processes shows the importance of simulation in order to optimize the growth arrangement and reduce the experimental risk. The problems of shape stability (the three-phase equilibrium at the meniscus) and *in situ* control of specific crystal profiles to reduce machining of the bulk product are carefully shown for crystal pulling arrangements in Chapter 16 (V. A. Tatarchenko, 95 pp.). The ability of the stationarity analysis of Lapunov to find the stable growth parameters for nearly all melt growth configurations (Czochralski, floating zone, Stepanov, edge-defined film-fed, Verneuil, vapour–liquid–solid whiskers growth) is demonstrated convincingly.

After this well balanced coverage of the theoretical treatments of melt growth mechanisms come two treatises on special phase and morphological phenomena. Chapter 17 (J. D. Hunt & S. Lu, 51 pp.) deals with the crystallization of eutectics, monotectics and peritectics, and Chapter 18 (P. J. Phillips, 45 pp.) covers spherulitic crystallization in macromolecules. Somewhat removed from its main objective, the book finishes with two reviews on crystal growth from aqueous solution (Chapter 19, S. Sarig, 50 pp.) and in gels (Chapter 20, F. Lefancheux & M. C. Robert, 30 pp.), both of which belong better with the techniques-oriented Part 2*a*, although the articles also deal with important solution growth processes such as solubility and electrolytic growth kinetics and the influence of the gel structure on growth steps, especially of mechanically fragile or thermally unstable materials.

As was the case for Volume 1, both books of Vol. 2 are excellently edited. All contributions are of a high scientific level and demonstrate not only the present state of the art of crystal growth but show also the requirements and directions of future developments, thus stimulating creativity. Text, formulas and figures are of outstanding quality. Of course, such a comprehensive work has a very high information content. However, absolute completeness has not been obtained. Unfortunately, in the book on basic techniques, some important bulk methods of optical and laser crystal growth from the melt and melt solution, such as Verneuil, Kyropoulos, skull melting and travelling heater, as well as of SiC growth from the vapour by Lely transport, are not considered. There is no information on high-pressure diamond synthesis, and growth under microgravity conditions receives only occasional mention. Book 2*b* contains no discussions of such additional growth phenomena as twinning, precipitation and dendrite formation. On the other hand, the detailed discussions of the modern principles of mass crystallization and growth of biological crystals and macromolecules, which are included, are very welcome in that they enlarge the horizons of conventional single-crystal growth specialists and should guarantee a markedly wider circle of readers.

These books are recommended for specialists and students of materials science, physics, crystallography, chemistry, biology, medicine and pharmaceutics. They belong in every crystal-growth laboratory. However, even with a generous discount where the complete set is purchased, the books are expensive, and I would encourage a future paperback issue of the whole handbook to enable students to add it to their personal libraries.

PETER RUDOLPH

Institute of Crystal Growth
Rudower Chaussee 6
12489 Berlin
Germany

Acta Cryst. (1997). A**53**, 404–406

Handbook of crystal growth. Vol. 3: Thin films and epitaxy. *a*: Basic techniques; *b*: Growth mechanisms and dynamics. Edited by D. T. J. HURLE. Pp. xviii + 1065. Amsterdam: North-Holland Elsevier Science Publishers, 1994. Price Dfl 695. ISBN 0-444-81556-2. (Set price, 3 Vols., Dfl 1450. ISBN 0-444-8993-2.)

This third and last volume of the series covers the basic techniques, growth mechanisms and dynamics of thin films and epitaxial layers, with special emphasis on semiconductors. Part *a* deals not only with fundamental principles of chemical vapour deposition (CVD) but also with vapour-phase epitaxy (VPE) – including organometallic vapour-phase epitaxy (OMVPE) – molecular-beam epitaxy (MBE), liquid-phase epitaxy (LPE), solid-phase epitaxy (SPE), laser surface melting and laser ablation/deposition techniques. Part *b* is predominantly a survey of kinetic mechanisms governing vapour growth, LPE and CVD, the principles of nucleation and surface diffusion in MBE, photoassisted epitaxy and related structural effects.

