

*Crystal Growth  
from  
High-Temperature  
Solutions*

*D. Elwell and H. J. Scheel*

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



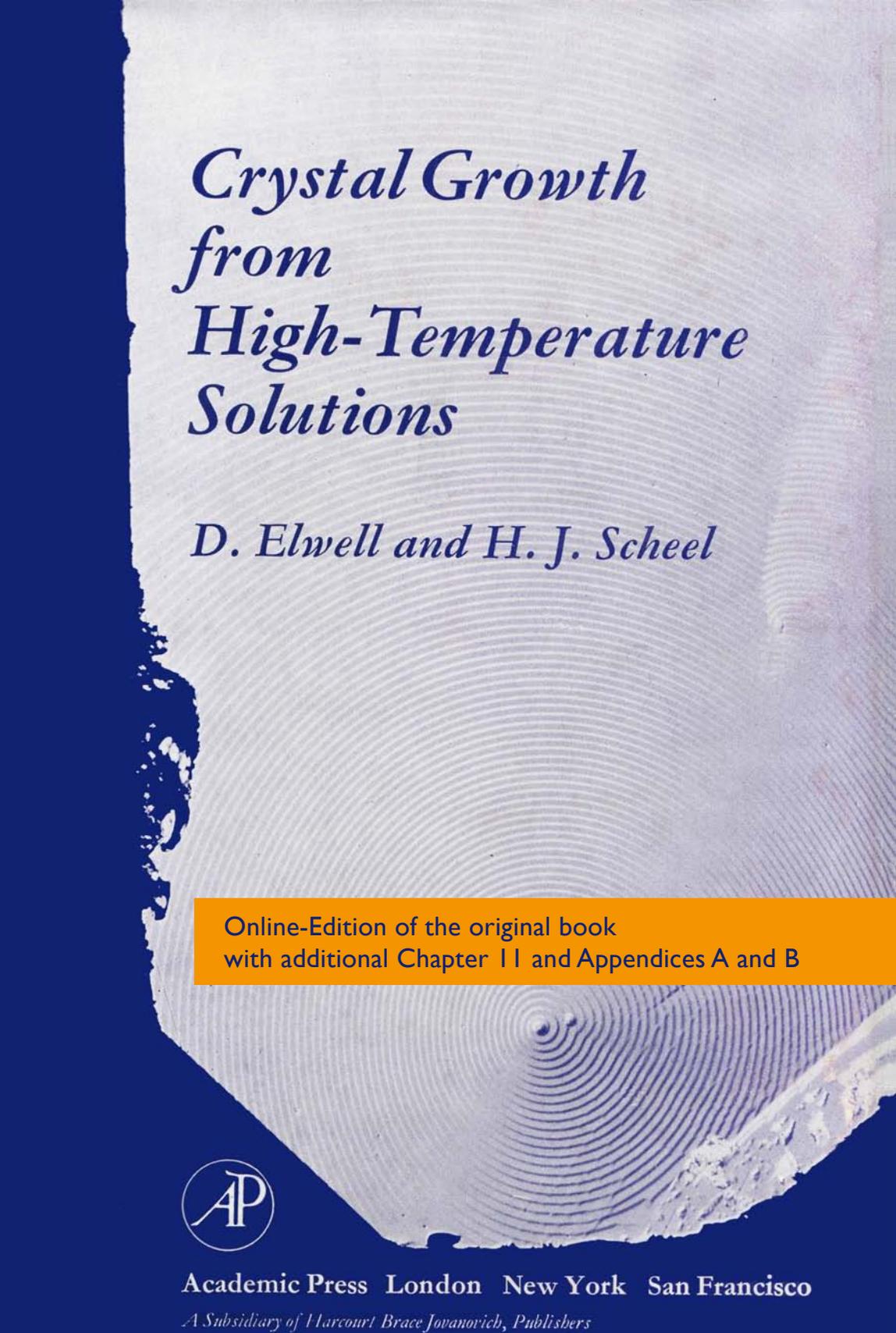
Academic Press London New York San Francisco

A Harcourt Brace Jovanovich, Publisher

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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”**

by D. Elwell and H.J. Scheel

- 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  $\Delta H_f$  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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1975



ACADEMIC PRESS

London New York San Francisco

*A Subsidiary of Harcourt Brace Jovanovich, Publishers*

ACADEMIC PRESS INC. (LONDON) LTD.  
24/28 Oval Road  
London NW1

*United States Edition published by*  
ACADEMIC PRESS INC.  
111 Fifth Avenue  
New York, New York 10003

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ACADEMIC PRESS INC. (LONDON) LTD.

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Library of Congress Catalog Card Number: 74-18000  
ISBN: 0-12-237550-8

Printed in Great Britain by  
Robert MacLehose and Co. Ltd  
Printers to the University of Glasgow

