Book Reviews

Works intended for notice in this column should be sent direct to the Book-Review Editor (R. F. Bryan, Department of Chemistry, University of Virginia, McCormick Road, Charlottesville, Virginia 22901, USA). As far as practicable, books will be reviewed in a country different from that of publication.

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Handbook of crystal growth. Vol. 2: Bulk crystal growth. *a*: Basic techniques; *b*: Growth mechanisms and dynamics. Edited by D. T. J. HURLE. Pp. xv + 1299. Amsterdam: North-Holland Elsevier Science Publishers, 1994. Price Dfl 695, US $397.00. ISBN 0-444-81554-6.

These two books comprise the second of the three volumes of this comprehensive handbook. The first volume, devoted to fundamentals of crystal growth, has already been reviewed in this journal [Wilcox & Regel (1994). *Acta Cryst.* A**50**, 652–653]. Part 2*a* presents the major techniques used for bulk single-crystal growth from melt, vapour and solution, while Part 2*b* deals with the basic mechanisms and dynamics of melt and solution growth. As was the case for Volume 1, the material presented here is very informative. Although these excellent reviews might seem somewhat unconnected at first glance, their overall effect does clearly achieve the editor's objective – to demonstrate the complexity and importance of the science and technology of crystal growth and its interdisciplinary interactions with many active branches of contemporary science.

The start of Part 2*a* is quite surprising, but successful. In contrast to artificial growth methods, Chapter 1 (I. Sunagawa, 49 pp.) introduces the natural crystal growth processes in the earth and planets. The author's commendable intent is to build a bridge between earth and planetary sciences and the science and technology of crystal growth. As he points out, 'the Earth is a ceaseless crucible growing crystals under an extremly wide range of conditions . . .'. The reader learns not only the fascinating genesis of precious stones but also experimental methods of laboratory simulation including the interpretation of the changes in the brightness of comet tails from a kinetical point of view! Chapter 2 (E. Monberg, 44 pp.) treats Bridgman growth techniques, mainly of III–V semiconductor compounds. Though numerous interesting details are discussed, the well manifested potential of this melt growth method for a much wider range of materials is covered too briefly. Chapter 3 (D. T. J. Hurle & B. Cockayne, 110 pp.) deals very carefully with the 'heart' of bulk crystal growth, the Czochralski method, showing the fundamentals and details of the method in real handbook style. The dominant position of this technique for the production not only of the world's most important single crystal – silicon – but also of numerous crystals for modern optics is demonstrated by the use of many excellent tutorial materials. Chapter 4 (J. Bohm, A. Lüdge & W. Schröder, 42 pp.) deals with growth by floating-zone melting, with a nearly complete consideration of the relevant literature (374 references!). The optimization of RF coil technology, especially for crucible-free silicon growth, is described in detail. However, a more helpful introduction and conclusion on the interrelations and future of this method might have been provided. Chapter 5 (D. T. J. Hurle & R. W. Series, 24 pp.) includes theory and experiments on the use of magnetic fields to damp the destabilizing natural convection flows in conducting melts; important, as the future superdiameter technology of silicon-crystal growth will require the application of special magneto-hydrodynamic know-how. Chapter 6 (P. J. Jansens & G. M. van Rosmalen, 25 pp.) introduces the methodology of fractional crystallization, a general term for separation processes that can be used for large-scale separation and ultrapurification of materials, *e.g.* organic compounds and polymers, that is of the highest importance for modern biology, medicine and the food industry. It is quite welcome that Chapter 7 (A. E. D. M. van der Heijden & G. M. van Rosmalen, 97 pp.) gives a complete overview of industrial mass crystallization. Usually, the basic literature on crystal-growth fundamentals omits this wide and important field of application where the control of the nucleation process and habitus phenomena play an essential role. Approaches to the artifical crystallization of biological macromolecules are discussed in Chapter 8 (A. McPherson, 44 pp.). Despite the complexity of the control of the incorporation of large biological molecules into the crystal structure ('a protein polymer may have literally thousands of degrees of rotational freedom . . .'), this will be one of the most fascinating fields of the science and technology of crystal growth in the near future, emphatically showing its interdisciplinary and key position in the modern science of life. Chapter 9 (K. Brappa, 95 pp.) is a very assiduous treatment of experimental results and theory on the hydrothermal growth of practically all inorganic compounds, principally quartz, berlinite, malachite *etc.* and includes numerous very helpful tables of material and growth parameters. In Chapter 10 (W. Tolksdorf, 46 pp.), the author describes his well tried long-term experiences on the flux growth of $Y_3Fe_5O_{12}$ crystals. The addition of further related methods not mentioned elsewhere, such as the accelerated crucible rotation technique, top-seeded solution and travelling solvent zone growth, is particularly valuable. Chapter 11 (E. Kaldis & M. Piechotka, 43 pp.) concludes Part 2*a*, and is a compressed description of bulk crystallization by physical vapour transport, concentrating on the authors' results with HgI_2 crystal growth by the Scholz method. Unfortunately, a wider view of further important developments of large-diameter vapour crystal growth by the pedestal technique of Markov, and the important consequences of Lely's method for SiC substrate production, are not given.

Part 2*b* starts with Chapter 12 (J. P. Garandet, J. J. Favier & D. Camel, 46 pp.) on segregation phenomena limiting the yield of bulk crystal growth from the melt. In very good harmony follows the comprehensive Chapter 13 (G. Mueller & A. Ostrogorsky, 103 pp.) on convection in the melt. The hydrodynamic fundamentals, simulation experiments and approaches to convection control of various materials as well as numerous tables of growth parameters are presented in quite exemplary fashion. Chapter 14 (J. Vökl, 51 pp.) covers modern concepts on modelling of dislocation multiplication during crystal growth and subsequent cooling, using the dynamic thermomechanical stress theory first developed by Alexander and Haasen. The voluminous and very informative Chapter 15 (F. Dupret & N. van den Bogaert, 133 pp.) on the development of the global computing of Bridgman and Czochralski growth

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.

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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