

be observable in the future. As Krügel says about the precise dielectric properties of astrophysical silicates, these differences between microcanonical and thermal-level populations may be of “secondary importance in view of our general ignorance about grain properties.”

This is a substantial book aimed at the specialized study of interstellar dust. I recommend that you definitely consider using this text if you have to teach a course about interstellar dust or want to do an independent study on the topic. But read chapter 14 first for an introduction to the field and then loop back to the beginning for the details.

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High Resolution Focused Ion Beams: FIB and Its Applications

Jon Orloff, Mark Utlaut,
and Lynwood Swanson
*Kluwer Academic/Plenum, New
York, 2003. \$145.00 (303 pp.).
ISBN 0-306-47350-X*

From elucidating the fundamental structure of matter to manufacturing integrated circuits, ion beams have played a well-known, central role in

science and technology for nearly a century. But perhaps less widely appreciated is the small revolution that began roughly 30 years ago in researchers' ability to generate intense beams of ions focused to nanometer dimensions and to deploy them rapidly in technologically useful ways. In *High Resolution Focused Ion Beams*, Jon Orloff, Mark Utlaut, and Lynwood Swanson describe both the science and technology behind those finely focused ion beams and their expanding role in a range of applications, such as microscopy and failure analysis. The authors have a long and distinguished history in this field, and their book is a welcome, up-to-date replacement for the now out-of-print *Focused Ion Beams From Liquid Metal Ion Sources* (Wiley, 1991) by Philip Prewett and Graeme Mair.

The development of the liquid-metal ion source was crucial in enabling the production of intense,

finely focused ion beams. The first and second chapters of the book present a comprehensive review of our current understanding of that ion source, provide a wealth of practical information on its characteristics and quirks, and, along with the concluding chapter on applications, include an excellent list of references.

The ion source, which emits a few microamps of metal ions, consists of little more than a sharpened needle coated with a thin film of liquid metal. The ions are produced in a nanometer-sized region at the apex of a liquid-metal cone that is perched at the tip of the needle. This method results in a remarkably bright ion source. Although the structure of this source is simple, the physics and physical phenomena governing its operation are not. The liquid cone is produced by competing surface tension and electrostatic forces. The current density at the emission site is great enough to cause significant space-charge effects. Liquid droplets charged to the point of near explosion are emitted along with the ions, and the hydrodynamics of liquid flow along the needle dominate the operation of the source. To their credit, the authors acknowledge that, although we know how to build and exploit these ion sources, our current understanding is incomplete at best, and a comprehensive model of the ion source simply does not exist.

The optics and instrumentation that scientists use to form high-resolution focused ion beam (FIB) systems are explained in the book's third and fifth chapters. The high brightness of the liquid-metal ion source allows researchers to use a simple electrostatic lens to generate, with relative ease, a focused beam with a diameter of a few hundred nanometers. The high brightness allows a useful amount of ion current to be focused in a small spot. However, producing a state-of-the-art focused beam with a 5- to 10-nm diameter that can be scanned over a 1-mm field requires a more sophisticated understanding of electrostatic optics and the optical properties of the ion source. The authors offer both a condensed review of charged-particle optics and in-depth material specifically geared toward the production of finely focused ion beams from point emission sources. But readers should keep in mind that this book is not an authoritative text on the broad field of particle optics, nor is it meant to be.

The fifth chapter is devoted to the practical aspects of FIB optics and systems. For example, it offers an excellent discussion on balancing the desire to have a good signal to noise in



an FIB imaging system with the need to not damage the sample. The authors also provide highly useful advice on defining and measuring the resolution of the FIB system.

The book concludes with an extensive sixth chapter on the applications of FIBs and a very brief review of the ion-solid interactions that are particularly relevant to those applications. Primary uses of FIB systems are to image a sample with nanometer resolution, or to deposit momentum in a small region to locally remove material via sputtering, or to locally decompose an adsorbed gas thereby allowing additional material to be deposited. Almost all of the applications of FIB systems are found in the semiconductor industry and include repairing defects in photolithographic masks, correcting design errors in integrated circuits, trimming disk heads, performing failure analysis, examining the grain structure of materials, and conducting sample preparation for transmission electron microscopy.

Although mask repair, a major application that has driven much of FIB science and technology, is not specifically covered in the book, detailed discussion of the other cited applications, processes, and "tricks of the trade," provide the reader with an excellent view of FIB technology. I was, however, disappointed to see photomask repair excluded, because it was the first technologically significant prototype micromachining application. Also, photomask repair is still an area of active R&D, and mentioning it would have been an excellent vehicle for illustrating all of the basic FIB processes, such as imaging, charging, three-dimensional micromachining, and ion-assisted chemistry.

High Resolution Focused Ion Beams is a much needed contribution to a fascinating field of science and technology. The book is intended as a reference not only for researchers but also users and developers of FIB technology. It succeeds admirably in that capacity.

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Unsolved Problems of Noise and Fluctuations. S. M. Bezrukov, ed. *AIP Confer-*

ence Proceedings 665. Proc. conf., Washington, DC, Sept. 2002. AIP, Melville, NY, 2003. \$175.00 (621 pp.). ISBN 0-7354-0127-6

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