

Cadmium telluride: semiconductor extraordinary

**Semiconductors and Semimetals,
Vol. 13 (Cadmium Telluride)**

K. Zanio
Academic, New York, 1978. \$19.50

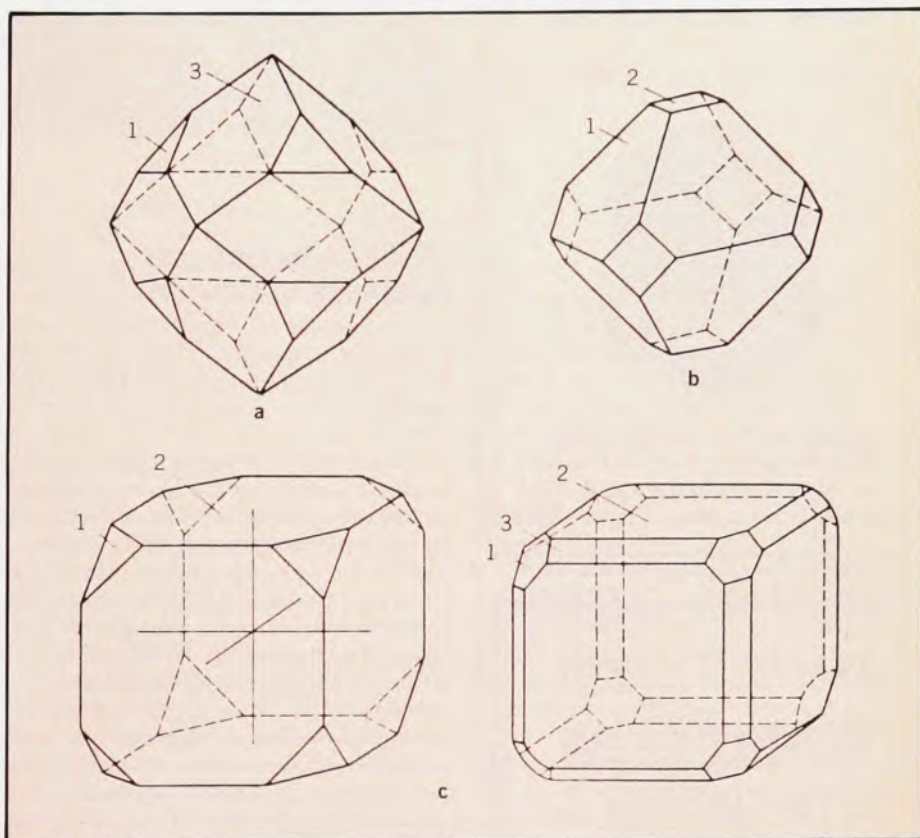
Reviewed by Fred H. Pollak

During the past several decades a close connection has existed between science and technology, particularly in the areas of semiconductors. A large part of semiconductor research has been associated with device development, a great deal of it pioneered by physicists since the invention of the transistor. Developmental efforts for semiconductor devices has often led to the availability of the highest-quality materials and structures for use in research. Thus, physicists were able to perform many significant experiments in these substances that ultimately resulted in very important fundamental and applied discoveries.

One of the examples of this type of interplay is the semiconductor cadmium telluride. The considerable amount of fundamental and applied work done on this material during the past decade has contributed to the knowledge of semiconductor physics. Single crystals have become useful as nuclear radiation detectors, as electro-optic modulators, as an optical material in the infrared, and as a possible candidate for economical terrestrial solar cells.

This book is only the second time that an entire volume of the excellent series *Semiconductors and Semimetals* has been devoted to one subject written by a single author. The first instance was *Volume 11 (Solar Cells)* by Harold Hovel. It therefore marks a very important decision by the editors. Unquestionably the book makes a very significant contribution to the knowledge of this material and devices made from it. The text is intended primarily as a reference book in developing those applications, although it can also be quite useful in understanding more fundamental aspects.

Kenneth Zanio, the author of the present volume, is a well-known scientist working at the Hughes Laboratories in Malibu, California. He has made major contributions to the field of semiconductor devices, particularly in the develop-



Forms of vapor-grown cadmium-telluride crystals include (a) rhombo-dodecahedral, (b) octahedral and (c) hexahedral. The (111), (100) and (110) planes are designated by the numbers 1, 2, and 3 respectively. P. Höschl and C. Koňák (*Phys. Status Solidi*, **9**, 167 (1965)) prepared these crystals; their drawings are reprinted in Kenneth Zanio's *Cadmium Telluride* reviewed on this page.

ment of CdTe as a room-temperature gamma-ray and x-ray spectrometer.

