Materials Science and Technology: A Comprehensive Treatment

Edited by R.W. Cahn, P. Haasen, and E.J. Kramer
(VCH Publishers, 18 volumes).
ISBN: 156081-190-0

The overall structure of this impressive 18-volume series is as follows (the seven volumes published to date and reviewed here are denoted by an asterisk):

The foundations of materials science (six volumes):
Volume 1—Structure of Solids
Volume 2—Characterization of Materials
Volume 3—Electronic and Magnetic Properties of Metals and Ceramics*
Volume 4—Electronic Structure and Properties of Semiconductors*
Volume 5—Phase Transformations in Materials*
Volume 6—Plastic Deformation and Fracture of Materials

The properties of specific materials (six volumes):
Volume 7—Constitution and Properties of Steels*
Volume 8—Structure and Properties of Nonferrous Alloys
Volume 9—Glasses and Amorphous Materials*
Volume 11—Structure and Properties of Ceramics
Volume 12—Structure and Properties of Polymers
Volume 13—Structure and Properties of Composites

The latest processing methods (four volumes):
Volume 15—Processing of Metals and Alloys*
Volume 16—Processing of Semiconductors
Volume 17—Processing of Ceramics
Volume 18—Processing of Polymers

Specific applications (two volumes):
Volume 10—Nuclear Materials
Volume 14—Medical and Dental Materials*

It is important to appreciate the scale of this enterprise. On its own, each volume merits a review of the length we have been allocated for the first (seven-volume) tranche of the series. Each volume has an editor who is well-established in the particular field, and most volumes comprise 600-800 pages each with up to 15 chapters covering specialized topics written by acknowledged authorities. Each chapter contains a notable list of symbols and abbreviations, and each volume has an excellent index.

Given the size and scope of the project, perhaps it isn't surprising that we were asked to take our traditional Open University team approach to reviewing it. Each of us has read at least two volumes, one as an expert and another as an informed browser.

It is a tremendous challenge to devise and implement a series with such ambitious aims: "It is intended to mark the coming-of-age [of materials science], define its nature and range, and provide a comprehensive overview of its principal constituent themes." This mission is impossible, of course, in the sense of satisfying all needs and interests. However, on the basis of the seven available volumes, and bearing in mind the qualifications outlined below, we are confident that the series will be acknowledged as a significant compendium of developments in materials science.

Of course, the nature of materials, and therefore their uses, is extremely diverse which means that the scientists and engineers involved in researching, developing, producing, and designing with them have a variety of backgrounds and interests. Ask any members of this materials community what they would like to find in a series entitled "Materials Science and Technology," and their answers will be disparate, as our small team demonstrated.

On the whole, our judgment is that those who work within the paradigm of materials science rooted in the "physics modeling" of materials (especially metals) which has developed rapidly since the 1950s and subsequently evolved to encompass modern ceramics, electronic materials, composites, and so forth, will welcome the series—albeit with reservations about the level of solid-state physics involved in some of the early chapters.

However, those who appraise the series more from the technology end of the materials science and materials technology spectrum may be disappointed. Some volumes, notably Volumes 7 and 14, have an overtly technological approach but, the overall emphasis appears to be on materials science per se with materials technology being an afterthought. (Hopefully Volumes 8 to 18, still to come, will refute this). Nevertheless, in this context it is important to remember that the two most widely used engineering materials are timber and concrete. Neither are featured in the series, nor are other vital materials such as paper, textiles, adhesives, abrasives, foams, and paints. Furthermore, materials technology is far more than the processing of materials. For instance, it is concerned with the interdependence of materials selection, process selection, and product design, and with design for service, manufacture, and increasingly, recycling and materials utilization. Materials science will continue to play an increasingly crucial role in all these aspects of materials use.

The series is directed at a broad readership. But rather than being broad for any one reader, it is broad by addressing a wide range of readers with different backgrounds, each of whom is likely to home in on particular volumes. The sheer size of the work makes it difficult to review, particularly as the treatment of some subjects is spread among several chapters, often in different volumes. While this is an excellent way to integrate the subject matter, it also creates problems for the potential users and, detailed as the volume indexes are, the usefulness of the complete work will depend heavily on the quality of the promised cumulative index.

Volume 3A—Electronic and Magnetic Properties of Metals and Ceramics

Edited by K.H.J. Buschow
(VCH Publishers, 1991, 641 pages).
ISBN: 089573-691-8

The editor states that this volume cannot be regarded as a standard textbook nor as an exhaustive or systematic catalogue of electronic/magnetic materials; rather, it focuses on topics which illustrate the main achievements. This description is accurate. In such a wide and extremely active area, it is perhaps not surprising that the result is a volume in two parts!

