Journal of
Applied Crystallography
ISSN 0021-8898

book reviews

Works intended for this column should be sent direct to the Book-Review Editor, whose address appears in this issue. All reviews are also available from **Crystallography Journals Online**, supplemented where possible with direct links to the publisher's information.

Transmission electron microscopy and diffractometry of materials. By B. Fultz and J. M. Howe. pp. xix + 748pp. Heidelberg: Springer-Verlag, 2001. Price DM 179.00, US $89.95. ISBN 3-540-67841-7.

Electron microscopy and powder X-ray diffraction continue to be important techniques for materials characterization, not only to obtain the obvious pictorial, symmetrical and dimensional information associated with these probes, but also to determine elemental compositions by inelastic interactions of electromagnetic radiation with matter. As described by the authors, this book is intended to be a text on these techniques for advanced undergraduates and beginning graduate students with a background in physical science. While not stated explicitly, it is clear that the major application to metallurgical samples is of most interest to the authors. Sections of the book are marked, apparently to allow the student to remain in a level commensurate with previous training and experience. Throughout the book concepts common to the scattering of both X-rays and electrons are indicated.

The first chapter presents the production and detection of X-rays and their use for powder diffractometry. Chapter 2 explains the design of the electron microscope, including beam production, design of electron lenses and sources of aberration that affect the final image. The third chapter is a general treatment of elastic and inelastic scattering, relating the form factors of X-rays and electrons. The use of inelastic scattering of electrons for spectroscopic purposes or the analysis of generated characteristic X-rays is discussed in some detail in Chapter 4. The next chapter describes the diffraction of radiation from crystals and is followed, in Chapter 6, by the specific application of electron diffraction, including convergent beam techniques, to describe the orientation and symmetry of crystals. The use of diffraction contrast in transmission electron micrographs to describe crystalline defects is explored in Chapter 7. Shape factors, introduced in Chapter 5 and including instrumental and sample origins, are discussed in the context of powder diffraction in Chapter 8. Chapter 9 is devoted to the Patterson function and how it may be used to analyze crystal disorder. High-resolution electron microscopy is presented in Chapter 10 with a more detailed description of how the effect of objective lens aberrations can be minimized. In the final chapter there is a detailed presentation of dynamical electron diffraction based on the Bloch wave theory. The book also contains a number of useful appendices, including typical indexed powder X-ray patterns from high-symmetry crystals, mass attenuation coefficients for characteristic X-rays, atomic form factors for X-rays and electrons, indexed electron diffraction patterns from various zonal projections of highly symmetric unit cells, typical stereographic projections, tables of Fourier transform pairs, and a general review of typical dislocations in materials. Finally, there are operational procedures for modern electron microscopes (JEOL and Philips) and a number of laboratory exercises.

Although the aim of the book is to depict how X-rays and electrons can be used to characterize materials, crystallographic structure analysis is not included in the discussion. The characterization of crystal defects by 'lattice imaging' *etc*. has been useful for understanding properties of materials and is treated extensively. Significant space is also devoted to spectroscopic characterizations, as identification of elemental composition and distribution has become an important tool in industrial and academic laboratories. It is gratifying that many important formulae associated with elastic and inelastic scattering are derived in detail, so that the work will serve as a useful reference.

Despite the avoidance of crystal structure determination, this is not a book to be approached without any previous knowledge of crystallography, even though the authors claim that 'these concepts are covered in this book'. Virtually no space is devoted, for example, to an introduction to crystal symmetry, and even though there is a detailed tabulation of how convergent beam electron diffraction can unravel space group identification, the space groups are nowhere described in detail. Little mention is made of reflection overlap in powder diffraction patterns and the resultant problem created for determination of symmetry and unit-cell dimensions. Evaluation of crystal orientation with stereographic projections is insufficiently portrayed and, indeed, the concept of diffracting planes is not well presented. The implication, in some diagrams, that atoms might lie only on unit-cell vertices (true enough for many metals perhaps) could be misleading to the unwary student. It is also a pity that only high-symmetry lattices are considered. A whole chapter devoted to the Patterson function might have mentioned, even in passing, how the positions of strongly scattering atoms can be found from this Fourier transform of the diffracted intensities.

However, the major criticism to be made about this book is not its content but its organization. It would have been very informative for the student if a systematic portrayal of Fourier transforms had been given in the very beginning, rather than in various parts of the book and the (insufficiently illustrated) table of Fourier transform pairs in the appendix. This could establish the reciprocal nature of signals in image and diffraction space. It would also show, for example, how a repeated motif eventually produces a 'spot' diffraction pattern after the accretion of a sufficient number of unit cells in a crystal. The concept of shape effects, when the number of repeating motifs is small, would then have been obvious. The reciprocity of convolution and multiplication could also have been explained more clearly. The discussion of Fourier transform pairs might also have included the concept of thermal motion, *e.g.* when the Gaussian distribution of scattering sites in the unit cell is transformed to another Gaussian function that multiplies ('sifts') the perfect crystal diffraction pattern and hence reduces the diffraction resolution.

Secondly, the concept of two-beam dynamical diffraction, important for both electron and X-ray scattering, should have been introduced very early in the book, *e.g.* before the kinematical phase-amplitude description in Chapter 7, which is an insufficient model for many of the phenomena developed there. This two-beam theory can be developed, making few demands on the student's mathematical background. From these underlying concepts, many of the arguments made later would be much clearer.

Although one greatly admires the intent of this book, and its utility as a reference work, there is very little need to abandon use of an often-quoted text, *Electron Microscopy of Thin Crystals*, by P. B. Hirsch *et al.* (Butterworth, London, 1977) or the more recent *Diffraction Physics*, by J. M. Cowley (North Holland, Amsterdam, 1981) for didactic presentations of diffraction and electron microscopy. The concepts presented in the earlier texts are much more clearly established than in this newer work. Spectroscopic characterizations in the electron microscope have also been presented elsewhere. One also finds *Essentials of Crystallography* by Duncan and Christine McKie (Blackwell Scientific Publications, Cambridge, 1986) to be a well considered text for materials scientists that treats both X-ray and electron diffraction, with an excellent description of unit-cell geometry, symmetry and orientation (including a very clear explanation of stereographic projections).

Given research interests in recent years, I also think a serious discussion of the electron crystallography of hard materials remains to be written. This should include the use of Rietveld refinement of powder X-ray data, starting from an approximate crystal structure model derived from quantitative analysis of electron micrographs and electron diffraction intensity data. Crystallographic analysis has become an important component of materials characterization, after all, and is one of the reasons for the design of very high-resolution electron microscopes.

Douglas L. Dorset

ExxonMobil Research and Engineering Co.
1545 Route 22 East
Room LA-170
Annandale
New Jersey 08801
USA
E-mail: d.l.dorset@exxonmobil.com