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BOOK REVIEWS

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Handbook of Advanced Plasma Processing Techniques, edited by R. J. Shul and S. J. Pearton. Heidelberg: Springer-Verlag, 2000. ISBN 3 540 66772 5. DM249, £86, $138.

Plasmas are ubiquitous in modern industry. They play key roles in the semiconductor, materials and lighting industries, among others, and are used to process everything from microelectronic circuits to aircraft components. Understanding their properties is therefore a key technological challenge in a wide range of industrial sectors. Overcoming this challenge will require major advances in our knowledge of the fundamental physics and chemistry of plasmas. Companies are also becoming increasingly aware of the enormous potential for the use of low-temperature plasmas outside the relatively mature sectors, and applications are already under development in the information storage and display sectors. The next major industrial use for plasmas could well be the surface modification of materials.

This book concentrates on some of the most advanced, sophisticated and downright clever uses of plasmas: the processing of semiconductor-based devices in the microelectronics industry, with important chapters on microelectromechanical systems (MEMS) and magnetic materials. There is a strong emphasis on the etching process. The editors have drawn together an impressive collection of authors, all from the USA and mostly from universities and National Laboratories, probably reflecting the little time scientists, in an industry driven by Moore's Law, have to think about fundamental processes, let alone write book chapters. Having said that, in all the areas covered with which I am familiar, the authors work at the forefront of their field. Since it is a multi-authored book, each chapter is self-contained and I didn't find any cross-referencing between chapters, but the editors have managed to avoid any extensive repetition. The material is as up to date as is feasible in any textbook, and most chapters provide references up to 1998.

This is a 644-page book with 413 figures and 15 chapters. It provides a detailed and comprehensive treatment of the topics. Figures are used extensively and very effectively. The first two chapters provide a concise introduction to the fundamental chemical and physical concepts that lie behind the state-of-the-art plasma etching described later in the book. There follow two chapters on plasma modelling. The first is an overview of simulation techniques, gas-phase kinetics and surface reactions. The next chapter looks at approaches to computer-aided design of plasma processes and reactors. There are then two chapters on plasma diagnostics, the first dealing with electrical, microwave, optical and laser techniques. A minor point here is that I would have liked to have seen more on the use of electrical circuit measurements for process control and diagnostics. There is a separate chapter on mass-spectroscopic characterization. The two chapters on charging and on damage in plasma processing are well positioned to set the background for the etching chapters. The key issue of photomask etching, somewhat neglected by the academic community, is treated in Chapter 9.

In the last five chapters, four describe the approaches and problems to etching materials, beginning with MEMS, a spin-off of the ability to produce deep, high-aspect-ratio, anisotropic features on Si. Then III/V materials are covered, followed by ion-beam etching of compound semiconductors and dry etching of InP. Before the final chapter on dry etching of magnetic materials, deposition gets a look in, with a discussion of device damage during high-density plasma chemical deposition.

The editors state that the book is aimed at process engineers and industrial and academic researchers, along with those entering the field who need a single source review of particular subjects. This aim they have achieved. The book provides an excellent, detailed insight into the beautiful and intriguing environment that has enabled the microelectronics revolution. It also provides the reader with a background to appreciate the potential for the application of plasmas to other processes, I will certainly refer to it often if I can keep it on my shelf, since I expect there will also be a demand for it from my postgraduate students.

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Magnetic Reconnection: MHD Theory and Applications, by E. R. Priest and T. G. Forbes. Cambridge University Press, 2000. 600+xii pages. ISBN 0 521 481 79 1. £50, $85.

Reconnection has become a fashionable subject across the spectrum of physical sciences. Current interest embraces the reconnection of vortex lines in superfluids and superconductors, as well as the more classical problems involving magnetic field lines in plasmas. Anyone working in one of these fields should at least look at the phenomena described in this book, which offers a wide panorama of reconnection scenarios.

