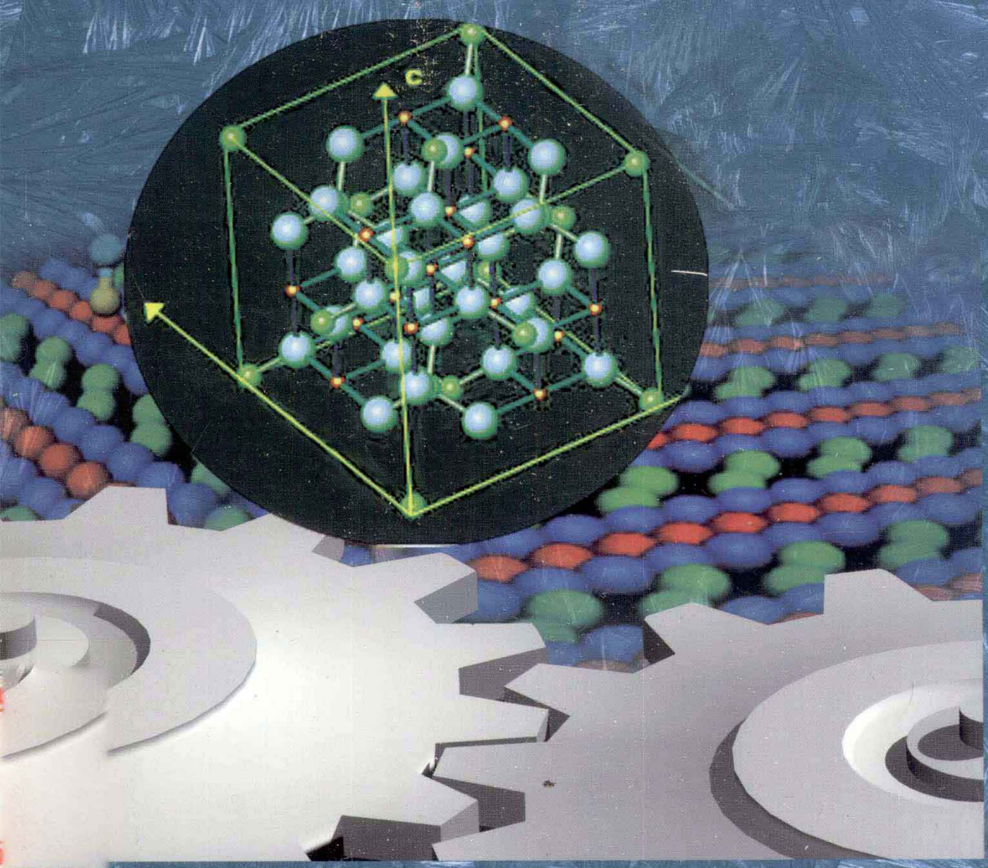
■ 高等学校理工科材料类规划教材

MECHANICAL ENGINEERING MATERIALS

机械工程材料（双语版）

齐 民/主编



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前 言

随着我国国民经济的发展,需要越来越多的国际化人才,同时也有越来越多的留学生来到中国学习,作为国际化语言的英语被逐步引入教学已经是一种趋势。材料是制造行业的基础,小到日用的杯子,大到航天飞机,任何产品都离不开材料。在大学本科教学中,大多数工科专业都开设了材料类课程,而很多工程材料课程都开展中英双语教学。在双语教材方面,目前多使用英文原版教材,但是篇幅都过大,而且目前引进的教材无论与我们的教学体系还是市场需求都不适应,迫切需要一本难度和内容适中的教材。基于此,我们编写了本书。本书以英文为主,各章、节标题均有中文对照,在每章的最后有中文的重点内容概述,在全书的最后附关键术语中文解释。

本书主要包括两部分:第一部分是基础部分,包括材料的性能、结构与组织,相图与相变,使学生一般性地建立材料的成分、组织、性能及工艺间的联系;第二部分是应用部分,介绍常用材料的成分、组织、性能及工艺间联系,也是对第一部分知识的巩固。每一章节前面以通俗的例子开始,逐渐引入专业概念,每章最后有供学生讨论的问题,以使学生迅速建立材料的科学基础,同时将所学知识尽可能与实际和应用相结合,提高分析问题和解决问题的能力。

考虑到本书的读者对象为非材料专业的学生,在材料分类方面更多从应用角度考虑,同时,考虑到各国在材料标号上的差异,在正文中尽量弱化材料标号,有标号的地方以美国标号为主,力求体现教材的国际化。

参加本书编写工作的有齐民(第 0、3 章),邓德伟(第 1 章),叶飞(第 2、4 章),朱小鹏(第 5 章),王伟强(第 6 章),王清(第 7、8 章),黄昊(第 9 章)和董旭峰(第 10、11 章)。全书由齐民统稿并最后定稿。

在本书的策划及编写过程中,美国密西根理工大学化工学院的齐骥在资料收集方面做了大量工作,大连理工大学材料科学与工程学院的陆山帮助处理了很多图表,美国宾夕法尼亚州立大学的 Zach Valenta 校对、审阅了书稿的英文部分,在英文表述方面提出了建设性的意见和建议,本书的出版还得到了大连理工大学教务处本科生教材出版基金的资助,在此一并表示衷心的感谢!