## Contents

Preface . . . . .	vii
Acknowledgements . . . . .	ix
1. Introduction to High-Temperature Solution Growth . . . . .	1
1.1. The Importance of Materials Research . . . . .	1
1.2. High-Temperature Solution Growth . . . . .	3
1.3. Alternative Methods of Crystal Growth . . . . .	6
1.4. Applications . . . . .	11
1.5. Current Problems and Future Trends . . . . .	16
References . . . . .	17
2. History of Crystal Growth from Solutions . . . . .	20
2.1. Development of Ideas on Crystals and Crystallization . . . . .	20
2.2. Early Crystallizations from High-Temperature Solution . . . . .	25
2.3. Comments on the Table of Early References . . . . .	31
References . . . . .	50
3. Solvents and Solutions . . . . .	59
3.1. Introduction . . . . .	59
3.2. General Solution Concepts . . . . .	61
3.3. Solute-solvent Interactions . . . . .	69
3.4. Chemical Equilibria and Complexes in Solutions . . . . .	72
3.5. High-Temperature Solvents and Solutions . . . . .	85
3.6. Choice of Solvents . . . . .	86
3.7. Practical Solvents and their Properties . . . . .	95
3.8. Determination of Solubility Curves and Phase Diagrams . . . . .	113
3.9. Selected Solubility Data and Phase Diagrams . . . . .	122
References . . . . .	127
4. Theory of Solution Growth . . . . .	138
4.1. Limitations of a Theoretical Treatment . . . . .	138
4.2. Nucleation . . . . .	139
4.3. Rough and Smooth Interfaces . . . . .	143
4.4. Models of Surface Roughness . . . . .	145
4.5. Stages in Growth from Solution . . . . .	148
4.6. The Boundary Layer . . . . .	151
4.7. Generation of Surface Steps . . . . .	156
4.8. The Theory of Burton, Cabrera and Frank . . . . .	160

4.9.	Should Surface Diffusion be Included?	166
4.10.	The Role of Desolvation	170
4.11.	Comparison of Solution Growth Theory with Experiment	171
4.12.	Non-Archimedean Spirals	176
4.13.	Surface Morphology of Flux-Grown Crystals	183
4.14.	Alternative Growth Mechanisms	189
4.15.	Summary	197
	References	198
5.	Crystal Habit	202
5.1.	Historical Development	202
5.2.	The Equilibrium Shape of a Crystal	203
5.3.	Influence of Growth Conditions on Habit	207
5.4.	Effect of Impurities on Habit	210
5.5.	Habit Changes in HTS Growth	215
5.6.	Summary on Habit Changes	231
	References	232
6.	Conditions for Stable Growth	237
6.1.	Stability of Growth	237
6.2.	Solution Flow and Stability	252
6.3.	Ultimate Limit of Stable Growth	255
6.4.	Experiments on Growth Stability	258
6.5.	Results of Unstable Growth	261
6.6.	Experimental Conditions for Stable Growth	264
6.7.	Summary	273
	References	274
7.	Experimental Techniques	278
7.1.	Principles	279
7.2.	High-Temperature Technology	330
7.3.	Special Techniques, Specific Problems	404
7.4.	Summary	420
	References	421
8.	Liquid Phase Epitaxy	433
8.1.	Introduction to Liquid Phase Epitaxy (LPE)	433
8.2.	Light-Emitting Diodes	434
8.3.	Bubble-Domain Devices	440
8.4.	Experimental Techniques	442
8.5.	Growth-Rate Controlling Mechanisms in LPE	459
8.6.	Important Factors and Future Trends	463
	References	467
9.	Characterization	470
9.1.	Necessity of Crystal Characterization	470
9.2.	Chemical Composition and Homogeneity	472
9.3.	Structural Aspects and their Determination	499
9.4.	Defects in Crystals and their Determination	512
9.5.	The Growth History of a Crystal as deduced from Characterization	538

CONTENTS

vii

9.6. Proposed Standard for Routine Characterization of Crystals	544
References	546
10. Crystals Grown from High-Temperature Solutions	558
Table of HTS-grown Crystals	560
References	597
Appendix to Chapter 10	615
References	620
Symbols and Abbreviations	623
Index	627

## 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. Wölfe 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*

## Acknowledgements

The book has benefited considerably from the criticism and comments of many colleagues who have read one or more chapters on their particular, specialized topics. The authors are indebted to the following for their contributions:

H. Arend, A. Armington, A. Authier, W. Bardsley, P. Bennema, S. L. Blank, R. W. Brander, J. C. Brice, B. Cleaver, B. Cockayne, T. F. Connolly, J. Felsche, R. Ghez, E. A. Giess, A. R. Goodwin, H. G. B. Hicks, B. Honigmann, D. T. J. Hurle, E. Kaldis, B. Lewis, R. C. Linares, D. J. Marshall, K. A. Müller, H. Müller-Krumbhaar, J. W. Mullin, J. W. Nielsen, D. Pohl, H. Posen, A. Preisinger, J. P. Remeika, J. M. Robertson, C. J. M. Rooymans, L. Rybach, C. S. Sahagian, M. Schieber, M. B. Small, S. H. Smith, W. Tolksdorf, B. M. Wanklyn.

The advice of P. Bennema, C. S. Sahagian and M. Schieber on important aspects is most appreciated. Valuable discussions with the following are also acknowledged with gratitude: S. L. Blank, C. H. L. Goodman, R. C. Linares, K. A. Müller, J. W. Nielsen, T. S. Plaskett, J. P. Remeika, J. M. Robertson, S. H. Smith, W. Tolksdorf, B. M. Wanklyn.

In addition, many colleagues, too numerous to mention, contributed pre-prints or other information. We are grateful to H. V. Alexandru, N. P. Luzhnaja, H. Sasaki and V. A. Timofeeva for their assistance with references, particularly those not easily accessible in languages familiar to the authors, to Dr. L. Bohaty for his translation from Russian work, and to Mrs. M. Scheel for collecting the data of Table 2.2.

Further comments and suggestions from readers would be highly appreciated by the authors.

Photographs or diagrams were kindly contributed by: A. Authier, Balzers AG, Liechtenstein (Dr. H. D. Dannöhl), W. T. Stacy, C. F. Cook, H. Frederiksson, S. E. R. Hiscocks, B. Isherwood, H. Klapper, D. E. Lepore, E. O. Schulz-DuBois, W. Tolksdorf, A. M. Vergnoux, B. M. Wanklyn, R. H. Wentorf, J. M. Woodall.

D.E.  
H.J.S.