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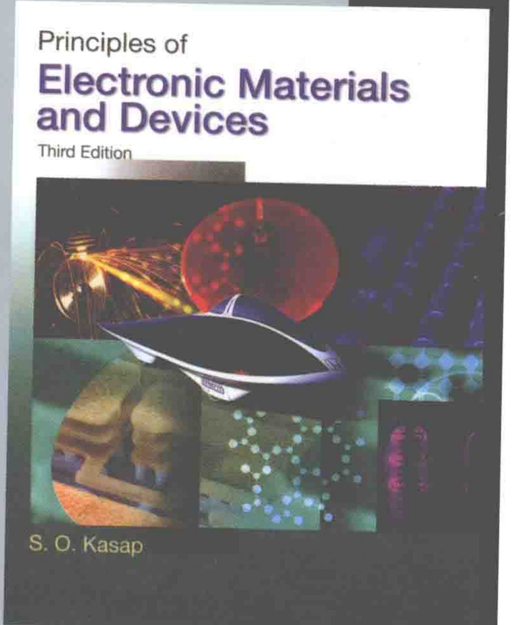
国外大学优秀教材——材料科学与工程系列（影印版）

S.O.Kasap

电子材料与器件原理

（第3版）

Principles of Electronic Materials and Devices (Third Edition)



清华大学出版社

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为了满足国内广大读者了解、学习和借鉴国外先进技术和管理经验的需要，清华大学出版社与国外几家著名的出版公司合作，影印出版了一系列英文版教材。鉴于大部分外版教材篇幅过长，我们请专家结合国内教学的实际需要，对所选图书进行了必要的删节。经过删节处理后的图书，页眉保留原版书的页码，页脚是连续的新书页码，目录未做改动。文中提到的页码均为原版书页码。有的内容或页码也有可能已被删除从而无法找到，由此会给读者带来诸多不便，在此深表歉意！

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清华大学出版社
2006 年 11 月

英文影印版序

“电子材料与器件”这门课程是美国大学工学院里电机和材料专业高年级本科的必修课或选修课，但对于不同的专业侧重有所不同。在传统的材料导论课程里，整个课程会广泛地介绍现代工业应用的一般材料，包括陶瓷、玻璃、高分子，以及复合材料。对于材料的性质，一般会过于强调材料的机械性质，从而忽略了物理性质，比如电性、光性、磁性和铁电、压电性质等。这种过于偏向力学性质的原因来自几个方面：其一是由于在介绍固体电学性质的时候需要有量子力学基础。比如能带理论、隧道效应和磁矩的量子化。在讨论电子能量分布时还需要统计物理的基础，而一般工学院材料系并不设置任何量子力学的课程。这为教学固体电性增加了关键性的困难；其二是由于美国工学院的资深教授大多来自传统的工程教育背景，那些非电机系出身的老师一般很少开设物理以及固体理论方面的课程。正是由于这两方面的历史原因，工科院系中的传统的材料课程一直有这种重视力学性质而忽视电学性质的倾向。但是在21世纪工业飞速发展的环境下，尤其美国工业界在近几十年来，飞速发展了功能材料，尤其是电子材料，包括智能材料、纳米电子器件、传感器、医用感应器，等等。这些器件材料大多是根据许多物理的基本原理和新概念而建立设计的。虽然工科非电机专业的学生并不一定直接涉及这些元器件的设计和制造，但在日常的工程实践中会经常接触到相关材料和器件的应用。比如测温、测压、磁场、光电、通信和医用中的设备和系统。这就要求工学院的材料专业的学生能够对材料的物理性质和概念有一定的掌握。本书就是按照这种需求而出版的。

对材料专业的学生，材料物理性质的教材可以来自两个方面：其一是一般材料导论教材，比如由 Donald Askeland 所著的 *The Science and Engineering of Materials* 中的电学性质的部分，但这部分内容比较浅显。而在此基础上，更高程度的材料电学性质就来自本书的主要章节。对于美国工科院校材料专业的学生，课时为三个学分（即一周 3 次课，每课 50 分钟），一般在大学三年级完成该课程。

本书可以分为两个部分，第一部分是基础部分。从第 1～4 章着重讨论与固体电性有关的物理理论。其中包括量子物理中的薛定谔方程、海森堡测不准原理、隧道效应、单粒子势阱等重要概念，并在这些物理理论的基础上建立能带理论，包括态密度、波尔兹曼统计、费米-狄拉克分布、费米能级等。在基础部分中，还给出了基本的导电与导热机制，其中包括趋肤效应和霍尔效应。在这个部分还介绍了一些典型的器件和集成电路的概念，比如霍尔器件。第二部分主要介绍不同种类的电子材料，包括半导体与半导体器件、介电材料和绝缘材料、磁性材料和超导材料。在介绍半导体的章节中(第 5，6 章)，本书讨论了半导体的基本概念，如电子和空穴、本征半导体、N 型和 P 型半导体、载体浓度、载体的温度特性、杂质行为、扩散方程、光吸收，以及缺陷和半导体结等。在第 7 章里着重介绍介电材

