普通高等教育创新型人才培养规划教材

Professional English for Microelectronics

微电子专业英语

Chen Xianping
陈显平

Zhang Ping Yang Daoguo Zhou Qiang Meng Ruishen
张 平 杨道国 周 强 蒙瑞燊

配有课件

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Summary

This book consists of 9 chapters which can be divided into four parts in content: Chapters 1～2 introduce the basic knowledge of semiconductor physics and semiconductor devices. Chapters 3～6 talk about the manufacturing technologies and processes. In addition, the integration processes for CMOS and MEMS are highlighted. Chapter 7 is to answer "what are the 'MtM' and 'MtM technologies'?" and to derive some indications on "how to develop a roadmap for the 'MtM'?". Chapters 8～9 are on professional English writing skills.

This book can serve as the professional English textbook for the undergraduate and postgraduate students committed to the microelectronic or electronic field or other related majors. Moreover, it can be used as a reference for researchers and engineers.

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责任编辑　宋淑娟　周方彦

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Preface

In the past few decades, the discipline of Microelectronic Science and Manufacturing Technology has played a fundamental role in shaping the semiconductor industry. Since the early 70's, Moore's Law has become the important engine to promote the sustainable development of the semiconductor industry. However, the industry is now faced with the increasing importance of a new trend, "More than Moore (MtM)". This great change results in an increased demand for the advanced knowledge of Microelectronic Science and Manufacturing Technology. Therefore, it is of great significance for both of students and researchers in this field to master the professional English. Meanwhile, master of these professional English skills, such as scientific paper or report writing skills, application ability of academic writing tools, searching ability of literatures and presentation skills, may play greatly positive effects on their careers. The purpose of this textbook is to help the people, who are dedicated to this field, to develop their professional English and professional English skills.

This book consists of 9 chapters which can be divided into four parts in content: Chapters 1～2 introduce the basic knowledge of semiconductor physics (semiconductor, charge carrier, band, and doping) and semiconductor devices (PN junction, Schottky and heterojunction diode, bipolar junction and MOS transistor). Chapters 3～6 talk about the manufacturing technologies and processes including photolithography, plasma/reactive ion etch, ion implantation, diffusion, oxidation, evaporation sputter, CVD, vapor phase epitaxial growth, etc. In addition, the integration processes for CMOS and MEMS are highlighted. Chapter 7 is to answer "what are the'MtM' and 'MtM technologies'?" and to derive some indications on "how to develop a roadmap for the 'MtM'?". Chapters 8～9 are on professional English writing skills, principally introduce the structure of academic research papers, writing skills of each part, academical tool (EndNote), and information searching methods in databases like Web of Science and Google Scholar. Moreover, the content about how to prepare a good professional presentation is discussed.

What makes this book different? Firstly, the "overview", "key words", and "with questions to read" design at the beginning of each chapter can help the readers to quickly grasp the key knowledge points. Secondly, plenty of schematic diagrams makes the abstract and the difficult knowledge points are easier for understanding. Furthermore, the recommended books and the references given in each chapter can assist the readers in advanced study. What is more? The readers can find a comfortable read feeling from the book.

This book can serve as the professional English textbook for the undergraduate and postgraduate students committed to the microelectronic or electronic field or other related majors. Moreover, it can be used as a reference for researchers and engineers.

This book is issued under the general editorship of Dr. Chen Xian ping from Guilin University of Electronic Technology. Due to the limited level of the authors, any comment on this book is very welcome!

Xianping Chen
Sept. 16, 2014

CONTENTS

PART I Basic knowledge of semiconductor physics and semiconductor devices

PART II Manufacturing technologies and processes

PART III Frontiers of science and technology

PART IV Development of professional English ability

PART I
Basic knowledge of semiconductor physics and semiconductor devices

Chapter 1 Semiconductor

OVERVIEW

This chapter provides an introduction to semiconductor. It begins with early history of semiconductors and lists the important events in the development of semiconductor process (section 1. 1). It then introduces the properties, materials of semiconductor and the common semiconductor materials. Meanwhile, the preparation methods of the semiconductor materials are illustrated (section 1. 3). Sections 1. 3～1. 5 aim to introduce the basic knowledge of semiconductor physics, including band theory of solids, charge carrier, electrical conduction, etc. The last two sections are dedicated to introduce the doping of semiconductor (acceptor and donor impurities) and types of semiconductor (N-tape and P-type).

