Materials and Process Characterization of Ion Implantation

M.I. Current and C.B. Yarling, eds.
(Ion Beam Press, Austin, TX, 1997)
488 pp., $120.00
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As transistor dimensions have shrunk, the integrated circuit (IC) manufacturing process has become very demanding. To achieve consistently high yields day-in and day-out requires an understanding of how the hundreds of process steps affect one another, knowledge of what parameters must be measured in order to control each step, and, finally, use of the measurements to achieve exquisite control of the entire manufacturing process. *Materials and Process Characterization of Ion Implantation* takes up the challenge of providing a complete guide to the measurements used in modern facilities to control ion implantation processes. Up to 20 different implants are performed in the course of IC fabrication, covering about six orders of magnitude in implanted dose, about four orders of magnitude in ion energy, and a half dozen different implanted species. As a result, the fact that the book needs nearly 500 pages to cover the measurement techniques is not surprising. Each technique is well covered, with a general overview of the technique, examples of data that can be obtained, and a good discussion of the limitations.

The first two sections, dose and profile measurement, relate to the desired effects of implantation: doping of semiconductors. The dose section covers sheet resistance, thermal wave, optical densitometry (a newer technique for low dose, high energy implants), and a good overview of simple device measurements. The profile section covers basics such as electrical measurements and secondary ion mass spectrometry (SIMS). Also, good sections are offered on two-dimensional dopant profiling using etching and atomic force microscopy (AFM) or transmission electron microscopy (TEM), which are useful in tuning implants to get better device parameters, such as accurate, lightly doped drain (LDD) profiles.

The second two sections on damage and contamination focus on the undesirable effects of ion implantation. The damage section includes four methods to investigate lattice (classic displacement) damage, as well as three sections covering the more insidious effects of electrical damage caused by spraying the charged implant beam on the wafer. The contamination section includes methods on measuring impurities with SIMS, total x-ray reflection fluorescence (TXRF), inductively coupled plasma-mass spectrometry (ICP-MS), and lifetime measurements. In addition, there are two articles on particles, a major device killer in IC fabrication. The volume closes with a good tutorial on how to actually use the measurement techniques to achieve true process control.

This volume should be useful to any ion implant process engineer, and I would also recommend it to device and process integration engineers. Although alone it is too focused for an undergraduate course, I plan to draw upon examples on process control from it when I next teach microelectronics fabrication. All in all, this is an excellent book.

Reviewer: *Jonathan Custer is a member of the technical staff at Sandia National Laboratories' Microelectronics Development Laboratories. He is currently on assignment to Washington State University's Vancouver, WA campus to help the new Manufacturing Engineering program include semiconductor manufacturing issues. He has worked in the past on ion beam modification of various materials, and more recently on chemical-vapor deposition of advanced diffusion barriers for copper metallization.*

Phase Equilibria, Phase Diagrams and Phase Transformations: A Thermodynamic Basis

M. Hillert
(Cambridge University Press, New York, 1998)
538 pp.
$110.00 Cloth, ISBN 0-521-56270-8
$44.95 Paper, ISBN 0-521 56584-7

This book is in many ways unique, refreshingly individualistic, and a testament to the unswerving views of the author over the years. The reader should not be put off by the rather staid title and the anodyne description given by the publisher, or the list of the topics covered in some 19 chapters, which are the expected content for a book of this nature, and none of which give much indication that the author is going to adopt a radically different approach.

Indeed it is vital to read the author's preface in order to obtain the real flavor of the book and to utilize it to the best advantage. This preface makes it clear that he believes that the role of thermodynamics in the teaching of science and technology has been declining in many faculties ["colleges" within a university] in the last few decades because students find thermodynamics an abstract and difficult subject and, more importantly, that very few of them expect to put it to practical use in their future career. The ambition of the author has therefore been to produce a text which provides a thorough background to the subject while persuading an engineer with even limited experience to make full use of thermodynamic calculations in solving a variety of complicated problems.

Achieving such a goal cannot of course be separated from the availability and power of thermodynamic software, which allows complex applications to be made without the need for remembering much traditional thermodynamics. This might be considered to mitigate against writing the present text. However Hillert has always insisted very strongly that, in order to avoid making mistakes, and to fully utilize the potential of such tools, it will always be necessary to have a good understanding of the basic principles of thermodynamics. Additionally, much of the prior literature as well as the software currently available relates to equilibrium conditions where the driving force approaches zero, and the author therefore must stress the way in which thermodynamics also plays a vital role in phase transformations, where the driving force varies continuously.

The author is clearly aware that there are considerable difficulties in achieving both breadth and depth within one treatise, and therefore warns the readers that if they meet a section which does not stimulate them, they should move on to other areas, noting that such sections may contain valuable reference material at a later stage. Likewise a fuller understanding of some aspects of many chapters can only be obtained by working through the exercises found at the end of every section. Skipping these exercises therefore offers another shortened route through the book. The book is clearly a mine of valuable information but needs to be negotiated with care.

As anyone with experience of the Hillert's lecturing style will expect, the material is presented in a very rigorous and mathematically impeccable manner. It is profusely illustrated, with a heavy bias to schematic explanations. A strong emphasis has also been placed on the many alternative ways of representing thermodynamic relationships, including projection techniques designed to reduce the number of dimensions required to represent multiple variables. As with a seamless garment, there are no loose ends and this is a self-contained classical treatise which does not attempt to incorporate or speculate about any links with more contemporary physics, and sets self-imposed limits on those sections dealing with physical properties.

This approach also means the reader is made unaware of the existence of alternative viewpoints, as evidenced by an extremely short list of 50 references. It is also somewhat surprising that the equations are not numbered, which would have enhanced the value of this monograph as a textbook for undergraduates.

In short, this book is more akin to the work of a musical composer, who has his own unique style and does not draw attention to the work of other composers. It is certainly a refreshing departure from the methodology adopted by most scientific contempories and must be considered as a compulsory purchase for all libraries and thermodynamics cognoscenti. It will be very interesting to see whether it will also achieve the author's wish to raise the level of thermodynamic awareness in science courses as a whole.

Reviewer: *Peter Miodownik is Professor Emeritus of Materials Science and Engineering, University of Surrey, Guildford, England. He has long been interested in phase equilibria in alloys and their calculation, with a special interest in magnetic properties.* □

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