The book covers quite extensively the key areas of interest on both the fundamental and applied levels. Zanio divides it into four chapters entitled "Materials Preparation," "Physics," "Defects" and "Applications." From a logical point of view it would probably have been better to put the second chapter first. Zanio discusses not only Bridgman and vapor-phase growth methods but also includes the more recent areas of crystal growth from Te-rich solutions. The chapter on "Physics" tabulates most of the physical, optical and transport properties of CdTe and wherever possible relates them to those of the more covalent group IV elemental and III-V compound semiconductors. Thus, the work on CdTe pro-

vides important insights as to how the more ionic II-VI compounds fit into the general trend of bands and bonds in semiconductors. Zanio discusses defects at both high and low temperatures. The last chapter deals with applications such as gamma-ray and x-ray spectrometers, electro-optic modulators and solar cells.

Although in general the book is very comprehensive, some weakness occurs in the area of fundamental physics. For example, Zanio does not discuss the magneto-optical studies performed on this material. Some of this work has provided the first quantitative experimental test of large polaron theory, while other investigations have yielded values for the conduction-band effective mass. The book does not list the latter parameter. The very brief discussion of non-

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linear optical properties omits a number of important theoretical works including those of James Phillips and James Van Vechten, Barry Levine, David Aspnes and Michael Bell. Also, Zanio misspells Nicolâas Bloembergen's name on page 209 and in the references.

In spite of some of these shortcomings the book makes a significant contribution to the field and is an important reference volume for workers in this area.

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Fred H. Pollak is Professor of Physics and Director of the Maxwell Maybaum Institute of Materials Science and Quantum Electronics at Yeshiva University. He has been active in the study of the optical properties and band structure of the groups IV, III-V and II-VI semiconductors.

Vibration Spectra and Symmetry of Crystals

H. Poulet, J. P. Mathieu

571 pp. Gordon and Breach, New York, 1976.
\$39.00

The spectra of vibrations of the atoms in a crystal may be studied by several experimental techniques. Two of the oldest are infrared-absorption (or reflection) and Raman-scattering measurements. In a first approximation these measurements give information about those *principal vibrations* (vibrations with null wave vector) that are infrared-active or Raman-active. The number of active principal vibrations depends on the symmetry of the crystal, and this also determines the selection rules for the nature of the infrared or Raman activity. The frequencies of the active vibrations depend upon interatomic force constants and hence on the nature of the bonding of the atoms in the crystal lattice. The strengths of the infrared or Raman spectra depend upon modulation by the active principal vibrations of the charge density and optical polarizability of the crystal, and the shapes of the principal vibration spectra are determined by damping of the principal modes due to interactions with other modes. This incomplete list of the nature of the results of vibrational Raman and infrared measurements on crystals indicates why these measurements are so important to crystal physics and chemistry. Measurements of vibrational spectra at nonzero wave vector by inelastic neutron and x-ray scattering complement the infrared and Raman measurements and in many cases allow a more complete model to be constructed of the interatomic forces.

The most appropriate time for Raman and infrared measurements on a given crystalline solid is when single crystals are available and after a few of the bulk

physical properties have been measured and the microscopic crystal structure has been determined. It is then possible to predict the number of principal vibrations, their symmetry and the infrared and Raman selection rules for active vibrations. Henri Poulet and Jean Paul Mathieu have been active in this field for several decades, and their *Vibration Spectra and Symmetry of Crystals* provides a full treatment of the theory of these effects, the most self-contained known to me.

Workers in the field of infrared and Raman spectroscopy of solids and students preparing to enter this field will find the book extremely valuable because of its detailed treatments of such topics as symmetry properties (including several appendices on group theory), quantization of lattice vibrations, and interactions of vibrations with electromagnetic radiation. Important phenomenological parameters, such as force constants, infrared effective charges and polarizability derivatives, are clearly defined, but the authors do not discuss detailed microscopic (that is, quantum-mechanical) calculations of such quantities.

Poulet and Mathieu include a nice discussion of two-phonon infrared and Raman processes, but they omit any mention of Fermi resonances between one-phonon and two-phonon processes. As its title implies, the book does not discuss infrared and Raman interactions with electronic excitations such as magnons or plasmons or with coupled phonon-electron modes. One type of coupled mode that is discussed in some detail is the infrared polariton. The authors have limited their discussion to a single polarization wave and have emphasized the dispersion relations and the physical coupling mechanisms. They have not provided the response function formalism necessary for a discussion of line-shapes. They mention only briefly the subject of soft-modes and phase transitions.

This book is for the committed reader who wants to learn how group theory explains the properties of principal lattice vibrations and their interactions with electromagnetic radiation, and who wants to use these results in his research. Its curt style will discourage the casual reader who does not have at least qualitative prior knowledge of the subject matter. There are many useful tables. In addition to the expected character tables for the 32 point groups, there are tables of irreducible representations, correlation tables and tables summarizing infrared and Raman selection rules for all point groups.

There is a large bibliography, but I was disappointed not to see references to several general works that partly overlap Poulet and Mathieu's book, namely M. M. Sushchinskii's *Raman Spectra of Molecules and Crystals* (1972), his review article with V. S. Gorelik in *Soviet Phys-*