Preface to the Third Edition

The development of electron energy-loss spectroscopy within the last 15 years has been remarkable. This progress is partly due to improvements in instrumentation, such as the successful correction of spherical (and more recently chromatic) aberration of electron lenses, allowing sub-Angstrom spatial resolution in TEM and STEM images and (in combination with Schottky and field-emission sources) much higher current in a focused probe. The incorporation of monochromators in commercial TEMs has improved the energy resolution to 0.1 eV, with further improvements promised. These advances have required close attention to the mechanical and electrical stability of the TEM, including thermal, vibrational, and acoustical isolation. The energy-loss spectrometer has been improved with a fast electrostatic shutter, allowing millisecond acquisition of an entire spectrum and almost simultaneous recording of the low-loss and core-loss regions.

Advances in computer software have made routine such processes as spectral and spatial deconvolution, spectrum-imaging, and multivariate statistical analysis. Programs for implementing density functional and multiple-scattering calculations to predict spectral fine structure have become more widely available.

Taken together, these improvements have helped to ensure that EELS can be applied to real materials problems as well as model systems; the technique is no longer mainly a playground for physicists. Another consequence is that radiation damage is seen to be a limiting factor in electron beam microanalysis. One response has the development of TEMs that can achieve atomic resolution at lower accelerating voltage, in an attempt to maximize the information/damage ratio. There is also considerable interest in the use of lasers in combination with TEM-EELS, the aim being picosecond or femtosecond time resolution, in order to study excited states and perhaps even to conquer radiation damage.

For the third edition of this textbook, I have kept the previous structure intact. However, the reading list and historical section of Chapter 1 have been updated. In Chapter 2, I have retained but shortened the discussion of serial recording, making room for more information on monochromator designs and new electron detectors. In Chapter 3, I have added material on energy losses due to elastic scattering, retardation and Cerenkov effects, core excitation in anisotropic materials, and the delocalization of inelastic scattering. Chapter 4 now includes a discussion of Bayesian deconvolution, multivariate statistical analysis, and the ELNES simulation. As previously, Chapter 5 deals with practical applications of EELS in a TEM, together with a discussion of factors that limit the spatial resolution of analysis, including radiation damage and examples of applications to selected materials systems. The final section gives examples of TEM-EELS study of electronic, ceramic, and carbon-based materials (including graphene, carbon nanotubes, and polymers) and the measurement of radiation damage.

In Appendix A, the discussion to relativistic effects is extended to include recent theory relating to anisotropic materials and magic-angle measurements. Appendix B contains a brief description of over 20 freeware programs written in MATLAB. They include programs for first-order prism focusing, atomic-displacement cross sections, Richardson–Lucy deconvolution, the Kröger formula for retardation and surface losses, and translations of the FORTRAN and BASIC codes given in the second edition. The table of plasmon energies in Appendix C has been extended to a larger number of materials and now also contains inelastic mean free paths. I have added an Appendix F that summarizes some of the choices involved in acquiring energy-loss data, with references to earlier sections of the book where these choices are discussed in greater detail.

Throughout the text, I have tried to give appropriate references to topics that I considered outside the scope of the book or beyond my expertise. The reference list now contains about 1200 entries, each with an article title and page range. They are listed alphabetically by first author surname, but with multiauthor entries (et al. references in the text) arranged in chronological order.

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