In keeping with the philosophy of the other two volumes of the series, specialists in the field provide in-depth review chapters that are generally unconnected and hence not fine-tuned. Inevitably, repetitions occur; *e.g.* Chapters 4, 5 and 15, dealing with molecular-beam epitaxy, cover such closely related material that a single chapter could have been justified. These repetitions, however, do serve to show the different views of a common subject adopted by authors with different specialities.

Chapter 1 (H. Watanabe, 39 pp.) contains vital information on the chemical processes occurring during growth of epitaxial layers of Si and GaAs from gaseous precursor species in open-tube reactors, as well as a thorough thermodynamic analysis of the growth rates, based on the equilibrium constants of the transport reactions and the chemical potentials involved. Chapter 2 (H. M. Cox, 47 pp.) describes a promising alternative to open-tube reactors in generating compound semiconductor heterostructures. An upward stream of chloride-transport vapour phase is used to levitate a circular wafer through a horizontally arranged porous frit in stagnation-point flow geometry. To produce step edges of uniform height and sustain their production through the growth process, layer growth following a Frank–van der Merwe model (layer-by-layer step-flow mechanism) has to be achieved, leading to the uniformity and interface abruptness needed for multiquantum wells and quasi-1D filaments ('quantum wires'). Chapter 3 (D. W. Kisker and T. F. Kuech, 60 pp.) analyses the effects of various process parameters (rate of delivery of the organometallic source compound, temperature, compound partial pressure, total reactor pressure) on the growth of III–III′–V (*e.g.* GaAlAs), III–V–V′ (*e.g.* InAsSb) and II–VI (*e.g.* ZnSeS) semiconductor alloys by OMVPE, a technique that allows the deposition of uniform high-quality layers of compound semiconductors for charge control devices such as metal semiconductor field-effect transistors (MESFET's) and heterostructure high-electron-mobility transistors (HEMT's). Chapter 4 (C. T. Foxon, 25 pp.) describes, in detail, aspects of the growth dynamic of the MBE process obtained from the reflection high-energy electron diffraction (RHEED) oscillation

technique employed to measure the growth rate of MBE film *in situ*, and allowing real-time control of film thickness and composition. Chapter 5 (H. Hirayama & H. Asahi, 37 pp.) emphasizes the advantages of MBE with a gaseous source over vapour-phase epitaxy. The required high substrate temperature of the latter process causes dopant diffusion and thus compromises the buried doping profile. The combination of an UHV technology and gaseous sources such as arsine, phosphine and group-IV hydrides allows precise control of gas flow rates by mass flow controllers. The process is characterized by real-time monitoring of the growing layers, absence of flow pattern and pre-mixing reactions and, most importantly, it allows rapid changeover of various gas sources to grow near ideal selective area structures, such as super self-aligned selectively grown base transistors (SSSBT) and high-quality metallo-organic MBE-derived (MOMBE) III–V heterostructures for electronic and photonic devices, such as HEMTs, laser diodes and detectors. Chapter 6 (M. B. Small, E. A. Giess & R. Ghez, 29 pp.) is a highly authoritative text summarizing the knowledge accumulated by the authors over an integrated period of 60 years; it describes, in particular, advantages and disadvantages of the LPE technique. LPE is a mature, economic, safe and flexible process that produces epitaxial layers with excellent opto-electronic properties owing to rather low processing temperatures (compared with the melting point of the substrate) that result in a low point-defect density. It suffers, however, from an intrinsic constitutional instability of the interfaces of heterostructures that is caused by intermixing between the substrate, the newly formed solid epitaxial layer and the solution. Chapter 7 (G. L. Olson & J. A. Roth, 46 pp.) reviews thermally induced solid-phase epitaxy (SPE), a process in which atoms of a metastable solid on a crystalline substrate reorganize epitaxially to become, through layer-by-layer addition, crystalline at temperatures for which the atomic mobility is extremely low (one-half to one-third of the melting point). The chapter describes in great detail SPE in amorphous silicon (*a*-Si), including: the thermodynamics and kinetics in *a*-Si films formed by Si^+-ion implantation and vapour-phase deposition; determination of activation energies; dependence of crystallization rate on substrate orientation, hydrostatic pressure and uniaxial stress; and the nature and concentration of dopants and impurities; as well as the effect of hydrogen on SPE in *a*-Si. Chapter 8 (P. Baeri & S. U. Campisano, 49 pp.) deals with selected problems of rapid solidification by laser annealing of semiconductor materials, including: kinetics of the melt front; determination of the melt depth; TEM studies of the structure and crystallinity of solidified silicon doped with P, As, Bi and In; as well as studies of the fast liquid-to-solid transition of binary silicides of Co, Ni, Fe and Ti, using Rutherford backscattering to determine the extent and the composition of silicide layers on silicon. Chapter 9 (O. Auciello, 34 pp.) covers the application of the pulsed eximer UV laser deposition (PLD) technique to deposit onto targets ferroelectric, electro-optical, optical, high-temperature superconducting and bioceramic thin films and coatings. Special emphasis is placed on major advantages (relatively high deposition rates, stoichiometry of multicomponent layers, microstructural control, compositional flexibility, and the possibility of time-sharing the laser beam) and disadvantages (particle formation on the film, the difficulty of scale-up to cover large areas, the need to use polished substrates, and the requirement to protect the vitreous silica windows of the UHV system from materials deposition). The final chapter of Part *a* (B. V. Spitsyn, 54 pp.) is concerned with the historical and current techniques of formation of diamond films from an activated vapour phase, single-crystal epitaxial and polycrystalline diamond film growth processes, characterization techniques for such films, and their application.