The style in each of the seven chapters in Volume 3A is lucid and authoritative, but the readers should be aware that the level at which information is imparted is comparable to that found in research papers relating to the various topics. Apart from the brief introductions to each chapter, there is little for the interested browser but a great deal for the scholar. For example, the first equation in Chapter 1 is a Hamiltonian for a system of ions with which electrons are interacting. Schrödinger, wave functions, and matrix elements follow in quick succession and all before the end of the introduction. Chapter 2—on the magneto-optical properties of metals, alloys and compounds—builds carefully but concisely from Maxwell's equations to the theory of Faraday and Kerr effects in terms of the complex conductivity tensor. Chapter 3, which deals with electronic transport properties in normal metals, swiftly develops into a consideration of a Boltsmann equation describing the evolution of the distribution function for electrons in the presence of electric and magnetic fields.

In these and subsequent chapters on superconductivity, magnetic properties of metallic systems, ultrathin films, and Fermi surfaces, the emphasis is clearly more on the solid-state physics of theoretical/ideal materials than with the materials science of real materials. However, Volume 3B promises chapters devoted to the properties of actual magnetic materials, and it is hoped that these will restore the balance.

Volume 4—Electronic Structure and Properties of Semiconductors

Edited by W. Schröter
(VCH Publishers, 1991, 603 pages).
ISBN: 0-89573-692-6

In the preface, the editor recognizes that the thrust of semiconductor materials research has been driven by the technological demands of the electronics industry, and states that the aim is to set the outcomes of this work in their technological context. Device fabrication, the other face of materials technology, has been held over to Volume 16.

The approach here differs from other texts in the field in which serious readers are referred to research papers for scientific understanding while authors explain the mysteries of devices based on semiconductors in various compositions, structures, and topologies. This volume is therefore successful, perhaps uniquely, in bringing together many facets of knowledge important to semiconductor engineers.

The opening chapter is essentially a standard text on the band theory of semiconductors, although its scope goes well beyond elementary texts. There follows an important review of charge transport mechanisms coupled with optoelectronic effects which have come to the technological forefront in recent years. The next six chapters take us away from ideal semiconductor crystals and into the real materials from which devices are made—with defects, impurities, nonequilibrium, and finite grains. This jump from ideal simplicity to the complex consequences of reality is one that all semiconductor engineers should make but which few achieve with broad understanding. Here is their opportunity. To the extent that 3d transition metals in silicon are unwanted impurities, the final chapter would have been better placed with Chapters 3 through 8, which treat the realities of crystal semiconductors. Two fields of recent interest, interfaces and quantum wires, find places later in the volume as does the expected chapter on amorphous silicon.

Overall, the book meets its aims, perhaps too well, in that it probably often goes beyond what engineers or researchers would want in even a detailed broad review.

Volume 5—Phase Transformations in Materials

Edited by P. Haasen
(VCH Publishers, 1990, 648 pages).
ISBN: 0-89573-693-4

This book provides a number of excellent reviews covering the science of phase transformations. The volume's tone is set in the first chapter on phase diagrams, which provides a good account of the thermodynamics underlying equilibrium phase diagrams, but does not attempt to cover their uses or limitations. Similarly, excellent reviews of the phase transformation theory—covering phenomena such as diffusion, solid-state precipitation, diffusionless transformations, spinodal decomposition, ordering and solidification—follow in subsequent chapters. Each provides a critical review of the area, is well-supported by experimental evidence, and is unashamedly mathematical in its approach. Although the volume is well-referenced, and good bibliographies are included, a previous knowledge equivalent to a degree in solid-state physics or materials science is assumed.

The majority of the coverage concerns metals, with some references to ceramics, but only cursory allusions to phase transformations in polymers. Given the structure of the series, however, perhaps these omissions will be rectified elsewhere in due course. In summary, readers are provided with a comprehensive review of the science of phase transformations in crystalline materials, but relatively little on the use of such transformations in materials engineering and technology.

Volume 7—Constitution and Properties of Steel

Edited by F.B. Pickering
(VCH Publishers, 1991, 824 pages).
ISBN: 0-89573-695-0

The preface states that this volume "is unashamedly technological in approach and content, but nevertheless shows how sophisticated are the concepts used in the processing of ... steel, and the firm scientific foundations upon which developments are based." Each chapter provides clear links between theoretical background and industrial practice. This volume is an outstanding example of the integration of materials science and technology, primarily because of its implicit philosophy that structure/property relationships are intimately dependent on processing.

The core of the volume (nine of 15 chapters) is concerned with specific types of steel—from the various mass-produced tonnage materials, through modern cast irons and stainless steels, to the complex tool steels and iron-, nickel- and cobalt-based superalloys. This core is supported by two chapters on the microstructures found in steel, the transformations producing them, and the properties, and then by three chapters on the processing of steel—from continuous casting to complex heat treatment. The volume concludes with two more chapters on processing and includes the vitally important topics of welding and surface treatment.

All informed browsers were happy with this volume, and its level is clearly appropriate to practicing engineers, metallurgists, and materials scientists who must relate underlying theoretical concepts to the properties and processing of commercial materials. It neatly fills the gap between reference works packed with technical data and information and the omnibus volumes on metallurgy/materials science written primarily for undergraduates.