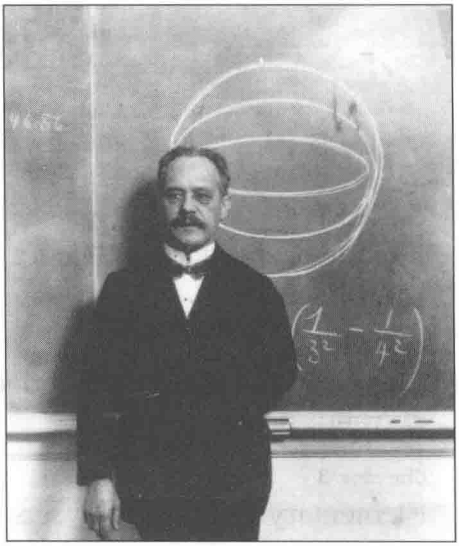
料，包括电子和离子在外场下的极化行为、频率特性、介电损耗、介电强度、介电击穿和电容。该章还介绍了铁电和压电的概念以及铁电压电器件，如石英振荡器和滤波器。第 8 章介绍磁性材料和超导材料。在这一章中，本书首先讨论了磁学的基本概念，比如磁矩、磁化率、磁化强度等，然后给出各种磁性的定义，比如顺磁、铁磁、反磁。该章详细地讨论了磁化饱和、居里点、磁畴与去磁效应。对于磁滞回线以及各种典型的磁性材料，该书也做了详细的介绍。第 8 章的最后一部分介绍了超导现象和超导材料，包括第一类和第二类超导体、迈斯耐效应、零电阻现象、约瑟芬结和超导电流密度，并介绍了磁性记录材料。第 9 章介绍光学性质和光学材料。

本书的作者 S.O. Kasap 博士是电子材料领域十分著名的专家。他在本书里不仅对材料的物理电学性质的介绍有独到的见解和非常精彩的阐述，而且对材料的基本结构也作了极为详尽的描述。更为可贵的是本书引入大量现代科技最新发展的成果。比如高温超导体、新一代数字芯片技术、高密度磁记录等。这为开拓学生眼界，熟悉相关领域动态，掌握现代工业发展有着极为积极的意义。

清华大学出版社在中国现代化飞速发展的今天，十分及时地选择 *Principles of Electronic Materials and Devices* 作为中国大学工科专业的主要材料学英文原版教科书并引进该书的版权，是有着非常重要的现实意义。它不仅可以在国内科技英文教学方面作为一个具有国际水准的工程院校的教学标准，也为一般的大专院校和科研单位的研究工作者提供了一本内容丰富、极具科研价值的参考书。我衷心祝愿本书的英文影印版受到国内学生、老师，以及科研同行的欢迎，并在教学和科研中起到重大的作用。

时东陆
美国俄亥俄州立辛辛那提大学工学院
材料科学与工程教授

2006 年



Arnold Johannes Wilhelm Sommerfeld (1868–1951) was responsible for the quantum mechanical free electron theory of metals covered in Chapter 4. Sommerfeld was the Director of Institute of Theoretical Physics, specially established for him, at Munich University.

| SOURCE: AIP Emilio Segrè Visual Archives, Physics Today Collection.

Felix Bloch (left) and Lothar Wolfgang Nordheim (right). Nordheim (1899–1988) received his PhD from the University of Göttingen.

| SOURCE: AIP Emilio Segrè Visual Archives, Uhlenbeck Collection.

PREFACE

THIRD EDITION

The textbook represents a first course in electronic materials and devices for undergraduate students. With the additional topics in the accompanying CD, the text can also be used in a graduate introductory course in electronic materials for electrical engineers and material scientists. The third edition is an extensively revised and extended version of the second edition based on reviewer comments, with many new and expanded topics and numerous new worked examples and homework problems. While some of the changes appear to be minor, they have been, nonetheless, quite important in improving the text. For example, the intrinsic concentration n_i in Si is now taken as 1×10^{10} cm^{-3}, instead of the usual value of 1.45×10^{10} cm^{-3} found in many other textbooks; this change makes a significant difference in device-related calculations. A large number of new homework problems have been added, and more solved problems have been provided that put the concepts into applications. Bragg's diffraction law that is mentioned in several chapters is now explained in Appendix A for those readers who are unfamiliar with it.

The third edition is one of the few books on the market that has a broad coverage of electronic materials that today's scientists and engineers need. I believe that the revisions have improved the rigor without sacrificing the original semiquantitative approach that both the students and instructors liked. Some of the new and extended topics are as follows:

Chapter 1	Thermal expansion; atomic diffusion
Chapter 2	Conduction in thin films; interconnects in microelectronics; electromigration
Chapter 3	Planck's and Stefan's laws; atomic magnetic moment; Stern–Gerlach experiment
Chapter 4	Field emission from carbon nanotubes; Grüneisen's thermal expansion
Chapter 5	Piezoresistivity; amorphous semiconductors
Chapter 6	LEDs; solar cells; semiconductor lasers
Chapter 7	Debye relaxation; local field in dielectrics; ionic polarizability; Langevin dipolar polarization; dielectric mixtures
Chapter 8	Pauli spin paramagnetism; band model of ferromagnetism; giant magnetoresistance (GMR); magnetic storage
Chapter 9	Sellmeier and Cauchy dispersion relations; Reststrahlen or lattice absorption; luminescence and white LEDs
Appendices	Bragg's diffraction law and X-ray diffraction; luminous flux and brightness of radiation

