21世纪高等学校双语教材

材料科学与工程导论

Introduction to Materials Science and Engineering

黄培彦 主编

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PREFACE

Designed to help improve bilingual education of students in materials science with the specific conditions of China taken into account, this booklet has mainly referred to the following textbooks for useful information.

1. William F. Smith, *Principles of materials science and engineering*, 2nd ed., McGraw-Hill, Inc., 1986, U.S.;

2. William D. Callister, *Materials science and engineering*: *An introduction*, John Wiley & Sons, Inc., 1985, 1991(2nd ed.), 2001(5nd ed);

3. R. A. Higgins, *Properties of engineering materials*, H. & S. E. A. Division of H. & S. LTD, 1977, Great Britain.

This booklet can be used both as a textbook or reference material by undergraduate and graduate students in relevant programs or as a good read by people engaged in theoretical study, design, management and development of materials, mechanics, civil engineering, communication, metallurgy, machinery, electric power, electronics, computer science, aeronautics and astronautics, etc.

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Editors

June 2007

前　言

本书为配合材料科学课程双语教学的需要，并考虑到中国高等学校的实际情况而编写。

本书可作为综合性或理工科大学有关专业的本科生、研究生双语教学教材，亦可供在材料、力学、土木、交通、冶金、机械、电力、电子、计算机、航空航天等专业部门中从事理论研究、开发、设计和管理的工作人员参考。

本书在华南理工大学交通学院、广东潮汕学院、华中科技大学材料科学与工程学院及土木与力学学院有关领导的关怀和支持下完成，同时也得到了许多教授和老师的热心帮助，如王惠珍、徐明英、陈霞、徐育澄、胡鹏等。The Institute of Technology of Brunei, School of Engineering 的系主任 Dr. Faqir Gul 为本书提供了许多有价值的参考资料，在此表示衷心的感谢。

本书由广东潮汕学院李建华、华中科技大学土木与力学学院李光霞编写，华南理工大学交通学院黄培彦主编，华中科技大学材料科学与工程学院肖建中主审。

由于水平所限，书中不当和错漏之处，敬请广大读者指正。

编　者

2007 年 6 月

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CHAPTER 1

INTRODUCTION

1.1 REVIEW AND PERSPECTIVE

Materials are probably 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' 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 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 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 50 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, which meet the needs of our modern and complex society; these include metals, plastics, glasses, and fibers.

The development of many technologies that make our existence so comfortable has been intimately associated with the accessibility of suitable materials. An-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 substitute. Or, in our contemporary era, sophisticated electronic devices rely on components that are made from what are called semi-conducting materials.

1.2 MATERIALS SCIENCE AND ENGINEERING

The discipline of 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. Throughout this text we draw attention to the relationships between material properties and structural elements.

"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 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. 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 corrosive. 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 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, corrosive characteristics indicate the chemical reactivity of materials. The chapters that follow discuss properties that fall within each of these six classifications. The main criterion for many materials applications is a mechanical integrity, since the most frequently encumbered external stimulus is a mechanical force; consequently, in these discussions, special emphasis is given to the mechanical properties.

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 a microprocessor "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; 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 that of 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 to produce the desired shape.

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.

1.3 CLASSIFICATION OF MATERIALS

Solid materials have been conveniently grouped into three basic classifications: metals, ceramics, and polymers. This scheme is based primarily on chemical makeup and atomic structure, and most materials fall into one distinct grouping or another, although there are some intermediates. What may be considered to be a fourth group—the composites-consists of combinations of two or more different materials. A brief explanation of the material types and representative characteristics is offered next. Subsequent chapters explore in some detail the various structural elements and properties for each.