Keywords

English	Chinese	English	Chinese
Impurity	杂质	Doping	掺杂
Rectification	整流	Dopant	掺杂剂
Seed crystal	籽晶	Crystal	晶体
Boule	晶锭	Orientation	晶向
Czochralski pulling technique(CZ)	丘克拉斯基提拉法	Bridgman directional solidification technique	布里奇曼下降法
Holder	固定器	Crucible	坩埚
Solidification	凝固	Wafer	晶圆片
Valence band	价带	Conduction band	导带
Excitation	激发	Fermi level	费米能级
Carrier	载流子	Hole	空穴
Transition	跃迁	Energy gap	能隙
Lattice	晶格	Majority carrier	多数载流子
Minority carrier	少数载流子	Mass action law	质量作用定律
Drift	漂移	Recombination	复合
Donor	施主	Diffusion	扩散
Intrinsic	本征的	Accepter	受主
Covalent bond	共价键	Ion implantation	离子注入
Extrinsic	非本征的	Degenerate	简并

With questions to read

1. *What's semiconductor?*
2. *What's the properties of semiconductor?*
3. *What's charge carrier?*
4. *What's the doping of semiconductor?*

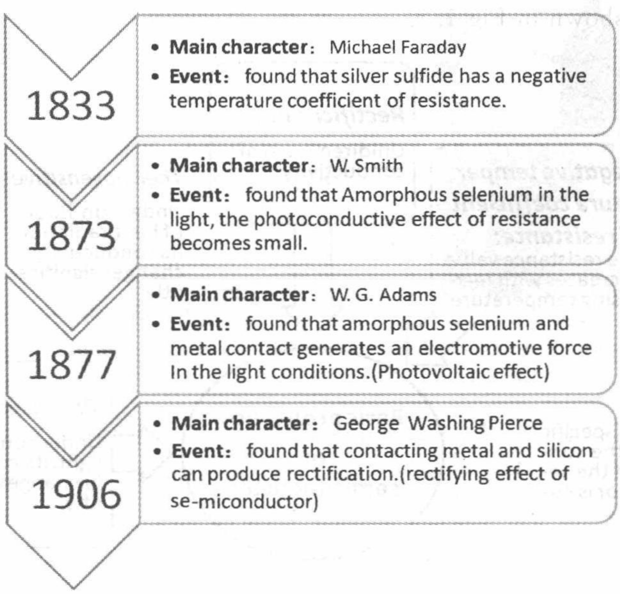
Recommended Book:

Electrical Engineering Materials

Basak TK. Kent, GBR: New Academic Science, 2012.

1.1 Early history of semiconductors

Semiconductor research began quite inconspicuously about 180 years ago with some observations on the electrical properties of silver sulfide. The progress was very slow for the next 50 years and then, about 1885, a mild interest developed with the discovery of point contact rectifiers. These devices were used as detectors until being displaced by the vacuum tube around 1915. Development of selenium (Se) and cuprous oxide rectifiers in 1930 revived the interest and the publication of a good theory of semiconductors in 1931 added still more momentum. The next period of active interest came around the World War II when the cat-whisker diode was revived and developed into an excellent radar detector. ***The announcement of the transistor in*** 1948 ***gave this field of research such a boost that it has become a real giant in the last few years and semiconductor electronics now rate as a major field of endeavor.*** As shown in Fig 1.1 is early development of semiconductors.