虽然编者在编写前参考了大量相关书籍，尤其是国际上相近内容的书籍，但是作者深刻感到无论在结构、内容，还是语言组织上都是一个挑战，其中的缺点和不足也在所难免，期待读者多提宝贵意见以便我们不断改进。

您有任何意见和建议，请通过以下方式与出版社联系：

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编 者
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Chapter 0 Introduction 绪 论

0.1 Materials Science and Engineering 材料科学与工程

When we look around our offices, we can see many goods like personal computers, telephones, windows, doors, book shelves, and so on. If we look inside these goods, we can distinguish materials like plastics, glasses and metals. We work with machine tools, and we travel by car, train, ship and aircraft, which are concerned with more complicated materials. Materials are everywhere, and we face materials every moment. In a word, we can do nothing without materials.

Materials are substances which are used to manufacture useful objects.

Materials have accompanied mankind virtually from the very beginning of its existence. Development and advancement of societies have been intimately tied to their members' ability to produce and manipulate materials to fill their needs. Historians and scholars have named certain ancient periods after the materials which were predominantly utilized at that respective time: the Stone Age, the Bronze Age and the Iron Age, respectively.

The earliest humans had access to only a limited number of naturally occuring materials, such as stones, woods, clays and skins. The Stone Age was considered to begin 2.5 million years ago. A revolutionary development happened at least 9 000 years ago, after the use of fire. When artifacts made of clay became permanently hard and water-resistant after heated on fire, pottery appeared. As early as 6000～5000 B.C., ancient Chinese had learnt firing pottery with clay. In order to hermetically seal the goods made of pottery, an additional processing step called glazing was introduced around 3000 B.C. by the Egyptians, then porcelain was born. The first glazed pottery in China was born as early as 1400 B.C. (the Shang dynasty). When porcelain with better properties was made in China during the Han dynasty (206 B.C.～200 A.D.), it named a nation, China.

As early as 3 000 B.C., usage of metallic alloys (copper alloys) started to circulate in the Mideast, which was considered the beginning of Bronze Age. Unlike stones or porcelains, copper alloys have high elasticity and particularly high plasticity, which allow sheets or chunks of copper to give useful shapes. By adding some elements, copper alloys could be highly strengthened, or easily cast into complicated shapes, especially for the purpose of making weapons. Chinese made bronze in around 2140 B. C. , and bronze had developed significantly since 1000 B. C. , during the Shang dynasty.

The Iron Age was considered to begin between 1500 and 1000 B. C. . Chinese began to use ironware before 770 B. C. , and had casting technique with iron mould after 770 B. C. . Coal had been used to melt iron in China around 200 B. C. .

Use of metallic tools including bronze and iron alloys aided ancient societies greatly. But the truly rapid development in material techniques is considered to begin from the so-called Industrial Revolution in UK in 1740s. Large scale industry represented by spinning machines and steamers required more materials with better properties, which promoted people to investigate materials deeply.

In 1863, Sorby in UK examined iron and steel specimens prepared by grinding, polishing and etching by means of a microscope of tens to the magnitude and observed lamellae like microstructure. He also discovered that different properties of steels through different treatments had relations with their microstructures, which announced the birth of metallography. In fact, as early as the seventh century A. D. , the Syrians near Damascus made famous Damascus swords, which were produced by joining and folding through hammer-welding bars of iron and steel alternately. The significance of Sorby's work was that he discovered the reason why differently treated steels have different properties. It marked the beginning of materials research from experience to science. Analysis techniques following like X-ray diffraction(the early of the twentieth century) and transmission electron microscope(TEM, 1930s) give researchers a deeper understanding. At the same time, development of theories, such as crystallography, dislocation, etc, allowed people a deeper understanding about the relationship between properties and microstructures of materials. The discipline of materials science and engineering appeared.

Materials science investigates the relationships that exist between compositions, structures and properties of materials. In contrast, materials engineering is, on the base of these structure-property relationships, designing or engineering the structure of a material to produce a predetermined set of properties.

The term 'structure' is concerned with how we detect materials, which can be divided into 6 levels: macrostructure, mesoscopic structure, microstructure, nanostructure, atomic structure and subatomic structure. Macrostructure is defined as that could be viewed with the naked eyes, and subatomic structure is concerned with the interaction between electrons and atomic nuclei. Most structure characteristics need to use some types of microscopes.

The term 'property' here refers to some types of responses when materials are exposed to external stimuli. The properties of solid materials may be grouped into 6 different categories: mechanical, electrical, thermal, magnetic, optical and deteriorative.

Different processes give materials different properties, even to the same composition of materials. So the discipline of materials science and engineering is to show the relationships between compositions, microstructures, properties and processing.

0.2 Major Classes of Materials 材料的分类

Generally, engineering materials can be divided into four classes: metals, ceramics, polymers and composites.

