BOOK REVIEW

An Introduction to Materials Engineering and Science for Chemical and Materials Engineers

By Brian S. Mitchell, Wiley, Hoboken, NJ, 2004, 976 pp., $145.00.

Professor Brian S. Mitchell's book is intended to serve as an introductory textbook in materials science for materials and chemical engineers. *An Introduction to Materials Engineering and Science for Chemical and Materials Engineers* is targeted to a narrower base than many other similar textbooks, in that it is not explicitly aimed for the electrical, civil, and mechanical engineers who are often required to take an introductory materials science course. This serves as an advantage in that the level of discourse is somewhat higher than usually seen in books of this nature, but has the disadvantage that many currently employed chemical and materials engineers are working in close collaboration with many of these other engineers in cross-disciplinary projects.

The book is arranged almost ideally. Most textbooks for this course have many chapters covering many apparently isolated and different aspects of the field, resulting in the feeling that the course is a mile wide and a micron deep. Each of the kinds of matter, metal, element, oxide, and polymer is covered separately. Chapters on electrical properties follow chapters on corrosion, which follow chapters on mechanical failure. Mitchell on the other hand has only eight chapters, where, for example, the structure of elements, metals, oxides, ceramics, polymers, composites, and biological materials are described and compared. The fact that complex materials like composites and biological materials are considered from the beginning is another of the real attractions of this book.

Each chapter consists of the application of a particular phenomenon, for example, kinetics, to the field of materials science. The text, in general is well written, and more than adequately supported by figures (plots and schematics) and comparative tables. Throughout each chapter are several cooperative learning exercise, where two students, working together, consider various aspects of a problem, and come together to compare their results and build to a further conclusion. While such problem solving techniques mimic real-world problem solving, it is not clear how well these will work in practice. I would like to actually try some of these exercises in a class. There are typically around 15 problems at the end of each chapter, graded by difficulty. One lacuna with this book is the relative lack of engineering applications of the material in the course. A few case studies are included in the last chapter—however, a stronger sprinkling of these kinds of problems throughout the book would be very advantageous.

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The first chapter considers the structure of materials. It starts with the forms of chemical bonding, and then deals with crystal forms of metals and alloys. This is followed by a better consideration of structures of ceramics and glasses than is usually seen in these kinds of textbooks. A good, interesting discussion of the structure of polymers follows. One of the advantages of this book is that the student immediately sees polymers in the same context as metals and oxides. The chapter ends with discussions of structures of composites and biological materials. The section on biological materials is necessarily brief, but considers sugars, proteins, and nucleic acids, but then discusses biological structures such as bone and muscle.

Once this introductory material is covered, Mitchell covers thermodynamics of metals and alloys, ceramics and glasses, polymers, composites, and biological materials. After a brief review of basic thermodynamics, simple phase diagrams are introduced. The Fe-C system, including the relationship of phase diagram, time-temperature history, and microstructure is considered in appropriate detail. Ternary phase diagrams are introduced in the section on ceramics and glasses. This is followed by a discussion of wetting behavior, followed by a description of sintering and densification. Finally, some of the phases and interphases present in composite and biological systems are discussed.

Kinetic processes are treated in the third chapter. First general rules of rate processes like the law of mass action, and the Arrhenius relation are discussed. Then, important processes in metals, such as the martensitic transition and corrosion, are covered in detail. Nucleation and growth is introduced under the subheading of kinetic processes in ceramics and glasses. Under polymers, the kinetics of polymerization is considered in some detail, followed by briefer discussions of polymer degradation. The chapter ends with brief discussions of chemical vapor deposition, and ligand binding to cell surface receptors. Once again, the presentation of the unifying themes of kinetic processes across the classes of materials is very satisfying.

The fourth chapter considers transport properties of materials. Thus, this chapter treats mass and momentum flow along with topics like viscosity, followed by heat flow, mass flow, and diffusivity. This is an important chapter, but I would probably reverse the presentation of material, going from diffusivity to heat flow to momentum/mass flow.

The mechanics of materials is the subject of Chapter 5. This is the chapter where one receives the real payback for understanding the structure, thermodynamics, and kinetics of metals and alloys, ceramics and glasses, and polymers. The chapter starts by explaining elasticity, ductility, and their molecular underpinnings with respect to metals and alloys. Then, one goes on to stress–strain diagrams and the associated notation. The mechanics of ceramics and glasses are a direct contrast of those metals because of their brittleness. Ideas like fracture toughness and fatigue are introduced to the student. Polymers are then treated along with ideas like viscoelasticity, and the WLF equation. The mechanical properties of polymers are discussed, and their basis in the molecular structure is described. Then, the mechanical properties of composites, especially fiber-filled, are discussed in detail. Rubber reinforced polymer, laminate, and ceramic-matrix composites are not neglected. Finally, the mechanical properties of biological structures like skin, teeth, and bone are discussed. This is one of the high points of the book, where one can see directly how the wide range of mechanical behaviors is shown to directly depend on the molecular structure and important, but relatively sophisticated materials, like composites are described in some detail.

Chapter 6 contains the usual discussion of the electrical magnetic and optical properties of materials. Conductors, insulators, and semiconductors are all considered. The electrical properties of polymers, composites, and biological materials are all discussed. The electrical properties of polymers are discussed in some detail. The magnetic and optical properties are then considered. If it were important to cover these subjects in a course, one might want to augment the material in the text. An introduction to the processing of materials is presented in Chapter 7. For metals, die-casting, forging, rolling, extrusion, powder sintering, and densification are each described, as well as their relationship on the microstructure and other properties. For ceramics, pressing, casting, firing, and vapor phase processing (for example, chemical vapor deposition and integrated circuit processing) are discussed. For the processing of polymers die forming, extrusion, calendaring, fiber spinning, injection molding, and compression molding are all considered. Processing of composites and biologics are briefly discussed.

Finally, a chapter of Case Studies in Materials Selection is included. A brief introduction including some useful Web sites is presented, followed by studies of materials selection for a compressed air tank, ceramic piping for coal slurries in a coal liquefaction plant, a composite for an automotive drive shaft, and materials for teeth coatings. These case studies are considered in fair depth, but only offer several illustrations of practical applications of the material. Clearly, an instructor would like to augment the presentation of the material in the rest of the text with other practical engineering example. The book ends with a series of practical appendices. The index is excellent, covering nearly 50 pages. There is no CD-ROM of ready-made transparencies.

In summary, I heartily recommend this book, primarily because of the unified presentation of topics across materials classes. All of the important topics in an introductory materials science class are presented well, and covered by the problems. There are perhaps too few examples of engineering applications for my taste.

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