The Introduction includes some history, starting from the 1940s. This is followed by the basic equations of magnetohydrodynamics (though without derivation) and also some useful approximations. Null points, current sheets and magnetic shocks wind up the theory. A table of plasma parameters is quoted. We are now prepared for current-sheet formation (Chapter 2), baaed on various stationary solutions. Quite a lot is introduced through the two-dimensional back door. This permits complex-plane analysis and attendant tricks. Recently, several of these simple solutions have been seen by simulations to be more relevant than previously thought. Chapter 3 treats magnetic-line diffusion and various flow phenomena. Temporal dynamics are introduced. A combination of numerics and exact models will accompany us throughout the book. Chapters 4 and 5 revert to steady-state reconnection, and are largely theoretical. Some of the simple, exact solutions would have been welcome as illustrations of phenomena introduced much earlier.

Chapter 6 gives an analysis of the tearing instability and how it can lead to an alteration of magnetic configurations. There is a welcome marriage of linear and nonlinear analysis. Other instabilities and their consequences are considered.

Chapter 7 derives the self-similar solution that illustrates 'scissoring' or else X-point collapse. Not all is well: to facilitate calculations, a parameter essential to the very existence of an X point is taken to be zero! An expansion in this parameter would have been a better idea. However, order-of-magnitude considerations are still correct (and very interesting).

Chapter 8 opens the subject of 3D reconnection. What we have learned from previous 2D examples is a huge help in understanding these more realistic cases. Magnetic helicity is used, and some theories are proved. Chapter 9 gives a panorama of laboratory devices. The authors concentrate on comparing characteristic lengths and other parameters. They have a good grasp of the essentials. The remainder of the book (Chapters 10–12) is on solar and astrophysical applications, and particle motion (Chapter 13). This last chapter treats transport theory and particle-shock interaction, among other problems.

There are 50 pages of references, invaluable to people in the field. There is a subject index, but no name index.

To conclude: this is a must for specialists. Parts of this book should be read by anyone interested in reconnection in any branch of physics: classical or quantum. Perhaps a second edition could include a chapter on reconnection in other media, just to point out analogies (and could clean up the theory where required). The price is reasonable.

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Physics of Ionized Gases, by Boris M. Smirnov, with the editorial collaboration of Howard R. Reiss. New York: Wiley-Interscience, 2001. 381 pages. ISBN 0 471 17594 3. £64.50.

This text is based on 30 years of the author's graduate lecture courses. It is his ninth book on the physics of ionized gases. With almost 30 books in total and over 300 research articles, as well as his role as a division head of the Institute for High Temperatures of the Russian Academy of Sciences, Professor Smirnov is ideally qualified to write a landmark text on the fundamental physics of ionized gases. This book uses some of the material from his earlier works, but also includes many new developments. Professor Smirnov states that his main goal is to provide both students and experienced scientists with the fundamental concepts of plasma physics. He achieves his objective admirably. There is no doubt that this book presupposes active participation by the reader, but there is an extensive bibliography of more than 50 texts recommended for further detail on specialized subjects.

Although he introduces the subject with qualitative discussions of illustrative examples, in the main text the author draws on particular insights of specialists to focus on the fundamentals. He achieves an excellent balance between current sophisticated plasma theory and simple descriptions that provide a clear and unified understanding of the basic physics. Limiting cases are used to reduce the obscuring complexity of the full general treatment.

The subject is introduced with an overview of real plasmas found in nature and in laboratory systems. The text provides very clear and insightful discussions of the basic plasma phenomena, both from the particle viewpoint and via macroscopic plasma behaviour. The early chapters deal with the foundational physics of the subject: the necessary statistical physics, elementary particle processes, the differing conditions encountered at low and high densities (with reference to ideal plasmas), and the effects of external fields. The book provides an extremely useful discussion of excitation, ionization and radiative processes in conjunction with the plasma physics of weakly ionized gases. When the fundamentals have been introduced, the author gives a very clear account of the complex issues of plasma instabilities, waves and nonlinear phenomena. There is a very thorough discussion of DC glow discharges in Chapter 20 and a fairly extensive account of the main aspects of atmospheric plasmas, as well as a chapter on dust particles in plasmas, a subject of great current interest. The final chapter consists of a large amount of tabulated data, which should prove very useful to scientists researching in this area.

