Introduction to the Modern Theory of Metals

Alan Cottrell

(The Institute of Metals, London, 1988), approx. 260 pages.
ISBN: 0-904357-97-X

This is a broadly based tutorial overview of the physics of metals, based on their electronic structure. The book aims to bridge the gap between the physics and materials science communities. While the theories treated go back as far as the beginning of the century, most of the discussion centers on developments within the last 30 years. The complementary free-electron and tight-binding paradigms for the electronic structure are given extensive discussion, with more emphasis on the free-electron approach.

The first chapter introduces the origins of both metallic and insulating behavior from several points of view, including the one-electron band picture, electron-electron interactions, and the dielectric theory. Localization effects are discussed as well. Several succeeding chapters discuss the rationale for treating metals as free-electron materials. The topics include the weak ionic pseudopotential, screening effects, and a brief account of Fermi liquid theory. This discussion leads into a treatment of cohesion in simple metals based on the Wigner-Seitz method and the pseudopotential theory. The energetics of several types of imperfect configurations, including vacancies, stacking faults, and liquids are described within this picture. Cohesion in transition metals is subsequently treated via simple square-band models of the electronic density of states in tight-binding models, as well as more detailed approaches describing structural energies. Corrections to the simple tight-binding theory based on more quantitative calculations are described.

The last three chapters emphasize three types of metallic properties: alloy heats of formation, surface electron distributions, and superconductivity. The Hume-Rothery rules for alloy formation are described, along with more recent calculations seeking to provide justification for them. Simplified d-band pictures appropriate for transition metals, and the empirical "Miedema" theory, are also presented. Surface energies and work functions are treated within the context of both "jellium" and tight-binding theories. In addition, surface geometries and adsorption are briefly discussed. The last chapter outlines the BCS theory of superconductivity, and describes possible mechanisms of high temperature superconductivity.

A very attractive feature of this book is its emphasis on the interface between physics and materials science. Thus, defect properties and empirical approaches are treated in more detail than in most comparable books. Methodologies which are useful in treating defect problems, such radial interatomic forces, are described and, where possible justified. The treatment of the moment method for tight-binding models is also a welcome inclusion. Unfortunately, the widely used "embedded-atom" method is omitted.

The theoretical treatment is given a strong observational background, which makes for very enjoyable reading. The level of the book emphasizes simple physical pictures; it should be accessible to beginning students in both physics and materials science. In this regard, Cottrell includes 13 appendices that provide background material on the fundamentals of quantum mechanics and several topics in solid state physics.

Reviewer: A. E. Carlsson is associate professor of physics at Washington University in St. Louis. His specialty is the theory of bonding in transition metals and semiconductors.

Electronic Ceramics - Properties, Devices and Applications

Edited by Lionel M. Levinson

(Marcel Dekker, Inc., New York, 1988), 533 pages.
ISBN: 0-8247-7761-1

Electronic ceramics is one of the most rapidly developing fields of science and technology today. *Electronic Ceramics - Properties, Devices and Applications* provides an excellent introduction to the field of electronic ceramics for people with diverse backgrounds.

The book consists of eight chapters, written by different authors who have published extensively in their respective subject areas. The eight chapters describe the following subjects: (1) ceramic packaging for integrated circuits, (2) piezoelectric ceramics, (3) magnetic ceramics, (4) ceramic capacitor technology, (5) surge protective devices (mainly ZnO varistors), (6) thick film technology, (7) electro-optic ceramics and devices, and (8) high temperature superconductors.

A thorough review of the history of ceramic packaging technology is presented. Although future trends in integrated circuit packaging are addressed, greater emphasis of this topic would have been desired. The chapter on piezoelectric ceramics does not cover traditional piezoelectric materials and properties, but emphasizes the fracture behavior of these materials and the development of piezoelectric and electrostrictive composites. The chapters on magnetic ceramics and ceramic capacitor technology discuss the most important issues of these two technologies and give insight to future directions in these fields.

An excellent review of ZnO varistor technology is given by F. Martzloff and L. Levinson in the chapter on surge-protective devices. Thick film paste formation, firing, laser trimming, resistors, dielectrics, solderable electrode pastes, and copper material systems are among the topics covered in the chapter on thick film technology. A very thorough treatise on electro-optic ceramics and devices is presented by C. Haertling; the chapter emphasizes the fabrication and properties of PLZT. J. Bray and H. Hunt, authors of the chapter on high temperature superconductors, readily acknowledge that their chapter may be obsolete by publication time for this fast moving field. Nonetheless, a concise overview of type I and type II superconductors is given, and the initial developments of the "123" material are reviewed.

Overall, the book gives a fine review of electronic ceramics today, with a pertinent blend of theoretical and practical examples. Although ferroelectric thin film technology was in its infancy as the book was being compiled, a discussion of this high impact technology would have been appropriate. A positive aspect of the book is that many of the references are current (from 1985 and 1986) for the publishing date. Thus, *Electronic Ceramics - Properties, Devices and Applications* is highly recommended as a reference to the rapidly developing field of electronic ceramics.

Reviewer: Bruce A. Tuttle is a senior member of the technical staff at Sandia National Laboratories. His R&D activities include grain-boundary-controlled electronic ceramic materials, optoelectronic components, and ferroelectric thin films.

