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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.

High-resolution electron microscopy. 3rd edition. By John C. H. Spence. Pp. xvi + 401. Oxford University Press, 2003. Price GBP 69.95. ISBN 0-19-850915-4.

The uninitiated might query the necessity for another book on transmission electron microscopy (TEM), given the several excellent books that have been published in recent years. However, the past decade has seen the realization of some very significant advances across the entire field of TEM based upon a combination of dramatic improvements in electron optics, electron detectors and data processing. At the time when the first edition of this book was published in 1980, the technique of lattice imaging was well established even for crystals with small unit cells, but interpretation was contentious and uncertain. Certainly one could never claim that anything approaching a true structure image where atomic species and positions could be assigned by simple inspection was remotely possible. This conclusion applied with particular force to the central mission of electron microscopy, namely to elucidate the structure of materials defects on an atomic scale, both within crystals and at surfaces, grain boundaries and interfaces. The second edition of this book was published in 1988 when a new generation of microscopes with improved optics had been available for some years, coupled with a steady improvement in the methods for simulating realistic lattice images for comparison with experimental data. The second edition was considerably updated to include these developments but did not represent a major change in the contents of a classic text.

It is now important to reassure readers that the third edition is essentially a new book, completely rewritten and much expanded to encompass a host of new developments, at the same time retaining and expanding the core aspects of dynamical scattering theory that apply across all methods of transmission microscopy. Subjects that are discussed only in summary include the alphabet zoo of associated techniques such as CBED, LACBED, EELS, EXELFS, CL, EDX and ALCHEMI. Also omitted is the standard discussion of diffraction contrast imaging for defects and interfaces. For readers that require a more detailed introduction to dynamical theory, it may be helpful to have available the author's companion book (*Electron Microdiffraction* by J. C. H. Spence and J. M. Zuo, Plenum, New York, 1992). It is perhaps important to emphasize that this is not a text suitable as an introduction to TEM for students with a limited background in diffraction physics: one could operate an electron microscope quite successfully without the deep knowledge of instrumental aberrations and scattering theory required to record, interpret and compute images with a point resolution below 2 Å.

The initial chapters serve as an introduction to the design of electron optics in a modern TEM, with a critical discussion of the factors controlling the spherical and chromatic aberration constants that limit the point and line resolutions, respectively. As continued throughout the book, references at the end of each chapter are not included on the shotgun approach, but are carefully chosen to include both the classic papers and also more recent reviews and books that expand upon topics mentioned briefly in the text. A feature that should become standard practice is that all references include the title, allowing the reader to make some initial judgement of their relevance. Electron optics is followed by another brief chapter on the wave optical approach using the Fresnel propagator to make a direct connection with the diffraction limit to resolution based upon Abbe theory and Fourier optics. The subject of Fourier optics is further expanded in the following chapter to include the vital topics of lateral and longitudinal coherence, and application of the van Cittert–Zernike theorem to thermionic and field-emission electron sources. Detailed discussion of the theory is supplemented by practical examples for typical microscopes.

The previous chapters now act as background for an extended discussion of lattice imaging in standard mode, including the assumptions behind the various approximations used in calculations such as thin and thick phase objects, the multislice and Bloch wave algorithms, partial coherence and inelastic scattering. An especially useful section is the comparison between quantum-mechanical and crystallographic sign conventions. The discussion of perfect crystals is followed by examples of recent advances in imaging planar boundaries in different projections, equivalent to tomography with atomic resolution. The high-resolution microscopy of biological samples is the subject of the following chapter. Specimens such as isolated macromolecules or imperfectly crystallized monolayers of proteins are highly sensitive to radiation damage and visible only by phase contrast in defocused images. Progress has been spectacular, based upon a combination of cryomicroscopy, coherent imaging, low-dose techniques and tomography, used to synthesize an averaged three-dimensional molecular image with sub-nanometre resolution. For readers unfamiliar with the field, this chapter gives an excellent overview of the progress that has become possible only with advanced instrumentation and sophisticated image processing.

A similar sense of rapid progress occurs in the following chapter, where various schemes for sub-ångström point resolution are discussed. Again, computer assistance has been essential, either to reduce spherical aberration by precise alignment of a complex sequence of multipole lenses or by processing through-focal sequences of images, equivalent to in-line (Gabor) holography. A connection is made with X-ray crystallography by the application of direct methods to phase higher-order reflections. The importance of coherent imaging is again emphasized in the discussion of ptychography, ronchigrams and holography. All of these subjects have developed rapidly in the past decade and are no longer niche topics pursued by a few enthusiasts. The next chapter is devoted to a detailed discussion of one of the most significant developments in high-resolution imaging. It is now accepted that a scanning transmission microscope (STEM) equipped with a probe of atomic dimensions and an annular detector to collect high-angle thermal diffuse scattering gives lattice images that are relatively insensitive to strain, tilt and specimen thickness. Furthermore, the image intensity exhibits some measure of correlation with atomic number and density in the diffracting column. The theory is difficult and remained controversial for some years, but there is now general agreement that annular dark-field STEM with an aberration-corrected objective lens is one of the brighter prospects for interpretable sub-ångström imaging of nanostructures. Again, the author discusses the relevant theory, optics and experimental results in considerable detail.

In the spirit of a subject that requires a good understanding of both theory and equipment, the final chapters are devoted to recent progress in the design of electron sources and detectors, including the field-emission gun, CCD detectors and image plates. This is followed by a description of practical methods for measuring the aberration constants, beam coherence and microscope stability. It is essential reading for anyone planning to install a high-resolution instrument, as is the chapter that describes how one actually acquires a high-resolution image.

Overall, the book is an impressive snapshot of the state of the art in transmission microscopy at a time of rapid progress. It should not be quickly outdated because it seems probable that developments for the next few years will be incremental, based upon advances in column optics and detectors that are already becoming available to the wider community of microscopists. As stated above, the book is demanding because the theoretical background is discussed in considerable detail but it can be read with profit by anyone with experience of microscopy. Almost every page contains some insight or comment that illuminates what might seem to be a familiar topic.

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books received

The following books have been received by the Editor. Brief and generally uncritical notices are given of works of marginal crystallographic interest; occasionally, a book of fundamental interest is included under this heading because of difficulty in finding a suitable reviewer without great delay.

Outline of crystallography for biologists. By David Blow. Oxford University Press, 2002. Price GBP 25 (paperback). ISBN 0-19-851051-9.

A review of this book, by R. M. Sweet, has been published in the May 2003 issue of *Acta Cryst.* Section D, page 958.

The physics of ferroelectric and antiferroelectric liquid crystals. By I. Musevic, R. Blinc & B. Zeks. Singapore: World Scientific, 2000. Pp. 680. USD 129, GBP 88. ISBN 981-02-0325-X

A review of this book, by Nicholas Roberts and Helen Gleeson, has been published in the June 2003 issue of *J. Appl. Cryst.*, page 958.