

Interlayer Dielectrics for Semiconductor Technologies

Shyam P. Muraka, Moshe Eizenberg, and Ashok K. Sinha, Editors

(Elsevier Academic Press, 2003)

480 pages; \$185.00

ISBN 0-12-511221-1

Moore's law predicts that the number of transistors in a semiconductor device will double every 18 months. As those in the semiconductor field may attest, it seems as though the amount of information generated to engineer these devices follows the same trend. The aim of this text is to give the reader an understanding of the issues involved with interlayer dielectrics as applied to silicon-based semiconductor devices, and to give readers an information base that will allow them to stay knowledgeable about the latest developments. The book is a compilation of works assembled from a mix of both academic and industrial authors that gives the reader a broad feel for all aspects of interlayer dielectric science and integration.

Due to the generalized nature of the book, it is most applicable for those first studying interlayer dielectrics. This text explains some of the basic science behind using different materials in device manufacturing and introduces some of the issues associated with their integration. Both silicon-based and polymeric low- κ dielectrics are treated. The editors seem to understand the trends for expanding information, and have thus chosen to give an overview of the basics in order to extend the useful lifetime of the book. Published in 2003, some of the information is dated, and some newer technologies are not introduced.

The reader interested in industrial integration of interlayer dielectrics will generally be pleased with the treatments in this text. The reader interested in fundamental materials science aspects of interlayer dielectrics may be disappointed, with a couple of notable exceptions. Of note to materials scientists are three chapters dedicated to processing low- κ dielectrics, one chapter to low- κ characterization, and one chapter to nanoporous dielectrics in general. The latter is of special note, due to the authors' careful treatment of pore structure-materials property relationships.

Chapter 1 of the text defines interlayer dielectrics as those used during device processing, such as etch stops and anti-reflection coatings; those insulating between metal lines or adjacent transistors, such as low- κ dielectrics; and those that are active during the device operation, such as gate oxides. The reader should note, however, that the majority of this text deals mainly with low- κ materials,

with the exception of a single chapter addressing high- κ gate oxides and a single chapter dealing with optical waveguides. While technically interesting and summarized as well as could be expected in a single chapter, these subjects are deserving of their own texts.

In summary, this text is highly recommended for the industrial semiconductor engineer beginning work with low- κ dielectrics or wanting a basic introduction to many aspects of interlayer dielectrics. This text will continue to be applicable to semiconductor technologies for longer than expected from Moore's law.

Reviewer: Brian P. Gorman is an assistant professor of materials science and engineering at the University of North Texas. His research interests include supercritical processing and mechanical characterization of low- κ dielectrics and transmission electron microscope characterization of interlayer dielectrics.

Elementary Electronic Structure (Revised Edition)

Walter Harrison

(World Scientific, 2004)

838 pages; \$86.00

ISBN 981-238-708-0

"Why does this material behave this way?" is one of the toughest questions facing materials scientists. For those interested in finding not only an answer, but also the underlying understanding, this 800-page textbook is a wonderful resource. Being guided by the application of well-established computational approaches in condensed-matter physics to a wide range of systems, the reader acquires a valuable intuition leading to the understanding of trends. This is particularly important in the era of *ab initio* calculations, which correctly predict the behavior of materials, but do not necessarily provide an answer to the question "why?"

To a large degree, finding the simplest way to explain a certain phenomenon without oversimplification is an art, one in which Walter Harrison is an established master. The tools of his art are the one-electron approximation, pseudopotentials, and the tight-binding model. He applies this set of tools to explain the electronic structure and the nature of bonding in materials ranging from metals to covalent and ionic crystals.

Harrison guides the readers skillfully through phenomena of current interest, including defects and impurities; strongly correlated *f*-systems; and low-dimensional systems including surfaces, interfaces, and nanostructures. Readers interested in why carbon forms a large variety of structures with very different properties will find an answer in the discussions of not only dia-

mond and graphite, but also the carbyne chain, fullerenes, and nanotubes. For those interested in semi-quantitative estimates related to electronic structure and bonding, the book contains valuable tables and ready-to-use expressions for matrix elements in the Schrödinger equation. Illustrating trends across the periodic table resulting from changes in the electronic structure, the author provides the basis for a physically sound intuition, which is most precious in materials science.

Reviewer: David Tománek is professor of physics at Michigan State University, specializing in computer simulations of nanostructured materials.

Correlation Spectroscopy of Surfaces, Thin Films, and Nanostructures

Jamal Berakdar and Jurgen Kirschner, Editors

(John Wiley & Sons, 2004)

238 pages; \$180.00

ISBN 3-527-40477-5

Recent advances in electronics, scientific instrumentation, theoretical methods, and computational resources have resulted in numerous advances in the understanding of the physical and chemical properties of materials. This book contains 16 chapters that are derived from the conference Coincidence Studies of Surfaces, Thin Films, and Nanostructures, held in September 2003 in Germany. There are over 70 contributions from experts at some 50 laboratories from various countries. The book does an excellent job of presenting the synergism between theory and experiment, with many examples of how one helps to guide the other. The latest developments in both theoretical and experimental surface physics are covered, and future research directions are considered.

