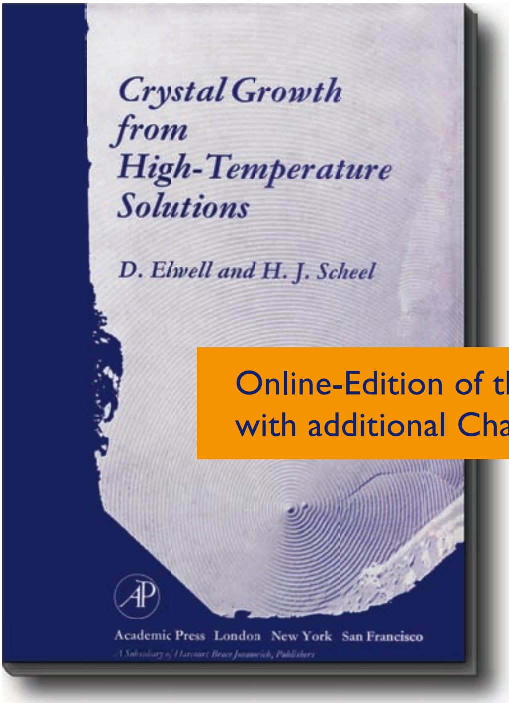

Online-Edition of the original book
with additional Chapter 11 and Appendices A and B

Part 001

Crystal Growth from High-Temperature Solutions

D. Elwell and H. J. Scheel

Online-Edition of the original book
with additional Chapter 11 and Appendices A and B

Academic Press London New York San Francisco

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Preface for the scanned edition of

"Crystal Growth from High-Temperature Solutions"

by Dennis Elwell and Hans J. Scheel

The original edition of „Crystal Growth from High-Temperature Solutions", published by Academic Press 1975, went out of print many years ago. We authors separately moved around the world, and occasional attempts to reprint this book as paperback to make it available for students, failed.

The reasons for scanning this work are primarily that there is no other comprehensive book in this area of crystal growth, since the original version was recognized at an early stage as a definitive work covering theoretical, experimental and technological aspects, with much data. Second, there has been increasing demand for the book for teaching purposes, especially in China, India and Japan, where students made copies of the book and copies of copies. Also letters signed by professors and students have been received to support a reprint. Third, crystal growth from high-temperature solutions including liquid phase epitaxy (LPE) has evolved into a significant industrial field. Applications include LPE of light-emitting diodes LEDs, solar cells and detectors, and bulk growth of garnets, emerald, ruby, etc. Furthermore, it is a key technology for LPE and bulk growth of high-temperature superconductors (HTSC) and of group III nitrides.

In this digital version we have added a new **Chapter 11** covering crystal growth and LPE of HTSC, including phase relations, crucible corrosion problems and identification of key issues for future development. Progress in this promising field has been hampered by the complexity of the materials engineering problems which are increasing with higher critical temperatures. In view of the large potential of HTSC for saving energy, for energy storage and for renewable energy, great efforts in physico-chemical and material-engineering problems including crystal growth and LPE in combination with education of crystal technologists are required: thus this book may be useful.

We have also added a short **Appendix A** summarizing the theoretical and technological solutions to solve the important problem of growing striation-free crystals of solid solutions which have potential applications as substrates for strain-free epitaxy and as optical crystals with optimized properties.

A last **Appendix B** gives a fresh look at epitaxial growth and at control of the eight epitaxial growth modes to achieve highest-performance devices. Large-scale LPE should develop into an economic and ecological technology for many applications, besides magneto-optic applications for LEDs and for high-efficiency concentrator photovoltaic solar cells based on III-V compounds.

We hope that this digital version of the book Crystal Growth from High-Temperature Solutions will assist experimental crystal growers in laboratories in industries, and that it will be used in the education of material engineers and scientists and hopefully soon of crystal technologists.

The authors wish to thank the library of ETH Zurich, director Dr. Wolfram Neubauer, and co-workers Mrs. Anka Diekmann and Mrs. Yvonne Inden for making this book worldwide available.

One of the authors (HJS) is grateful to Prof. Jürg Nänni and to Mr. Peter Bosshard for the artistic and professional design of the website where this book will be attached or indicated.