Chemical Sensing with Solid-State Devices

Marc J. Madou and S. Roy Morrison

(Academic Press, San Diego, CA, 1989), 557 pages.
ISBN: 0-12-464965-3

The field of chemical sensors is rapidly growing and highly diverse. The stated purpose of Madou and Morrison's book is to guide its audience, namely scientists and engineers with background in the physical sciences, through this multidisciplinary world. The book is well suited to this task, particularly for those who are new to the field or wish to broaden their perspectives. It is certainly not another of the "quick and dirty" chemical sensor books which covers the fundamental science in only a cursory manner. The book's strongest selling point is the centralized collection of a large portion of the extensive physics, chemistry, and electrical engineering background one must understand to conduct sensor research using the scientific, rather than the overly popular Edisonian method.

Chapters 1 through 6, entitled *Introduction, Solid State Background, Solid/Gas Interfaces, Solid/Liquid Interfaces, Catalysis Background, and Membrane Background*, provide a good foundation for understanding the fundamentals of chemical sensors in general and the material contained in the remainder of the book in particular. These introductory-sounding titles should not lead one to believe that applications are absent from these chapters, however. For example, a discussion of the currently active area of microelectrodes as chemical sensors is tucked away in a section of the *Solid/Liquid Interfaces* chapter. The topic does fit in with the surrounding material, but it is slightly annoying to have to look under "ultrasmall electrodes" in the index to locate this material. (Ultrasmall has apparently been added to micro and ultramicro as a prefix for such electrodes.)

Chapters 7 through 12, entitled *Biosensor Principles, Principles of ChemFET Operation, Silicon-Based Chemical Sensors, Thin-Film Gas Sensors, Solid Electrolytes - Devices*, and *Gas Sensors Based on Semiconductor Powders*, do a credible job of describing the current state of understanding in these fields. Although the first six chapters include no biological background, the biosensors chapter, which is introductory in nature, is sufficiently self-contained (including a short glossary of terms at the end) that anyone comfortable with the other parts of the book should have no difficulty here. Chapter 13, *Application of Solid-State Chemical Sensors*, provides an inventory of the most popular commercially used chemical sensors, along with an appraisal of the technological and economic barriers to commercial acceptance and widespread use of the various technologies outlined throughout the book.

The ten-page index is reasonably complete and helpful. Conspicuously absent is a table of symbols and notation, which would be invaluable for comprehending equations without the need to scan the text for definitions. Notably absent as well are chapters on at least two other promising solid-state chemical sensor device technologies: optical (fibers and waveguides) and piezoelectric (surface and various bulk acoustic waves). Admittedly, the authors limited themselves to solid-state sensors for which the response is due to "electrical effects in the solid," and the optical and acoustic technologies are somewhat outside their expertise. Nevertheless, much of the background laid down in the first six chapters would serve well for chapters on other technologies.

Although it contains numerous examples from the recent literature, with an average of 70 supporting references per chapter, the book is not intended to be a comprehensive review of the very latest chemical sensor literature. Rather, the references are used mainly to illustrate and support the description of the various sensors and their operating principles. Most of the references and the material borrowed from them are appropriate for the topic under consideration. Occasionally, however, the chosen example is less than optimal. In the introduction to cyclic voltammetry, for example, the "typical" voltammogram displays a sharp upturn in anodic current, probably due to solvent breakdown, closely following the anodic peak of the redox couple; no mention is made of the fact that this upturn is not part of the redox couple's voltammogram. Points such as this, which would not perturb an electrochemist but might perplex a physicist, illustrate the difficulty of writing a book that is equally comprehensible to everyone from electrical engineers to chemists.

The task of editing the book was not accomplished in a stellar fashion: many commas are missing or out of place, words or phrases are occasionally omitted, a few sentences run on and a few have been fragmented, and strange constructions are used here and there (one of my favorites: "...a thin layer of Na_2SO_4 was formed...and a Nernst equation was observed." I too have found that excessive exposure to electrochemistry causes me to observe Nernst equations). Taguchi sensors are referred to in the index as SiO_2, rather than SnO_2, sensors. Errors of this sort are only a relatively minor distraction and do not often obscure the point being made.

All in all, *Chemical Sensing with Solid-State Devices* should prove most valuable to those planning to enter the chemical sensor research field and to those with a need to understand the science behind chemically sensitive solid-state devices. With the addition of problem sets, it might serve as the basis for a graduate course on chemical sensors as well.

Reviewer: Antonio J. Ricco joined Sandia National Laboratories' Microsensor Research Division in August 1984. His research centers around solid-state chemical microsensors, particularly those based on surface acoustic wave devices, acoustic plate mode devices, optical fibers and waveguides, and silicon-based devices. □

Candidates Sought for MRS Fall Student Awards

The MRS Awards Committee is presently accepting applications for 1990 MRS Fall Meeting Graduate Student Awards. Designed to recognize outstanding research by a graduate student, the award consists of a plaque, paid Fall Meeting registration, and a $250 cash prize. To be eligible, a student must be the author or co-author of a symposium paper being presented at the 1990 MRS Fall Meeting, but need not be the presenting author of the paper during the symposium.

A group of finalists will be selected from the award applications and notified by October 1. Finalists will be required to give a ten-minute presentation based on their symposium paper at a special student presentation session at the Fall Meeting in Boston on Tuesday, November7, 1990. The winners will be announced during the Von Hippel Award ceremony to be held Wednesday evening, November 28.

Deadline for applications is **August 31, 1990.** To obtain an application form, contact the Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237; phone (412) 367-3003; fax (412) 367-4373.