Part *b* of Vol. 3 starts with a fundamental chapter (A. A. Chernov, 32 pp.) describing the driving forces in physical (PVD) and chemical deposition (CVD); the dependence of the growth rate of CVD films on vapour pressure, gas flow rate and temperature; surface structure determination, including surface roughening by 2D nucleation; step flow kinetics as described by RHEED oscillations in MBE; and nucleation at, and growth of, reconstructed surfaces. Chapter 12 (G. B. Stringfellow, 48 pp.) concentrates on the kinetic aspects of OMVPE, including results from MBE, chemical beam epitaxy, MOMBE and gas-source MBE, by describing homogeneous reaction kinetics for cation, anion and combined source molecules; heterogeneous reaction kinetics on semiconductor surfaces; and the application of optical [STM, RHEED, FTIR, reflectance difference spectroscopy (RDS)] and mass spectroscopy tools for *in situ* measurement of the growth kinetics of epitaxial films. Chapter 13 (K. F. Jensen, 57 pp.) reviews fluid flow, heat and mass transfer, and chemical reaction processes in VPE reactors, including modelling results that were contrasted with the results of tracer experiments. Chapter 14 (T. Suntola, 59 pp.) is a thorough treatment of atomic layer epitaxy (ALE), a technique that by its inherent self-control – obtained by reactant surface saturation through deposition of one atomic layer ('monolayer') per single surface reaction sequence – provides a cost-effective technique, as large batches of substrates can be handled in a small reactor volume. In this chapter, several reactor types are described and data on ALE growth of II–VI and III–V materials – oxides, nitrides and group-IV semiconductors – are given. Chapter 15 (T. Nishinaga, 24 pp.) provides information on nucleation and subsequent surface diffusion, obtained by measuring the critical temperature that characterizes the transition between a growth mechanism controlled by 2D nucleation and that controlled by a unidirectional flow of steps of atomic height; it includes information on surface diffusion of Ga atoms on a non-planar (001) GaAs substrate surface on which the Ga atoms attain an extraordinary diffusion length of up to 10 μm. Chapter 16 (Y. Horikoshi, 51 pp.) covers basic characteristics of migration-enhanced epitaxy compared with conventional MBE, its application to quantum wells and superlattice structures, and as a means to lower the epitaxial growth temperature, allowing growth of a new class of superlattices (ZnSe/GaAs, GaAsSi/GaAs) with superior quality. Chapter 17 (L. Samuelson & W. Seifert, 37 pp.) treats growth and characterization of ultra-thin quantum wells and heterostructures in the systems GaInAs/InP and GaAs/GaInP, as well as the experimental conditions under which the low growth rates at simultaneously high supersaturations, required to grow these structures, can be realized. Chapter 18 (S. J. C. Irvine, 30 pp.) reports on a fledgling technique that intends to stimulate epitaxial growth processes by using a laser beam to modify precursor molecules, either directly by photodissociation or indirectly by photosensitization, thus generating radical species that enhance film properties; *e.g.* the conductivity of a CdTe layer grown by MBE [photoassisted MBE (PAMBE)] processes through low-temperature desorption of excess tellurium. Chapter 19 (C. Pickering, 60 pp.) presents a thorough state-of-the-art review of real-time *in situ* non-invasive monitoring to rapidly optimize MBE and VPE growth conditions by applying