1. Metals

Metallic materials include pure metals and their alloys. Atoms composed of metals are combined by means of metallic bonds, that is, the free electrons surrounding an atomic nuclear not bound to particular atoms. Metals are good conductors of electricity and heat, having lustrous appearances, such as gold, silver, copper and iron. Iron-based metals are called ferrous metals, while others are non-ferrous metals. Common metals are strong and deformable.

2. Ceramics

Ceramics are general names of a series of inorganic compounds. Atoms in ceramics are combined by ion or covalent bonds. Ceramics are divided into conventional ceramics and fined ceramics. Conventional ceramics , mostly used for daily life, are often mixtures of natural materials like clay, quartz, and feldspar, and are usually called porcelain. Conventional ceramics are brittle. Fined ceramics are mainly composed of artificial compounds like oxides, nitrides and carbides. Ceramics have high chemical stability. Engineering ceramics are mostly fined ceramics.

3. Polymers

Polymers are organic compounds that are chemically based on carbon, hydrogen and other nonmetallic elements. They have very large molecular structures. Atoms in molecule are combined by covalent bonds, while combination among molecules is often weak. Polymers have low density, and are often flexible.

4. Composites

Composites are groups consisting of more than one material type, such as polymer-compound and metal-compound. Glass fiber which reinforced plastics is a typical polymer based on composites, in which glass fibers are embedded in polymeric material. A composite is designed to combine the advantages of each component material. More and more composites are used in high-technique fields, like aviation and aero-space.

0.3 Materials in Engineering 工程中的材料

With the development of science and technique, a greater variety of materials with different properties are available for selection than ever before. Innovation in engineering often means the clever use of a new material. It is vital that the professional engineer knows how to select materials to best fit the demands of design-economy and aesthetics, as well as the demands of strength and durability. First, a designer must understand the properties of materials, as well as their limitations. Engineering disasters are frequently caused by the misuse of materials. Second, a designer should know that the better the properties, the higher the cost of materials. Third, a designer needs to consider about factors of resources and environment.

This book includes mainly two parts: the first part concerns fundamentals of materials science and engineering, including properties, structures and microstructures, phase diagram and transformation, to make students establish the relationships between properties, compositions, microstructures and processes; the second part concerns application of the first part, including materials commonly used in engineering. There are questions and discussions at the end of each chapter, to help students understand the concepts deeper, apply the learnt knowledge to practice as much as possible, and enhance students' ability of analyzing and solving problems.

Questions and discussions

1. Give an example of material that you are familiar with and show its properties and features as many as you can.
2. Try to give a classification of the materials discussed thus far.
3. Indicate the concept of microstructure by using examples.

重点内容概述

材料是用来制作有用器件的物质，是人类生产和生活的基础。材料的发展水平和利用程度的提高是人类文明进步的标志之一。人类对材料的认识是由表及里，由简单到复杂，由宏观到微观不断深入的过程。随着理论和技术的发展，人们逐渐建立起材料的性能—成分—微观结构与组织—加工工艺之间的联系，形成了材料科学与工程这一学科。

材料可以分为金属材料、高分子材料、陶瓷材料以及由这三种材料以不同形式组合而成的复合材料。

作为工程师，在设计产品和选择材料时，不仅要考虑性能是否满足应用要求，还必须考虑资源情况、加工成本、可回收性以及环境是否友好等问题。

Chapter 1 Properties of Materials 材料的性能

Many materials, when in service, are subjected to forces or loads; examples include aluminum alloys by which airplane wings are constructed and steels in automobile axles. In such situations, it is necessary to know the characteristics of materials and to design compositions from which it is made such that any resulting deformation will not be excessive and fracture will not occur. The mechanical behavior of a material reflects the relationship between its response or deformation and an applied load or force. Important mechanical properties are strength, hardness, ductility and stiffness. Mechanical properties are most essential and important in engineering. In addition, materials often work under environments like high temperature, corrosive media, magnetic field, et al. During production of components, materials often experience thermal processes. Physical and chemical properties of materials have to be considered, too.

1.1 Mechanical Properties of Materials 材料的力学性能

Components used in mechanical engineering usually have to bear high mechanical loads. It is, thus, of considerable importance for students of mechanical engineering and materials science to thoroughly study the mechanical behaviors of materials. There are different approaches to this subject. The engineers are mainly interested in designing rules to dimension components, while materials scientists usually focus on the physical processes during mechanical loading. Ultimately, both aspects are important in practice. Without a clear understanding of the mechanisms of deformation of materials, an engineer might apply design rules uncritically and thus cause 'unexpected' failure of components. On the other hand, all theoretical knowledge is practically useless if the gap to practical application is not closed. Standard methods are often used to characterize mechanical properties of materials, such as tensile testing, compression testing, bending testing, torsion testing, hardness testing, impact testing, fatigue testing, fracture mechanics testing, and so on.

1.1.1 Strength and Plasticity of Materials 材料的强度与塑性

Tensile testing is the most popular method for measuring strength and plasticity of materials. There are two kinds of specimen geometries(flat and round-cross section) rec-