Physics of Thin Films, Vol. 13

Edited by Maurice H. Francombe and John L. Vossen

(Academic Press, 1987)

The 13th volume of *Physics of Thin Films* contains five excellent review chapters. The first two deal with film deposition, the third with ion beam modification of films, the fourth with laser-induced etching, and the last one with contacts to GaAs devices.

The first chapter, by T. Takagi, reviews ion-cluster-beam deposition, a technique he introduced more than 16 years ago and has developed into both a deep science and a fine art. First, he considers the formation and properties of clusters. Then he explains how accelerated ionized clusters provide the kinetic energy needed to promote surface migration so that the atoms find their proper lattice sites even at substrate temperatures substantially lower than required for epitaxy by conventional methods. Takagi then gives examples of various materials that have been deposited as films and discusses factors affecting their crystallinity.

In the second chapter R.F. Bunshah and C. Deshpandey review the Reactive Evaporation Process pioneered by Bunshah. The technique consists in reacting a metal vapor produced by thermal evaporation with a gas to form a solid compound that deposits as a film. The gas may be preionized to make it more reactive. This technique is most useful for synthesizing films of refractory materials, such as oxides, nitrides and carbides.

In the third chapter, U.J. Gibson is concerned with the ion beam deposition and processing of optical films. This necessarily includes a review of ion generators and their use in film deposition, overlapping briefly with the coverage of the first two chapters. The author, being primarily interested in optical films, concisely summarizes optical and structural properties of thin films and of methods for assessing their properties. Ion bombardment before, during and after deposition affects the properties of the optical films; these are mostly oxides.

The first three chapters have extensive references to very recent literature.

In the fourth chapter, C.I.H. Ashby reviews the laser-induced etching of thin films by thermal ablation and photochemical reaction with either a gaseous or a liquid ambient. This process is important in microlithography, hence the appropriate concerns for resolution and depth-to-width aspect ratio. There are useful tables listing the wavelengths suitable for etching numerous organic and inorganic materials.

Contacts to GaAs Devices is the subject of the last chapter, by J.M. Woodall, N. Braslau, and J.L. Freeouf. The authors review the history of metal-semiconductor interfaces, and there is a good discussion of Fermi-level pinning at the surface and how it is affected by oxide layers in various III-V compound semiconductors. Still, the problem of making a low-resistance ohmic contact is very difficult. Heavy doping near the interface and the use of an InAs layer to form a conducting heterojunction are possible solutions.

All the chapters go into considerable depth to please the specialists, but the book is also good for tutorial value and should appeal to a broad readership.

Reviewer: Jacques I. Pankove is professor in electrical and computer engineering and manager for materials and devices at the Center for Optoelectronic Computer Sciences. His specialty is in semiconductors and optoelectronics.

Constitutive Laws and Microstructure

Edited by D.R. Axelrad and W. Muschik

(Springer-Verlag, 1988)

This book is an account of invited presentations and discussions from the seminar on "Constitutive Laws and Microstructure" held at the Wissenschaftskolleg (Institute for Advanced Study) Berlin, West Germany, February 23-24, 1987. The seminar was held in cooperation with the Institute of Theoretical Physics and the Hermann Fottinger Institute of the Technical University, Berlin with the purpose of discussing some recent developments in the theory of materials.

The title might be misleading because the book actually covers a relatively narrow range of topics, representing work done within the time of a short seminar.

Such as it is, this volume might be useful to familiarize readers with the fundamental issues of material theories and to indicate possible ways future research may aid in formulating more rigorous material theories.

The main topics in the book include thermodynamics of materials presented by W. Muschik's paper on thermodynamical constitutive laws; thermodynamical considerations on plastic and viscoplastic behavior by Th. Lehmann; metal plasticity as a problem of thermodynamics by J. Kestin; and description and simulation of shape memory by I. Muller.

Other topics include the stochastic processes and material behavior covered by papers such as "Markov—Chains as Models for the Inelastic Behavior of Metals" by E. Steck and "Stochastic Analysis of Structural Changes in Solids" by D.R. Axelrad.

