BOOKS: MATERIALS SCIENCE

Structural Catholicism

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Structure is perhaps the single most important determinant of a material's property, and is deserving of an integrated textbook. Samuel Allen and Edwin Thomas offer such a book in *The Structure of Materials*, noting in their introduction the methodology they have chosen: "Our text looks at one aspect of our field, the structure of materials, and attempts to define it and present it in a generic, 'materials catholic' way." In the traditional approach, ceramics, metals, polymers, and other types of materials are treated separately. Recognizing that there is a substantial amount of overlap in the description of the structure for such material classes, the authors adopt the more generic approach of developing structural descriptors for the various states of condensed matter. Their perspective certainly reflects modern thought in materials research and development.

The Structure of Materials
by Samuel M. Allen and Edwin L. Thomas
Wiley, New York, 1999. 463 pp. $102.95. ISBN 0-471-00082-5.

The Structure of Materials is based on the curriculum of the Department of Materials Science and Engineering at the Massachusetts Institute of Technology. Although primarily geared toward undergraduate students, the book contains interesting information for investigators at all levels. Advanced researchers, however, will find that the simplifications necessary in a textbook leave them wishing for a more thorough presentation.

Allen and Thomas present chapters on the main condensed states of matter: liquids and glasses, crystals, and liquid crystals. Two final chapters are devoted to imperfections and defects in ordered media and to the key concept of microstructure. Major advances in producing materials with desired properties can often be traced to control over and improved understanding of defects and microstructure. The topics presented in these final chapters are typically missing in conventional textbooks on solid state or condensed matter physics. The treatment of these topics clearly demonstrates that the authors' intended readers are materials scientists and engineers.

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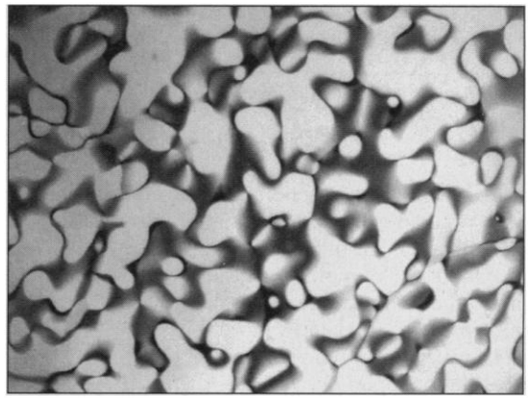
Among the most enjoyable aspects of the book are the copious sprinkling of examples of actual materials and their applications. Some of these, such as amorphous semiconductors in xerography, twisted nematic liquid-crystal displays, and thermoset–carbon fiber composite laminates, play important roles in our modern, technological world. The text also contains numerous well-chosen pedagogic illustrations that will help students relate to the presented material.



Nonperiodic structure. Antiphase boundaries form the dark lines in this transmission electron micrograph of thin-foil Fe_3Al.

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As with many other multi-author books, *The Structure of Materials* exhibits differences in authors' preferences and backgrounds, leading to a somewhat heterogeneous presentation. The chapter on the crystalline state is rather formal and tedious The one on liquid crystals, however, is very well written and deftly integrates concrete examples and mathematical description. (This is not surprising, given Thomas's background in liquid crystals.)

The authors sometimes hint at how structure relates to a particular property of materials, but in other cases this relationship is begging to be pointed out. For example, optical microscopy is one of the most important methods for identifying the phase of a liquid crystal, and the book includes exquisite optical micrographs of liquid crystalline films under polarized light. But the uninitiated reader will have no idea which optical properties lead to the distinctive patterns of the nematic, cholesteric (which, in my view erroneously, the authors call "twisted nematic"), and smectic phases. It would have been well worth spending a few pages explaining these.

I like the treatment of microstructure and inherent nonequilibrium. The beautiful example of metal forging drives home the importance of structural hierarchies of length scales spanning from the centimeter to the angstrom. The use of phase transformations to achieve certain microstructures with well-defined morphologies is documented with excellent examples. It would have been appropriate, though, to attempt to explain the physical mechanisms leading to phase transformations such as spinodal decomposition, which typically form approximately periodic, interconnected, two-phase microstructures.

The biggest surprise of the book is the authors' decision to restrict all their structural description to real space. This might, at first glance, seem like a very down-to-earth approach, suitable for students with modest mathematical training. And it does work reasonably well for the description of the liquid state, where the isotropic nature of the structural order collapses descriptors such as the pair distribution function into one-dimensional functions. In the chapter on the crystalline state, however, the avoidance of Fourier inverse space becomes painfully artificial. X-ray diffraction, which yields a Fourier map of a material's structure, has arguably had a greater impact on the advancement of our knowledge of structure than any other technique. The reason for its success lies in its ability to extract the essential characteristics of a periodic structure in an elegant way. Thus, to talk about the structure of crystals without invoking diffraction, even at the elementary level of Bragg's law, seems very incomplete. A lack of space cannot explain the absence of this topic; if space were the issue, I would gladly have sacrificed the eight pages devoted to the mathematics of second-rank tensors for some treatment of the reciprocal lattice. Students often find crystallography quite dry, and the authors' mathematical and symbolic method of presentation does little to alleviate this problem.

This shortcoming leads me to a suggestion for future treatments of the crystalline state. With the ubiquitous accessibility of the Internet and its tools, the time has come to leave the legacy of the formal description with arcane symbols to die-hard professional crystallographers. Students, in particular undergraduates, should be introduced to the symmetry operations, point groups, space lattices, and space groups with the aid of computer graphics. Having the ability to interactively use such computer tools could, to some extent, take the place of the good old ball-and-stick models.

Overall, *The Structure of Materials* is enjoyable to read. Allen and Thomas motivate and teach through well-chosen examples of important applications. The book will be a valuable tool in the hands of materials researchers, engineers, and all who are interested in matter in its condensed states.