optical techniques such as RDS, spectroscopic ellipsometry, photoreflectance, Raman spectroscopy and second-harmonic generation. Chapter 20 (E. Bauser, 60 pp.) shows that LPE, by combining the advantages of bulk solution growth and epitaxy, provides a useful technique to prepare multilayer structures with high-quality interfaces, by an atomic growth mechanism controlled by pure step flow that can result in minimum defect density. Chapter 21 (E. I. Givargizov, 53 pp.) treats epitaxial phenomena occurring during growth of crystals and crystalline films on amorphous substrates that are governed not by atomistic crystallographic factors, as in classical heteroepitaxy, but by macroscopic effects (macrosteps, macroparticles) brought about by external interactions through mechanical, thermal, chemical or electric fields. The last chapter of Part *b* (A. Zunger, 53 pp.) contains experimental evidence and physical explanations for coherent epitaxy-induced structural changes in thin films relative to bulk solids that reveal themselves in: (i) formation/stabilization of compound crystal structures unstable in bulk form at otherwise equivalent conditions; (ii) epitaxial stabilization of binary and ternary alloy solid solutions having only limited stability in bulk form; (iii) composition pinning in epitaxial alloys lattice-matched to the substrate; and (iv) electronic consequences of coherent epitaxy.

The editorial and typographical quality of the book is generally very high. Unfortunately, this cannot be said about the subject index, which is rather trivial and only poorly reflects the true content of the articles. A hierarchical listing of the entries would have been preferable. The volume is a treasure trove of state-of-the-art information on one of the technologically most important crystal-growth techniques. Crystal growers, solid-state physicists and chemists, semiconductor physicists and engineers, electronic engineers and materials scientists will all benefit from studying this comprehensive treatise.

ROBERT B. HEIMANN

Department of Mineralogy
Freiberg University of Mining and Technology
D 09596 Freiberg
Germany

Acta Cryst. (1997). A**53**, 406

Books Received

The following books have been received by the Editor. Brief and generally uncritical notices are given of works of marginal crystallographic interest; occasionally, a book of fundamental interest is included under this heading because of difficulty in finding a suitable reviewer without great delay.

Ordering and phase transitions in charged colloids. Edited by A. K. ARORA and B. V. R. TATA. Pp. xi + 361. Weinheim: VCH Verlagsgesellschaft, mbH, 1996. Price DM 185.00. ISBN 1-56081-917-0. Colloidal dispersions have many interesting properties that 'almost mimic all the phases of condensed matter'. This volume covers a wide range of experimental and theoretical investigations into the title topic. Experimental techniques discussed include video microscopy, optical Bragg and Kossel diffraction, light scattering and ultra-small-angle X-ray scattering. Theoretical tools discussed include density-function theory, computer simulations and inversion methods. Both the 'repulsive' and the 'attractive–repulsive' schools of thought are represented.

Metallomesogens – synthesis, properties and applications. Edited by J. L. SERRANO. Pp. xix + 498. Weinheim: VCH Verlagsgesellschaft, 1996. Price DM 298. ISBN 3-527-29296-9. A review of this book, by Peter Maitlis, has been published in the April 1997 issue of *Acta Crystallographica Section B*, pages 323–324.