books

Unifying the study of materials science

The Mechanical and Thermal Properties of Materials

A. McB. Collieu, D. J. Powney
283 pp. Crane, Russak, New York, 1973. $9.25

Statistical Physics of Materials

L. A. Girifalco
346 pp. Wiley, New York, 1973. $21.95

Reviewed by Herbert Herman

Ultra-pure glass is melted in a radiofrequency field by direct coupling with a water or gas-cooled crucible. This technique for melting batch materials, developed at Standard Telecommunication Laboratories in the United Kingdom, eliminates contamination by crucible degradation.

Materials science, both in the university and in industrial research laboratories, has come to represent the unification, at least in a titular sense, of solid-state physics and chemistry, metallurgy and ceramics. The reason for and the consequences of this tendency to converge these activities into one apparently unified field of study have received considerable attention (such as "Materials and Man's Needs—Materials Science and Engineering," National Academy of Science, 1974). But somewhat less attention has been devoted to the development of appropriate curricula of undergraduate and graduate training of materials scientists; a case in point is the lack of adequate textbooks in the field.

The current university departments of materials science generally have evolved from what were originally metallurgy and ceramics departments. The orientation has changed gradually with the coming of new faculty, trained in physics and chemistry, and more recently, in materials science. However, in spite of new directions that have been taken in materials-science education, there are few innovative teaching books that specifically approach the requirements of this new field.

The two books reviewed are at extreme ends of a wide spectrum; from an undergraduate "general" textbook on the basic physics of matter to a first-year graduate text on statistical physics. The former *The Mechanical and Thermal Properties of Materials* by Anthony McB. Collieu and Derek J. Powney is an undergraduate British text covering heat and mechanics, but with a wealth of applications to materials. The latter, *Statistical Physics of Materials*, by Louis A. Girifalco, introduces and employs statistical mechanics to explore the dynamical properties of crystals, from lattice vibrations to atomic migration. Both books generally succeed in a unifying of the study of materials science.

The Collieu and Powney approach is refreshing in that physical properties are related to actual laboratory experiences. For example, in the chapter on fluid flow, they discuss the concept of non-Newtonian liquids in the context of lubrication. This connection between theory and practice is natural (though not usually stressed in most physics texts) and leads to continuity between the fundamental and the applied. Experiments are outlined with sufficient detail, so that a physical concept, such as thermal conductivity, can be readily appreciated through an illustration of how the relevant measurements are obtained. The questions for each chapter are at three levels, from elementary to advanced. These questions are generally rather good, and many are thought provoking. Answers are given for all questions requiring numerical calculations. This book should be considered as a possible text for a first course in technical or general physics for undergraduates majoring in materials science.

Girifalco's book fills an important need in materials science graduate curricula. The book is intended for first-year graduate students, but could also play a role as a refresher volume. It is a readable book that requires little in the way of advanced mathematics. A good introduction develops the concepts of statistical physics. This is followed by the usual applications to the solid state, such as simple crystals, free-electron theory and kinetic theory of electron transport. The author also covers order–disorder phenomena, point defects and diffusion in crystals. The volume is self-contained and would form a fine text for a course oriented to materials-science students. It is important to note that the similarity of Girifalco's book to previous treatments ends at the table of contents. Girifalco has a unique ability to make a subject interesting and indeed understandable. I am reminded of a little book that he wrote some years ago on diffusion "for the everyman" (*Atomic Migration in Crystals,* Blaisdell, New York, 1964); This little gem has received insufficient attention. It is likely that *Statistical Physics of Materials* will become an accepted graduate volume, though I think that the absence of problems will limit the book's appeal as a textbook.

These two books are an indication that the needs of education in materials science are beginning to be recognized. Both books are welcome contributions.

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Liquid State Physics—A Statistical Mechanical Introduction

C. A. Croxton
421 pp. Cambridge U.P., New York, 1974. $28.50

Liquid-state physics is a popular and growing field. The theory of simple atomic liquids has made enormous progress during the last decade. This progress evolved from the detailed "experimental" information determined from computer simulations of atomic fluids. Armed with this information, workers have formulated a few basic concepts that provide the foundation of the modern theories of atomic liquids. These theories are both simple and quantitatively accurate. Further, there is every reason to expect that the same concepts will lead to a successful treatment of complex molecular fluids. Thus, it seems that the time has come for a monograph or textbook that explains both the basic concepts and the theoretical techniques used in implementing the concepts. Unfortunately, Clive Croxton's book, *Liquid State Physics—A Statistical Mechanical Introduction,* does not succeed at this task.

The topics touched upon in the book are certainly the ones that should be included in a good text. These are cluster expansions, functional derivatives and functional Taylor expansions, integral equations for the equilibrium pair correlation function, perturbation theories of liquids, equilibrium theories of the liquid–vapor interface, both the Monte Carlo and the molecular dynamics techniques for computer simulations, time correlation functions, and transport phenomena. However, Croxton's treatment of each of these subjects is inadequate for several reasons.

To begin with, there are many undefined symbols and concepts in the text. For example, Croxton's first use of the structure factor, $S(k)$, occurs on page 53 in an equation. There is no statement before or near the equation that defines $S(k)$. Later on, he presents a figure showing an experimentally determined $S(k)$. Yet Croxton never states how or why $S(k)$ is measured, and he never explicitly relates it to the r-space pair correlation function. One also finds mention of the compressibility equation of state; but the compressibility theorem is never derived or stated.

These kinds of omissions make the text nearly unintelligible unless the reader is already familiar with the topics being discussed. But an even worse stumbling block to the uninitiated is the large number of typographical and conceptual errors in the book. The first conceptual error is found on page 3 where Croxton presents an example of a cluster diagram, which he says is reducible. He also explains why he thinks it is reducible. But, in fact, the diagram is irreducible.

In some portions of the book, Croxton's choice of material seems outdated. For example, in his long chapter on dynamic properties, Croxton emphasizes the kinetic-theory approach developed in the 1950's and earlier by John Kirkwood, Stuart Rice, and their coworkers. A modern treatment of linear-response theory is not to be found in the book Indeed, the relationship between measurements and time-correlation functions is not discussed.

Many parts of *Liquid State Physics* simply paraphrase sections of older monographs in the field—especially