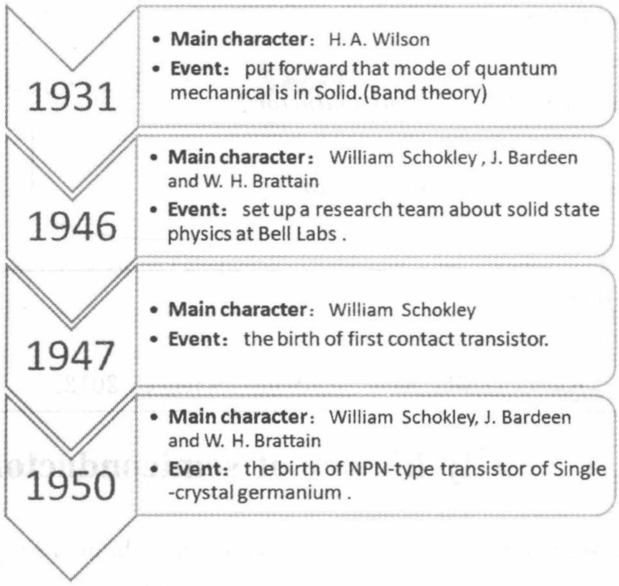


Fig 1. 1 Early development of semiconductors

1. 2 Properties and materials of semiconductor

In general, the main factors that determine basic properties of semiconductors are related to the chemical composition, the (crystallographic) structure, the presence of various defects and impurities (both intentional and unintentional), and the dimensions of the semiconductor or semiconductor structure. ***Semiconductor has five basic properties: doping, negative temperature coefficient of resistance, rectification, thermosensitive and photosensitivity***, as shown in Fig 1. 2.

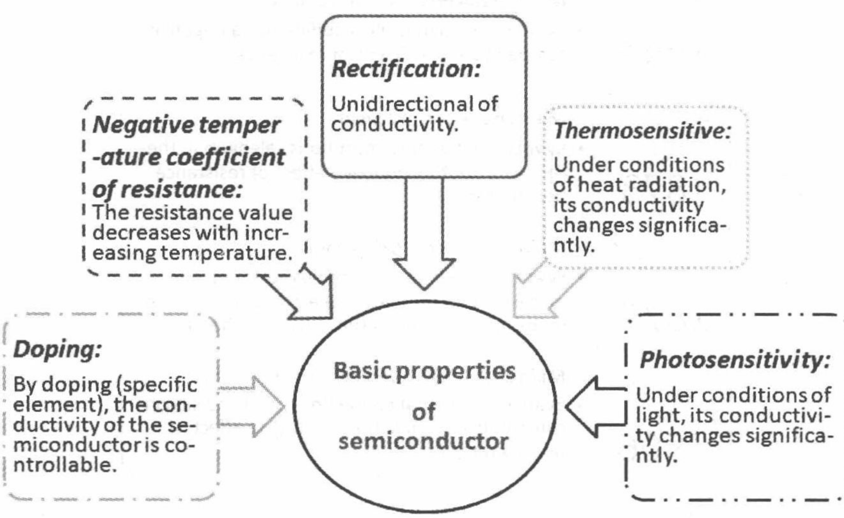


Fig 1. 2 The basic properties of semiconductor

Semiconductor materials are insulators at absolute 0 ℃ that conduct electricity in a limited way at room temperature. The defining property of semiconductor material is that it can be doped with impurities that alter its electronic properties in a controllable way. Because of their application in devices like transistors (and therefore computers) and lasers, the search for new semiconductor materials and the improvement of existing materials is an important field of study in materials science. The list of common semiconductor materials is shown in Tab 1.1. The most commonly used semiconductor materials are crystalline inorganic solids. These materials can be classified according to the periodic table groups from which their constituent atoms come.

Tab 1.1 Common semiconductor materials

Element	Group IV	C, Si, Ge
Compound	Group IV	SiC, SiGe
	Group III～V	AlN, InAs, etc
Alloy	Ternary	AlGaAs, InGaAs, etc
	Quinternary	AlGaInp, InGaAsP, etc
Other	Organic semiconductors	Triphenylamine, Polyacetylene, etc
	Magnetic semiconductors	TiO_2, CuO, GaN, etc

In general, the majority of semiconductors in various applications are prepared as bulk crystals or thin films. Bulk crystals are typically produced as single crystal (cylindrical) boule by employing, e.g., the Czochralski pulling technique (as shown in Fig 1.3) or the Bridgman directional solidification technique (as shown in Fig 1.4). In the Czochralski growth method, *a seed crystal (having the required crystal orientation), which is attached to a holder, is inserted into a crucible of the molten material and then is slowly pulled from the melt.* This results in crystal growth by solidification of the molten material on the seed crystal surface with the crystal structure and orientation of the growing material being identical to those of the seed crystal. Thus, a cylindrical crystal bar (referred to as a boule) is produced. The crucible is placed inside the graphite, which is heated by employing radio frequency (RF) induction coils. In order to ensure the crystal growth uniformity, the growing crystal and the crucible are rotated at several revolutions per minute. The typical pulling speeds are on the order of several centimeters per hour. And the boule diameter can be controlled by changing the temperature, pulling speed and rotation rate. Then the boules are sliced into wafers (with