Criticisms? Coverage of the vast subject of plasmas for materials processing would seem to be rather thin (15 pages in Chapter 22). Also, I would make a further small point. I thought it a little strange that the conditions for gas breakdown and the Townsend criterion are not discussed until as late as page 340. Readers should not expect discussion of diagnostic techniques or instrumentation. As the title implies, this is a book about the fundamentals. These points aside, I strongly recommend this book for the great clarity of understanding and insightful discussion of the key concepts of the physics of ionized gases.

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The Fourth State of Matter: An Introduction to Plasma Science, 2nd edition, by S. Eliezer and Y. Eliezer. Bristol: Institute of Physics Publishing, 2001. 224+xi pages. ISBN 0 750 30740 4. £19.99, $32.50.

This is the second book on plasmas for the layman to be reviewed in this Journal within little more than a year [see the review of H. Wilhelmson's *Fusion: A Voyage through the Plasma Universe* in vol. 64, p. 201 (2000)]. In contradistinction to the previously reviewed book, which was written by a specialist for the non-specialist, this effort was co-authored by a husband and wife team. The husband is active in the field in the USA, but did not feel he could make himself understood to the layman. His wife, the departmental secretary, had no physics background. They decided that she should be the spokesperson.

Many analogies to everyday life liven things up. One example is how she compares the four states of matter to different dance situations, heating up as the music accelerates. (here a solid is compared to when the dancers are immobile, waiting for the first sound of music, etc.) Another splendid analogy is the statement that the ratio of radiated energy to mass for the Sun is worse than for a lit match so much better than just saying that the sun is an inefficient energy producer.

The book is strong on history, not only of plasma, but also of atomic physics and electromagnetism. There is a panorama of 19th and 20th century efforts, leading to plasma theory as we know it. There is also quite a lot of interesting information on how the research grew out of defence work. The sections on plasma in industry and the energy problem are very informative. Numerous examples of both plasma tools and future applications are given. These latter even include using the solar wind to propel spaceships. There is a list of dated landmarks, an appendix of poems that cover virtually all the material of the book, a glossary, bibliography and index.

This second edition includes new material covering developments of the last ten years, especially on plasma in industry and the fusion effort. The bibliography is new.

There is one statement that I find it hard to agree with. The authors state that 'this book is not for physicists'. At least one such enjoyed it and found it useful.

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Reviews of Plasma Physics, Volume 22, by V. D. Shafranov. New York: Kluwer Academic/Plenum Publishers, 2001. 348 pages. ISBN 0 306 11067 9. $140 €160.00, £98.00.

The latest volume of this well-known series contains two extensive articles. The first is on 'Cooperative effects in plasmas' by the late B. B. Kadomtsev, and is an English edition of material that originated from lectures given at the Moscow Institute of Physics and Technology. It provides a review of a range of topics, including linear and nonlinear waves, plasma confinement by a magnetic field, and wave–particle interactions. The attraction is not the novelty of the material but the style in which it is presented. Throughout there is a minimum of mathematical complication and an emphasis on clear explanation of the principles and insight into the physics involved. It is a pleasure to have an English translation of this work by a very distinguished plasma physicist. It can be recommended to students as an introduction to some important issues in plasma physics and as enjoyable and instructive reading for anyone with an interest in the subject.

The second article is a more specialized one on 'Relativistic interaction of laser pulses with plasmas', written by a long list of authors, all of whom are well known in this field. In the last few years, laser systems that can produce intensities in excess of 10^{18} W cm^{-2} have become widely available, and the state of the art is some three orders of magnitude above this. In this regime, the quiver velocity of the electrons is very close to the speed of light and a whole new area of nonlinear plasma physics opens up. As well as its basic interest, there may be applications to compact particle accelerators, fast X-ray sources, and inertial confinement fusion. The authors provide a review of some of the main features of the laser–plasma interaction, with particular emphasis on the use of computer codes to simulate the behaviour. The article will be of interest to all researchers in this very topical area.

With its combination of an elegant review of some basics of plasma physics by a master of the subject and a review of one of the most active areas of current research, this volume should be of wide interest, and is a worthy addition to a distinguished series.

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