Recent developments in electronics have made possible new experiments involving coincidence and correlation spectroscopy for electron-electron, electron-atom/ion, and atom/ion-ion(atom) dynamics at surfaces. These coincidence and correlation measurements provide extremely detailed information about dynamic processes involved in surface physics. Specific atomic and electron encounters and interactions can be delineated. Many different surface physics experimental methods are encountered throughout the book, and the experimental results are related to the modern theories. Some of the experimental methods include Auger electron spectroscopy and diffraction, electron spectroscopy, Auger-photoelectron coincidence spectroscopy, electron energy-loss spectroscopy, electron momentum spectroscopy, electron stimulated

desorption, electron removal spectroscopy, time-of-flight methods, x-ray photoelectron spectroscopy, and translation energy spectroscopy, among others.

Paralleling and often leading these experimental innovations are new theoretical techniques. These techniques include many-body approaches, *ab initio* methods, the jellium model, dynamical mean-field theory, random phase approximation, wave packet propagation, time-dependent perturbations, spin-orbit coupling, scattering cross sections, quantum interference, perturbation theory, screening potentials, configuration interaction, exchange correlation, density functional theory, and many others.

I recommend this book to serious researchers involved in surface physics and chemistry, as the book provides an excellent snapshot of the status of state-of-the-art research along with projections about future directions of the field.

Reviewer: J. Wayne Rabalais is Distinguished Professor of Chemistry in the Department of Chemistry and Physics at Lamar University.

Advances in Amorphous Semiconductors

Jae Singh and Koichi Shimakawa
(CRC Press, 2003)
329 pp.; \$95.00
ISBN 0-415-28770-7

Two accomplished researchers working on amorphous and glassy materials have collaborated to produce this interesting new book. Its purpose, as suggested in the preface, is to offer a new text for students, researchers, and teachers in this area of materials science. The book offers a masterful review of the classic literature in the area and achieves this in a convenient 300-page volume. The book is well written, presented in a logical manner, and reasonably easy to read.

The book touches upon most aspects of these important materials, but its prime focus is on electronic and optical properties, with a detailed discussion of defects, transport, photoconductivity, and light-induced effects. There is a strong emphasis on amorphous silicon hydride (a-Si:H) and less frequent discussion of amorphous germanium and chalcogenide glasses such as AsSe and As₂Se₃. Passing mention is made of a-C; a-SiO₂ is not discussed. Where a-Si:H is concerned, the book complements the classic work of the area (R. Street, *Hydrogenated Amorphous Silicon*, Cambridge University Press, 1991) with a more detailed treatment of mathematical techniques to model optical

properties, photoluminescence, and transport. The book concludes with a compact chapter on applications.

For a broad survey of amorphous materials, I would still recommend R. Zallen, *The Physics of Amorphous Solids* (Wiley, 1983) and S.R. Elliott, *Physics of Amorphous Materials* (Longman, 1990). In the areas of emphasis, Singh and Shimakawa offer many valuable updates to these excellent but aging references.

I believe that this book should indeed be in the collection of anyone interested in electronic and optical properties of glasses and amorphous materials. Self-contained treatments of theoretical techniques are presented, and some discussion of experiments is offered, particularly those connected to spin resonance and defect spectroscopy.

The only shortcoming I can report is that there is little discussion of a large literature on the modeling of these materials. A principal current tool for studying disordered phases of materials is molecular dynamics (both empirical and *ab initio*). While these methods are mentioned in passing with Monte Carlo techniques, the book includes few references to models generated with these techniques, and to the physical insights these computational tools provide to structure, defects, and electronic properties.

Reviewer: David A. Drabold, professor of physics at Ohio University, focuses on structural modeling of glasses and amorphous materials, electronic structure and photoresponse, and computational methods.

The Story of Semiconductors

John Orton
(Oxford University Press, 2004)
522 pages, \$54.50
ISBN 0-19-853083-8

This book tells about those semiconductors that have had a substantial technological impact during the past half-century. Author John Orton witnessed and helped with the creation of the age of semiconductors at the Mullard Research Laboratories (later Philips) in Redhill, England, and then at the University of Nottingham, where he held the Philips Chair in Optoelectronics in the Department of Electrical and Electronic Engineering. To cover such a vast topic in 500 pages requires selectivity, but few topics of real significance are missing.

The title is apt. The book tells the story of three entangled main themes: semiconductor physics, semiconductor materials, and semiconductor devices. It does more, setting historical and economic contexts and offering glimpses into the personali-

ties of key people. Those readers will get the most from it who have some knowledge of the three themes. People with less interest in technical details should be able to follow the narrative threads by reading the main text and skipping the more technical "boxes." Given the book's wide coverage and Orton's pleasant, somewhat informal style, experts in semiconductors should also find much to enjoy.

