

CONTENTS

<i>Chapter 1</i>	SINGLE CRYSTALS	1
1.1	What Is a Crystal?	1
1.2	Experimental Evidence for Crystallinity	7
1.2.1	Rotating-Crystal Methods	9
1.2.2	Powder Methods	9
1.2.3	Laue Methods	11
1.2.4	Low-Angle Scattering	11
1.3	Imperfections in Crystals	11
1.3.1	Vacancies	12
1.3.2	Dislocations	13
1.3.3	Grain Boundaries	15
1.3.4	Twins	17
1.3.5	Stacking Faults	19
1.3.6	Vicinal Faces	20
1.3.7	Other Imperfections	21
1.4	Methods of Studying Perfection	21
1.4.1	X-ray Methods	21
1.4.2	Etching	25
1.4.3	Decoration	31
1.4.4	Direct Observation of Surface	32
1.4.5	Observation with the Electron Microscope	33
1.4.6	Observation with Field-Ion Microscope	33
1.5	Why Are We Interested in Crystals?	33

Chapter 2 CRYSTAL-GROWTH EQUILIBRIA 39

- 2.1 Classification of Growth Processes 39
- 2.2 Equilibria in Crystal Growth 40
- 2.3 Monocomponent Solid-Solid Equilibria 42
- 2.4 Monocomponent Solid-Liquid Equilibria 46
- 2.5 The Distribution Coefficient 47
- 2.6 Phase Diagrams and the Phase Rule 51
- 2.7 Conservative Processes 54
- 2.8 Nonconservative Processes 58
- 2.9 Monocomponent Gas-Solid Equilibria 63
- 2.10 Growth from Solution 64
- 2.11 Growth by Chemical Reaction 70
- 2.12 Growth of Metastable Phases 73

Chapter 3 KINETICS OF CRYSTAL GROWTH 77

- 3.1 The Rate Determining Process 77
- 3.2 Diffusion 77
- 3.3 Crystal Surfaces 79
- 3.4 Processes Which Take Place During Growth From Solution 86
- 3.5 Processes Which Take Place During Growth By Various Types of Equilibria 89
- 3.6 Crystal Growth as a Consecutive Reaction 92
- 3.7 Reaction Steps in the Interfacial Process 94
- 3.8 Movement of Steps 98
- 3.9 Nucleation 101
- 3.10 Effect of Rate on Distribution Constant 103
- 3.11 Constitutional Supercooling 104
- 3.12 Formation of Growth Facets 106
- 3.13 Formation of Cells 108
- 3.14 Correlations with Entropy 109

Chapter 4 CRYSTAL GROWTH BY SOLID-SOLID EQUILIBRIA 113

- 4.1 Solid-Solid Growth Methods 113
- 4.2 Recrystallization by Annealing Out Strain 114
 - 4.2.1 General Considerations 114
 - 4.2.2 Equipment Used in Strain Annealing 127
 - 4.2.3 Growth of Specific Crystals by Strain-Annealing 132
 - 4.2.3-1 Aluminum, 132. 4.2.3-2 Copper, 135.
 - 4.2.3-3 Iron, 135. 4.2.3-4 Other Materials, 142
- 4.3 Growth by Sintering 143
- 4.4 Growth by Polymorphic Transition 144
 - 4.4.1 Iron 145

- 4.4.2 Uranium 146
- 4.4.3 Quartz 146
- 4.4.4 Ferroelectrics 149
- 4.4.5 High-Pressure Polymorphic Transitions 150
 - 4.4.5-1 Diamond, 150. 4.4.5-2 Boron Nitride 151.
 - 4.4.5-3 Silica, 151.
 - 4.4.5-4 Other Materials, 152.
- 4.5 Devitrification 152
- 4.6 Polycomponent Solid-Solid Growth 153

Chapter 5 CRYSTAL GROWTH BY MONOCOMPONENT LIQUID-SOLID EQUILIBRIA 159

- 5.1 Introduction 159
- 5.2 Uncontrolled Freezing 160
- 5.3 Bridgman-Stockbarger and Related Techniques 161
 - 5.3.1 Equipment 164
 - 5.3.2 Growth of Specific Crystals 168
 - 5.3.2-1 Metals and Semiconductors, 168.
 - 5.3.2-2 Nonmetals, 172.
- 5.4 Czochralski and Related Techniques 174
 - 5.4.1 Equipment 177
 - 5.4.2 Growth of Crystals—General Considerations 180
 - 5.4.2-1 Semiconductors, 191. 5.4.2-2 Insulators and Metals, 196.
- 5.5 Zone-Melting Techniques 199
- 5.6 Other Crucibleless Techniques 206
 - 5.6.1 Flame Fusion 206
 - 5.6.1-1 Apparatus and Technique, 208.
 - 5.6.2 Techniques Related to Flame Fusion—Plasma and Arc Heating 210
- 5.7 Other Liquid-Solid Methods 216
- 5.8 Dendrite Growth 216

Chapter 6 CRYSTAL GROWTH BY VAPOR-SOLID EQUILIBRIA 225

- 6.1 Introduction 225
- 6.2 Sublimation-Condensation 226
- 6.3 Sputtering 230
- 6.4 Growth by Reversible Reactions 233
 - 6.4.1 Theory 233
 - 6.4.2 Typical Systems 239
 - 6.4.2-1 Hot-Wire Process, 239. 6.4.2-2 Other Processes, 240.
- 6.5 Growth by Irreversible Reactions 249
 - 6.5.1 General 249
 - 6.5.2 Typical Systems 250

Chapter 7 **GROWTH FROM LIQUID SOLUTION 257**

- 7.1 Introduction 257
- 7.2 Aqueous-Solution Growth 259
 - 7.2.1 Holden's Rotary Crystallizer 264
 - 7.2.2 Mason-Jar Method 266
 - 7.2.3 Temperature Differential Method 267
 - 7.2.4 Other Methods—General 270
 - 7.2.4-1 Chemical Reactions, 270. 7.2.4-2 Gel Media, 271.
 - 7.2.4-3 Electrochemical Reactions, 275.
- 7.3 Hydrothermal Growth 275
 - 7.3.1 Equipment 278
 - 7.3.2 Phase Equilibria and Solubility 281
 - 7.3.3 Kinetics—Quartz 282
 - 7.3.4 Perfection 287
 - 7.3.5 Growth of Other Materials 289
 - 7.3.5-1 Sapphire, 289. 7.3.5-2 Yttrium-Iron Garnet, 291.
 - 7.3.5-3 Zinc Oxide, 293.
- 7.4 Molten-Salt Growth 293
 - 7.4.1 Equipment 294
 - 7.4.2 Phase Equilibrium and Solubility 295
 - 7.4.3 Growth by Slow Cooling—Typical Crystals Grown 297
 - 7.4.3-1 Garnet, 297. 7.4.3-2 Barium Titanate, 302.
 - 7.4.4 Growth by Evaporation 305
 - 7.4.5 Seeded Growth 309
- 7.5 Growth from Liquid Metal Solvents 312
- 7.6 Temperature-Gradient Zone Melting 314
- 7.7 Composite Growth Methods—Vapor-Liquid-Solid Growth 316

Appendix **BIBLIOGRAPHICAL NOTES 325**

AUTHOR INDEX 327

SUBJECT INDEX 334