DENNIS ELWELL
HANS J. SCHEEL

December 2011

List of Corrections and Remarks for the 1975 Print Version of the Book

"Crystal Growth from High-Temperature Solutions"

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p. 22	0.6	Huygens in 1690 postulated …(not 1960)
p. 54	0.7	Kepler, J. (1611)"Strena seu de nive sexangula" Tampach,Frankfurt/M.
p. 62	eq.3.6	In this Van't Hoff equation, for non-ideal solutions replace ΔH_f by $\Delta H_{sol.}$
p.101	0.55	combinations of …
p. 131	0.5	Hiskes, R. (1974), J. Crystal Growth **27**, 287.
p. 152	0.1	Eq. 4.13: delete $-n_0$
p. 205	0.6	The Hartman-Perdok PBC method
p. 221		see explanation of growth of thin platelets by LEG mechanism in Chapter 11 on p. 647-648.
p. 264	0.3	… discussed in Section 6.2. (not 6.5)
p. 280	0.6	… supersaturated solutions …
p. 299	0.6	… experimenter …
p. 313	0.6	include GaP by "SSD" = VLSR by J.P. Besselere and J.M. Le Duc, Compt. Rend.(1967)C -2945.
p. 321-328		Section 7.1.3: See also Appendix A "Growth of striation-free crystals"
p. 353	0.3	… the temperature is shown …
p. 383	0.5	… (see Fig. 6.18) and thus …
p. 433-469		Chapter 8: see also Appendix B "Epitaxy and the importance of LPE" & Chapter 11: "Crystal Growth and LPE of High-Tc Superconductors"
p. 489-499		Section 9.2.4: See also Appendix A "Growth of striation-free crystals"
p. 623	0.5	Insert g gravity
p. 635		The Chapter 11 was written 1997, final version 2000.

Crystal Growth from High-Temperature Solutions

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Contents

Preface

In this book a comprehensive account is given of experimental and theoretical aspects of the growth of crystals from mainly molten salt and metallic solutions. Although several reviews have appeared on flux growth, this is the first extended account dealing in detail with this topic. Its preparation seemed appropriate at this time since, firstly, the subject is in a state of transition from an art to a science and, secondly, the potential of high-temperature solution growth for the preparation of crystals for research and applications is becoming more and more apparent. The book is designed to become the standard reference work in the field of crystal growth from high-temperature solutions, and it is hoped that it will stimulate both experimental and theoretical work on this comparatively unexplored crystal-growth technique.

The book will be of assistance to both lecturers and students of graduate courses in crystal growth and materials science, but it was primarily written for those engaged in research and development in experimental crystal growth. A review is included of the current situation of the relevant theory, and several proposals for future research are indicated. Many of the principles are applicable to crystal growth from aqueous or organic solutions as well as to several crystallization processes in nature. Topics of general interest to crystal growers, especially crystal characterization, are treated in detail and the book is, for the most part, of interest to materials scientists, solid-state chemists and physicists, electrical engineers, mineralogists, gemmologists and inorganic and physical chemists. It is assumed that the reader is somewhat familiar with the basic concepts of crystal structure and crystal growth and with the principles of the major crystal-growth techniques. Many references to review articles and books have been included with the aim of facilitating reference to associated fields, which are numerous because of the interdisciplinary nature of crystal growth.

Solution growth is the most widely applicable method of crystal growth since solvents can be found for almost all materials. A central purpose of this book is to demonstrate the potential of high-temperature solution growth for classes of materials which are difficult to grow by other techniques or which have been relatively neglected. Large crystals some centimeters in size and several hundred grams in weight, inclusion-free and of a very high purity, have been grown of several interesting materials, and pilot plants for production of a variety of crystals and crystalline layers are expected to lead to the development of large-scale production plants. Interest in high-temperature solution growth was particularly stimulated by the development of devices based on the epitaxial deposition of high-quality layers on crystalline substrates. *Liquid phase epitaxy* is accordingly treated in a separate chapter where an attempt is made to relate the film quality and device performance to experimental variables.

Most chapters are written as relatively independent units except for cross-references where appropriate. This philosophy has resulted in a certain amount of repetition, which should, however, assist the reader. In the first two chapters an account is given of the basic concepts of HTS growth, its history and its relation to other growth methods. Chapter 3 contains a detailed account of solution principles, with emphasis on their relation to crystal growth. The theoretical principles of high-temperature solution growth are outlined in Chapters 4–6 and are related where possible to experimental observations. Chapters 7 and 8 treat the experimental techniques for the growth of bulk crystals and epitaxial films. Crystal characterization is considered in detail in Chapter 9, and the final chapter and its Appendix contain an extensive tabulation of the crystals grown from high-temperature solutions.

The typescript and many illustrations were prepared by the Publications Department of the IBM Zurich Research Laboratory under the supervision of Mrs. D. Brüllmann who also devoted much of her time to proofreading. Our task was greatly facilitated by the particular skills of Miss A. Huwyler, Mrs. R. Wölfle and Mr. U. Bitterli of the Publications Department. We are deeply indebted to the IBM Corporation, especially to Prof. Dr. K. A. Müller of the IBM Zurich Research Laboratory, for continuous support and encouragement. The efficient and cooperative handling of the manuscript and preparation of the book by the Publisher is very much appreciated. One of the authors (H. J. Scheel) wishes to express his gratitude to Prof. Dr. F. Laves for his kind encouragement and help and for introducing him to the field of materials science. Finally, to our wives and children we express our deepest gratitude for their patience and forbearance (sometimes!).

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HANS J. SCHEEL

Portsmouth and Zurich
April 1975

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