The book also deals with the constitutive relations for simple fluids and microphysics of solids. Here we find papers on molecular dynamics: "Test of Microscopic Models for the Material Properties of Matter" by S. Hess and W. Loose; "Localization of Waves Due to Disorder in Solids" by Ch. Enz; "Electromagnetic Control of Material Properties in Multipole Elastic Composites" by R. Hsieh; "Thermodynamic Modeling of Polymers in Solution" by G. Maugin and R. Drouot; and "A Microphysical Model for Crystallizing Polymers" by K. Wilmanski.

Discussions with the symposium's participants are also published and give an idea of the problems treated in the meeting as well as the extent and nature of the scientific community's interest in this area.

Reviewer: Minko Balkanski is professor of physics and director of the Solid State Physics Laboratory at the University of Pierre and Marie Curie, Paris.

Diffusion Processes in High Technology Materials

Edited by D. Gupta, A.D. Romig Jr., and M.A. Dayananda

(Trans Tech Publications, 1988)

The 277-page volume contains 21 papers presented at the symposium on "Diffusion Processes in High Technology Materials" sponsored by the Atomic Transport Activity of the American Society for Metals. The symposium was held during the 1987 Fall Meeting of The Metallurgical Society in Cincinnati, Ohio. The papers were originally published in the journal *Diffusion and Defect Data.*

The 21 invited and contributed papers cover a broad range of topics in diffusion. Several papers deal with diffusion problems related to electronic device applications, such as diffusion barriers, electrical contacts, and interconnects for VLSI packaging. Many of the papers discuss the fundamental aspects of diffusion in solids (including diffusion in semiconductors, crystalline and amorphous metallic thin films, and in nanocrystalline materials) as well as more traditional topics such as oxidation, interfacial segregation, and grain growth. Various experimental techniques for diffusion studies are examined with additional focus on several emerging and promising experimental techniques, in particular, high resolution transmission electron microscopy and tunneling microscopy.

Most of the papers are review papers written by experts active in their fields. Ap-

propriate introductions to history and background as well as extensive references are given in the review papers. Several papers, presumably the contributed ones, focus on new results such as diffusion in amorphous alloys and ordering kinetics. More detailed discussions on these new results have subsequently been published in other scientific journals.

Overall the book represents current work in diffusion in high technology materials. The papers have a uniform high quality, which is not easily achieved in normal conference proceedings. The editors should be congratulated for such an achievement.

The book is paperbound and consists of camera-ready copy of mixed type styles. I would have preferred an arrangement of papers into groups and identification of invited papers. At the current price, $88.00, the book may not be for everyone, but the broad, in-depth nature of this collection of papers should be a valuable reference for those whose work is related to diffusion in solids. This book should also be helpful to new graduate students since it provides a general overview of this broad field.

Reviewer: Y-T. Cheng is a senior research Scientist in the Physical Chemistry Department, General Motors Research Laboratories.

Sol-Gel Technology for Thin Films, Fibers, Preforms, Electronics, and Specialty Shapes

Edited by Lisa C. Klein

(Noyes Publications, 1988)

The title accurately indicates the book's content and philosophy: it presents a survey of applications with emphasis on the technology rather than the science. For gel enthusiasts whose managers ask "But what is it good for?", this book provides a score of answers. It is divided into groups of 3-4 chapters on each of the topics; the chapters are generally 20-30 pages long and have references up to early 1986. The strengths of the volume are its breadth and the inclusion of some good review articles. Its weaknesses are those inherent in a collection of articles: uneven quality, omissions, and some redundancy. There is also a shortage of discussion of fundamentals (e.g., mechanisms of reaction, principles of gelation, drying, sintering, crystallization, film deposition); the technical level of the presentation should be quite understandable for a first-year graduate student.