ORGANIZATION AND FEATURES

In preparing the text, I tried to keep the general treatment and various proofs at a semiquantitative level without going into detailed physics. Many of the problems have been set to satisfy engineering accreditation requirements. Some chapters in the text have additional topics to allow a more detailed treatment, usually including quantum mechanics or more mathematics. Cross referencing has been avoided as much as possible without too much repetition and to allow various sections and chapters to be skipped as desired by the reader. The text has been written to be easily usable in one-semester courses by allowing such flexibility.

Some important features are

- The principles are developed with the minimum of mathematics and with the emphasis on physical ideas. Quantum mechanics is part of the course but without its difficult mathematical formalism.
- There are more than 170 worked examples or solved problems, most of which have a practical significance. Students learn by way of examples, however simple, and to that end nearly 250 problems have been provided.
- Even simple concepts have examples to aid learning.
- Most students would like to have clear diagrams to help them visualize the explanations and understand concepts. The text includes over 530 illustrations that have been professionally prepared to reflect the concepts and aid the explanations in the text.
- The end-of-chapter questions and problems are graded so that they start with easy concepts and eventually lead to more sophisticated concepts. Difficult problems are identified with an asterisk (*). Many practical applications with diagrams have been included. There is a regularly updated online extended *Solutions Manual* for all instructors; simply locate the McGraw-Hill website for this textbook.
- There is a glossary, *Defining Terms*, at the end of each chapter that defines some of the concepts and terms used, not only within the text but also in the problems.
- The end of each chapter includes a section *Additional Topics* to further develop important concepts, to introduce interesting applications, or to prove a theorem. These topics are intended for the keen student and can be used as part of the text for a two-semester course.
- The end of each chapter also includes a table *CD Selected Topics and Solved Problems* to enhance not only the subject coverage, but also the range of worked examples and applications. For example, the selected topic *Essential Mechanical Properties* can be used with Chapter 1 to obtain a broader coverage of elementary materials science. The selected topic *Thermoelectric Effects in Semiconductors* can be used with Chapters 5 and 6 to understand the origin of the Seebeck effect in semiconductors, and the reasons behind voltage drift in many semiconductor devices. There are numerous such selected topics and solved problems in the CD.
- The text is supported by McGraw-Hill's textbook website that contains resources, such as solved problems, for both students and instructors. Updates to various articles on the CD will be posted on this website.

CD-ROM ELECTRONIC MATERIALS AND DEVICES: THIRD EDITION

The book has a CD-ROM that contains all the figures as large *color diagrams* in *PowerPoint* for the instructor, and class-ready notes for the students who do not have to draw the diagrams during the lectures. In addition, there are numerous *Selected Topics* and *Solved Problems* to extend the present coverage. These are listed in each chapter, and also at the end of the text. I strongly urge students to print out the CD's *Illustrated Dictionary of Electronic Materials and Devices: Third Student Edition,* to look up new terms and use the dictionary to refresh various concepts. This is probably the best feature of the CD.

ACKNOWLEDGMENTS

My gratitude goes to my past and present graduate students and postdoctoral research fellows, who have kept me on my toes and read various sections of this book. I have been fortunate to have a colleague and friend like Charbel Tannous who, as usual, made many sharply critical but helpful comments, especially on Chapter 8. A number of reviewers, at various times, read various portions of the manuscript and provided extensive comments. A number of instructors also wrote to me with their own comments. I incorporated the majority of the suggestions, which I believe made this a better book. No textbook is perfect, and I'm sure that there will be more suggestions for the next edition. I'd like to personally thank them all for their invaluable critiques, some of whom include (alphabetically):

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"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."

Sir William Lawrence Bragg

To Nicolette

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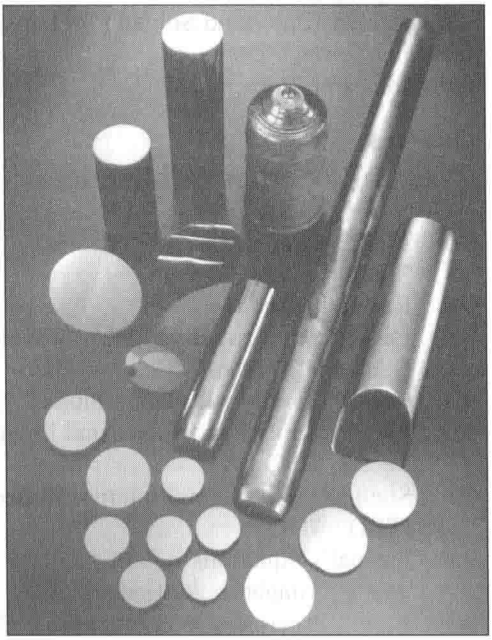

GaAs ingots and wafers.
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