are the only materials which have this unique property.

1.3.2 Ceramics

Ceramic materials are very hard and brittle. Generally, they consist of one or more metals combined with a nonmetal such as oxygen, carbon, or nitrogen. For example, common ceramic materials include aluminum oxide (or alumina, Al_2O_3), silicon dioxide (or silica, SiO_2), silicon carbide (SiC), silicon nitride (Si_3N_4), and, in addition, what some refer to as the traditional ceramics——those composed of clay minerals (i.e., porcelain), as well as cement and glass. They have strong covalent and ionic bonds and very few slip systems available compared to metals. Thus, characteristically, ceramics have low failure strains and low toughness or fracture energies. In addition to being brittle, they lack uniformity in properties, have low thermal and mechanical shock resistance, and have low tensile strength. On the other hand, ceramic materials have very high elastic moduli, low densities, and can withstand very high temperatures. The last item is very important and is