In the first chapter Ian Thomas provides a practical discussion of the relative merits of chemicals used as precursors in sol-gel processing, and the tricks by which one produces a homogeneous product. The next two chapters have little to do with applications: Steve Garofalini briefly introduces the use of molecular dynamics for simulating chemical reactions, and Mike Weinberg and George Nielson discuss the reported differences in phase transformation behavior between gel-derived and conventional glasses (concluding that melted gels are indistinguishable from melted glasses, but allowing that sintered gels might be different). These are good articles (particularly the latter), but the space might better have been used for background relevant to the following chapters.

The next section consists of three chapters on films. Helmut Dislich surveys the numerous possibilities and provides a catalog of the properties of coatings produced by Schott using gels; unfortunately, he says nothing about principles or processing. Pettit et al. present a solid discussion of the means of controlling the properties of antireflection coatings, including aging of the sol (promoting the growth of fractal oxide clusters whose structure controls the porosity of the deposited film) and etching. Pantano et al. offer an excellent discussion of the preparation, structure, and properties of oxynitride films which can contain up to 40 mole % N.

The following three chapters discuss fiber drawing from sols. Sumio Sakka reviews the effects of the conditions of hydrolysis and choice of precursor on the structure of the inorganic polymer, which determines the drawability of a sol. Harold Sowman describes the commercial process for fabricating alumina borosilicate fibers, which can be woven into cloth and used for applications including filtration or reinforcement. Bill LaCourse's chapter relates the processing of the fiber to its strength; it is somewhat redundant with respect to Sakka's, but does discuss some novel precursors.

Masayuki Yamane provides a very good introduction to the preparation of monolithic gels (usually uncracked pieces with the smallest dimension greater than a few millimeters). He goes through the process step by step and relates the processing to the structure of the gel and to its survivability. Jochen Fricke details the thermal properties of aerogels (made by drying a gel under supercritical conditions), but does not discuss the process, nor the other uses of such gels (e.g., as catalytic substrates and Cherenkov detectors); however, he does give adequate references to those topics. Shyama Mukherjee's chapter on ultrapure glasses reduces to some obvious advice—use clean precursors and work in a clean room. Eliezer Rabinovich reviews the fabrication of gels made from particles (usually generated by flame oxidation, e.g., Cab-o-Sil®, but sometimes made from solution) which can be used to prepare larger pieces than can be made from alkoxides. The discussion is almost entirely limited to work done at AT&T Bell Laboratories. John Blum's chapter on electronic ceramics, which should have been the longest in the book, is only 6 pages with 26 references. Boilot and Colomban present a good review of the preparation and properties of superionic conductors from gels. Sol-gel processing helps by opening new fields of composition, including organically modified oxides, but also creates problems such as cracking and carbon retention. Downs et al. describe, from a process engineer's point of view, the preparation of hollow spheres (typically 10-200μm diameter) for use as fuel containers in inertial confinement fusion. Finally, Lisa Klein briefly mentions preliminary work on fabrication of "membranes" from gels, but offers no data at all on their performance as membranes.

This book gives a broad survey of existing and potential applications of sol-gel processing, and can be recommended to any applied scientist thinking about getting into the field. It is quite generally true that technology precedes scientific understanding, and that has been true in sol-gel too, but not to the extent that one might infer from this volume. This is not to suggest that the authors are not acquainted with the underlying science (indeed, many of these authors contributed significantly to our present understanding), but that aspect is not the object of this book. The novice is advised to supplement this book with proceedings of topical meetings on gels, including *Better Ceramics Through Chemistry* (MRS), *Ultrastructure Processing* (J. Wiley and Sons), and *International Workshop on Gels* (J. Non-Cryst. Solids). Those already working in the field will probably find this volume most interesting for the discussion of commercial processes and the references to the patent literature. The volume is inexpensively produced (equations and tables are apparently pasted in from the original manuscripts), but the text and photos are generally clear.

Reviewer: George W. Scherer is a research scientist in the Central R&D Labs of the Du Pont Company, working on fundamental aspects of drying and sintering of gels. □