The book's organization is historical, within each of several materials categories. After an introduction to semiconductor concepts and some of the early applications of semiconductors, Orton takes us through the invention of the transistor and then to silicon metal oxide semiconductor devices, integrated circuits, and microelectronics—the basis of the second industrial revolution. He treats the unexpected discovery of the quantum Hall effect and its application as the most accurate standard of resistance. Specialized high-power uses of silicon (e.g., in thyristors) are discussed for controlling motors and for rectification. Next, Orton treats compound semiconductors with their applications in high-frequency devices and as sources and detectors of light. Planar heterostructures are featured, with their huge impact on device technology, but more exploratory work on quantum wires and dots is also discussed. The story of optical communications is told succinctly, with its intricate coupling of the science and technology of the optical fibers with that of the semiconductor receivers and laser sources. Semiconductor detectors and imaging devices for infrared light are also discussed, along with some civilian and military applications. The book ends with polycrystalline and amorphous semiconductors, especially silicon, and their use in solar cells and liquid-crystal displays.

There are numerous line drawings to illustrate fundamental physical principles and device layouts and 10 pages of remarkable photographs of some of the people featured in the text. I highly recommend *The Story of Semiconductors* for anyone who wants the big picture along with many of the details. My only complaint concerns the index. I would prefer to see it list more people, devices, and abbreviations.

Reviewer: Miles V. Klein is research professor of physics at the University of Illinois at Urbana-Champaign. A physicist of experimental condensed matter, he has worked on semiconductors and their alloys and heterostructures using Raman and other optical techniques.

The following recently published books, relevant to materials research, have come to *MRS Bulletin's* attention. Some of the books listed here may be reviewed in future issues of *MRS Bulletin*. To review a book from the list or to offer recommendations of additional books, contact K. Wilson, Editorial Assistant, *MRS Bulletin*, 506 Keystone Drive, Warrendale, PA 15086-7573, USA; e-mail bulletin@mrs.org.

History, Biography and Unclassified

Springer Handbook of Condensed Matter and Materials Data, W. Martienssen and H. Warlimont, Springer Publishing, 2005, 1120 pp., \$249.00, ISBN 3-540-44376-2.

Experimental Techniques

Introduction to Nondestructive Testing: A Training Guide (2nd Edition), Paul E. Mix, John Wiley & Sons Inc., 2005, 681 pp., \$99.95, ISBN 0-471-42029-8.

Inorganic Chemistry, Electrochemistry, Other Chemistry, & Ceramics

Electrochemical Aspects of Ionic Liquids, Hiroyuki Ohno, John Wiley & Sons Inc., 2005, 392 pp., \$150.00, ISBN 0-471-64851-5.

Principles of Inorganic Materials Design, John N. Lalena and David A. Cleary, John Wiley & Sons Inc., 2005, 419 pp., \$99.95, ISBN 0-471-43418-3.

Materials Processing

The Aqueous Cleaning Handbook, Malcolm C. McLaughlin, Alan S. Zisman, and the Technical Services Staff of Alconox Inc., Alconox Inc., 2005, 182 pp., \$39.95, ISBN 0-9723478-1-X.

Laser Processing of Engineering Materials: Principles, Procedure, and Industrial Application, John C. Ion, Elsevier, 2005, 556 pp., \$59.95, ISBN 0-7506-6079-1.

Powder Metallurgy and Particulate Materials Processing, Randall M. German, Metal Powder Industries Federation (MPIF), 2005, 536 pp., \$95.00, ISBN 0-9762057-1-8.

Metallurgy

Corrosion Resistance Tables: Metals, Nonmetals, Coatings, Mortars, Plastics, Elastomers and Linings, and Fabrics (4 Vol. set, 5th Ed., revised and expanded), Philip Schweitzer, Marcel Dekker Inc., 2004, 3500 pp., \$495.00, ISBN 0-8247-5676-2.

Handbook of Environmental Degradation of Materials, Myer Kutz, William Andrew Publishing, 2005, 632 pp., \$275.00, ISBN 0-8155-1500-6.

Selection of Engineering Materials and Adhesives (Dekker Mechanical Engineering Series, Vol. 186), Lawrence W. Fisher, CRC Press, 2005, 608 pp., \$99.95, ISBN 0824740475.

Physics & Electronics

Physics of Continuous Matter: Exotic and Everyday Phenomena in the Macroscopic World, B. Lautrup, Institute of Physics Publishing, 2004, 608 pp., \$45.00, ISBN 0-7503-0752-8.

Polymer Chemistry & Biomaterials

Organic Photovoltaics: Mechanisms, Materials, and Devices (Optical Engineering Series, Vol. 99), Sam Shajing Sun and Niyazi Serdar Sariciftci, CRC Press, 2005, 664 pp., \$149.95, ISBN 082475963X.

Organometallic Chemistry of the Transition Metals (4th Edition), Robert H. Crabtree, John Wiley & Sons Inc., 2005, 546 pp., \$94.95, ISBN 0-471-66256-9.

Practical Guide to Polyethylene, Cornelia Vasile and Mihaela Pascu, Rapra Technology, 2005, 184 pp., \$90.00, ISBN 0-85957-493-9.

Structure of Materials

Structure-Property Relations in Nonferrous Metals, Alan M. Russell and Kok Loong Lee, John Wiley & Sons Inc., 2005, 499 pp., \$125.00, ISBN 0-471-64952-X. □



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