

Preface

How is this book different from the many other TEM books? It has several unique features but what we think distinguishes it from all other such books is that it is truly a *textbook*. We wrote it to be read by, and taught to, senior undergraduates and starting graduate students, rather than studied in a research laboratory. We wrote it using the same style and sentence construction that we have used in countless classroom lectures, rather than how we have written our countless (and much-less read) formal scientific papers. In this respect particularly, we have been deliberate in *not* referencing the sources of every experimental fact or theoretical concept (although we do include some hints and clues in the chapters). However, at the end of each chapter we have included groups of references that should lead you to the best sources in the literature and help you go into more depth as you become more confident about what you are looking for. We are great believers in the value of history as the basis for understanding the present and so the history of the techniques and key historical references are threaded throughout the book. Just because a reference is dated in the previous century (or even the antepenultimate century) doesn't mean it isn't useful! Likewise, with the numerous figures drawn from across the fields of materials science and engineering and nanotechnology, we do not reference the source in each caption. But at the very end of the book each of our many generous colleagues whose work we have used is clearly acknowledged.

The book consists of 40 relatively small chapters (with a few notable Carter exceptions!). The contents of most of the chapters can be covered in a typical lecture of 50-75 minutes (especially if you talk as fast as Williams). Furthermore, each of the four softbound volumes is flexible enough to be usable at the TEM console so you can check what you are seeing against what you should be seeing. Most importantly perhaps, the softbound version is cheap enough for all serious students to buy. So we hope you won't have to try and work out the meaning of the many complex color diagrams from secondhand B&W copies that you acquired from a former student. We have deliberately used color where it is useful rather than simply for its own sake (since all electron signals are colorless anyhow). There are numerous boxes throughout the text, drawing your attention to key information (green), warnings about mistakes you might easily make (amber), and dangerous practices or common errors (red).

Our approach throughout this text is to answer two fundamental questions:

Why should we use a particular TEM technique?

How do we put the technique into practice?

In answering the first question we attempt to establish a sound theoretical basis where necessary although not always giving all the details. We use this knowledge to answer the second question by explaining operational details in a generic sense and showing many illustrative figures. In contrast, other TEM books tend to be either strongly theoretical or predominantly descriptive (often covering more than just TEM). We view our approach as a compromise between the two extremes, covering enough theory to be reasonably rigorous without incurring the wrath of electron physicists yet containing sufficient hands-on instructions and practical examples to be useful to the materials engineer/nanotechnologist who wants an answer to a

materials problem rather than just a set of glorious images, spectra, and diffraction patterns. We acknowledge that, in attempting to seek this compromise, we often gloss over the details of much of the physics and math behind the many techniques but contend that the content is usually approximately right (even if on occasions, it might be precisely incorrect!).

Since this text covers the whole field of TEM we incorporate, to varying degrees, *all* the capabilities of the various kinds of current TEMs and we attempt to create a coherent view of the many aspects of these instruments. For instance, rather than separating out the broad-beam techniques of a traditional TEM from the focused-beam techniques of an analytical TEM, we treat these two approaches as different sides of the same coin. There is no reason to regard ‘conventional’ bright-field imaging in a parallel-beam TEM as being more fundamental (although it is certainly a more-established technique) than annular dark-field imaging in a focused-beam STEM. Convergent beam, scanning beam, and selected-area diffraction are likewise integral parts of the whole of TEM diffraction.

However, in the decade and more since the first edition was published, there has been a significant increase in the number of TEM and related techniques, greater sophistication in the microscope’s experimental capabilities, astonishing improvements in computer control of the instrument, and new hardware designs and amazing developments in software to model the gigabytes of data generated by these almost-completely digital instruments. Much of this explosion of information has coincided with the worldwide drive to explore the nanoworld, and the still-ongoing effects of Moore’s law. It is not possible to include all of this new knowledge in the second edition without transforming the already doorstep sized text into something capable of halting a large projectile in its tracks. It is still essential that this second edition teaches you to understand the essence of the TEM before you attempt to master the latest advances. But we personally cannot hope to understand fully all the new techniques, especially as we both descend into more administrative positions in our professional lives. Therefore, we have prevailed on almost 20 of our close friends and colleagues to put together with us a companion text (TEM; a companion text, Williams and Carter (Eds.) Springer 2010) to which we will refer throughout this second edition. The companion text is just as it says—it’s a friend whose advice you should seek when the main text isn’t enough. The companion is not necessarily more advanced but is certainly more detailed in dealing with key recent developments as well as some more traditional aspects of TEM that have seen a resurgence of interest. We have taken our colleagues’ contributions and rewritten them in a similar conversational vein to this main text and we hope that this approach, combined with the in-depth cross-referencing between the two texts will guide you as you start down the rewarding path to becoming a transmission microscopist.

We each bring more than 35 years of teaching and research in all aspects of TEM. Our research into different materials includes metals, alloys, ceramics, semiconductors, glasses, composites, nano and other particles, atomic-level planar interfaces, and other crystal defects. (The lack of polymeric and biological materials in our own research is evident in their relative absence in this book.) We have contributed to the training of a generation of (we hope) skilled microscopists, several of whom have followed us as professors and researchers in the EM field. These students represent our legacy to our beloved research field and we are overtly proud of their accomplishments. But we also expect some combination of these (still relatively young) men and women to write the third edition. We know that they, like us, will find that writing such a text broadens their knowledge considerably and will also be the source of much joy, frustration, and enduring friendship. We hope you have as much fun reading this book as we had writing it, but we hope also that it takes you much less time. Lastly, we encourage you to send us any comments, both positive and negative. We can both be reached by e-mail: david.williams@uah.edu and cbcarter@enr.uconn.edu.



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