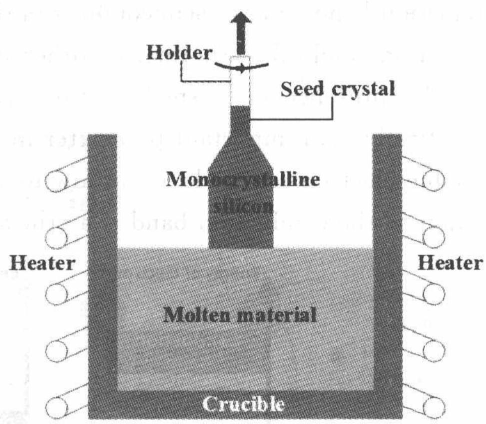


Fig 1.3 The Czochralski growth technique

thickness in the range between about 0.1 and 1 mm).

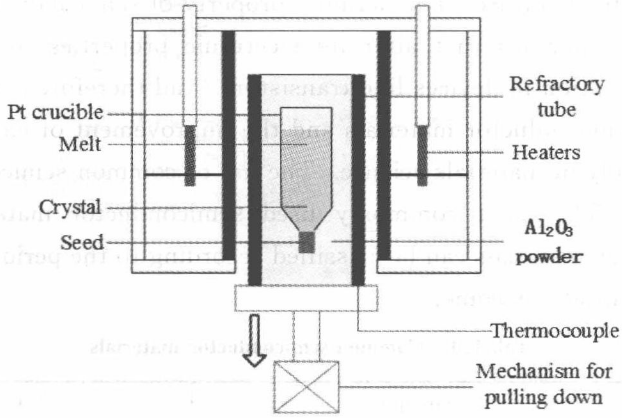
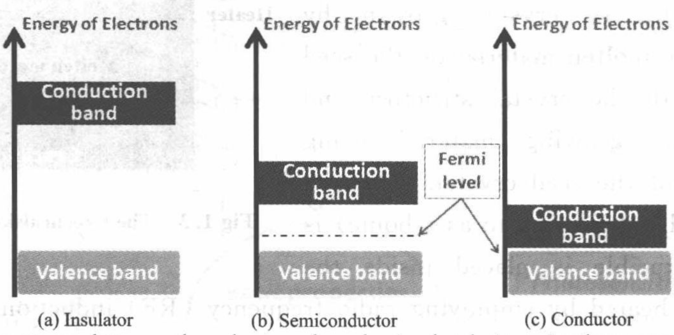


Fig 1.4　The Bridgman directional solidification technique

1.3　Band theory of solids

A useful way to visualize the differences between conductors, insulators and semiconductors is to plot the available energies for electrons in the materials, as shown in Fig 1.5. Instead of having discrete energies as in the case of free atoms, the available energy states form bands. *Crucial to the conduction process is whether or not there are electrons in the conduction band*. In insulators the electrons in the valence band are separated by a large gap from the conduction band, in conductors like metals the valence band overlaps the conduction band, and in semiconductors there is a small enough gap between the valence and conduction bands that thermal or other excitations can bridge the gap. With such a small gap, the presence of a small percentage of a doping material can increase conductivity dramatically. An important parameter in the band theory is the Fermi level, the top of the available electron energy levels at low temperatures. The position of the Fermi level with the relation to the conduction band is a crucial factor in determining electrical properties.



(a) The large energy gap between the valence and conduction bands in an insulator says that at ordinary temperatures, no electrons can reach the conduction band; (b) In semiconductors, the band gap is small enough that thermal energy can bridge the gap for a small fraction of the electrons; (c) In conductors, there is no band gap since the valence band overlaps the conduction band.

Fig 1.5　Energy Bands in solids