Volume 9—Glasses and Amorphous Materials

Edited by J. Zarzycki
(VCH Publishers, 1991, 797 pages).
ISBN: 0-89573-697-7

This volume contains 15 chapters with a treatment level similar to that of an extended review article, although the individual chapters tend to have broader coverage than is typical of a review article.

The book starts with a chapter on the classical technology of the oxide glasses and their development, continuing up to present-day processes for flat glass, containers, and fibers. This is followed by a review of newer and more novel methods of making glasses and amorphous materials (they are differentiated by the former exhibiting a glass transition) such as quenching, shock waves, pyrolysis, and the increasingly important sol-gel processing. The next two chapters cover, respectively, vitrification and crystallization, including glass transition and relaxation, and modeling the structure of noncrystalline materials. Oxide glasses, ion-implanted glasses, organic glasses (including polymers), and glasses based on the chalcogenides, the halides, metals, and carbon each have a chapter devoted to them. Optical, mechanical, and electrical properties are the subjects of the ensuing three chapters, and the book concludes with an account of optical fibers.

The content is reasonably up-to-date and represents a useful contribution to the literature; it is more for workers in adjacent fields and postgraduate students than for specialist researchers. Inevitably, any work of this sort will attract criticism for not going far enough in some area or not covering certain topics; so here's our ha'porth(!). The individual chapters on the glass types contain details on their optical, mechanical, and electrical properties. Unfortunately, instead of pulling these together, the three subsequent chapters on properties limit themselves to a narrow spread of materials (optical glasses, oxide glasses, and semiconducting glasses, respectively). Thus, an opportunity for some valuable syntheses across the field has been foregone.

Volume 14—Medical and Dental Materials

Edited by D.F. Williams
(VCH Publishers, 1991, 469 pages).
ISBN: 0-89573-801-5

This collection of review papers provides a useful and welcome introduction to selected aspects of medical and dental materials. Chapter 1 is an excellent review based on classifications for biomaterials in relation to their functional requirements, susceptibility to degradation, and the host response and its mediators. The following four chapters (Chapters 2 through 5) are devoted to synthetic materials in uses as diverse as joint replacements (excellent on metal components), artificial organs (somewhat cursory), and tissue healing (fascinating). Chapters 6, 7, and 13 consider materials for use in dentistry, ranging from restorative materials to false teeth. There was some overlap here, but all presented good overviews of current research. The diversity of biomaterials topics was further demonstrated by well-written chapters on the bioengineering of implantable sensors and electrodes (Chapters 9 and 10), drug delivery systems (Chapter 11), and ophthalmology (12).

Biomaterials is a subject that encompasses a diversity of disciplines. Consequently, it will always be a problem to produce a volume satisfactorily reflecting the field. Inevitably, then, this volume can be criticized as a rather *ad hoc* collection of review papers. On the other hand, it does give a useful introduction to some important developments for those who are not knowledgeable in the field; here the informed browser found access fairly straightforward and the effort very rewarding. Perhaps, as with Volume 7 on steels, this occurs because the materials science developed is limited to that needed to support the essentially technological considerations that the volume addresses. Having said that, in places—particularly Chapter 8 on models of adhesion and surface analysis—the scientific underpinning was rather skimpy.

Volume 15—Processing of Metals and Alloys

Edited by R.W. Cahn
(VCH Publishers, 1991, 628 pages).
ISBN: 0-89573-802-3

Although the title of this volume implies a rather wide coverage, its scope is limited because, along with most modern materials science and engineering undergraduate courses, the editor has chosen to consign extractive metallurgy to chemical engineering. So, our raw material is presumably metal ingot! Unfortunately, the volume does not follow current undergraduate course practice in considering the consequences of the interaction between materials properties, processing route, and product design, and only the chapters on solidification processing (casting) and powder metallurgy cover the shaping of metals to artifacts. The other chapters cover the production of novel materials by solidification, mechanical alloying, nanoprocessing and electrodeposition, and microstructural modification—either locally by ion implantation, laser treatment or globularly, or in bulk by recovery, recrystallization, and texture formation.

Although each chapter provides a useful review of its area, this volume lacks cohesion and suffers from the exclusion of solid-state forming and cutting. The connection between material microstructure and process route is paramount if optimum use is to be made of the many advanced materials and composites presently being invented. To relegate the forming and machining of these materials to the province of mechanical engineering is short-sighted, and hopefully a similar line is not taken in the volumes on processing ceramics and polymers. In short, this volume provides numerous reasonable physical metallurgical reviews but does not have the cohesion present in other volumes of the series.

At $265 each, these volumes are very expensive. Most are a must for materials libraries, but given the variation in approach and accessibility, it would be wise to assess them individually.

Review team: Nicholas Braithwaite, Lyndon Edwards, Charles Newey, Ken Reynolds, Graham Weaver, and George Weidmann are on the faculty of technology in the Open University, Milton Keynes, United Kingdom. Christina Doyle of Howmedica International was a consultant to the team. □

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