Contents

Preface v

1. Equilibrium Phase Diagrams 1

   1.1 General Theory 1
   1.1.1 Metallography and phase diagram 1
   1.1.2 Terminology 3
   1.1.3 Phase rule of Gibbs 10
   1.2 Binary Alloys in Equilibrium State 14
   1.2.1 How to express 14
   1.2.2 Isomorphous (complete) solid solution 18
   1.2.3 Eutectic alloy 21
   1.2.4 Eutectoid reaction 31
   1.2.5 Other eutectic-type invariant reactions 33
   1.2.6 Peritectic reaction 33
   1.2.7 Other peritectic-type invariant reactions 36
   1.2.8 Phase diagram containing an intermediate phase . . 37
   1.2.9 Two-phase separation versus ordering 38
   1.2.10 Summary 40
   1.3 Deviation from Equilibrium in Natural Cooling of Binary Alloys 46
   1.3.1 Isomorphous (complete) solid solution 46
   1.3.2 Eutectic alloy 48
   1.3.3 Peritectic alloy 48

2. Heat Treatment of Alloys 51

   2.1 Aging and Precipitation in Aluminum Alloys 52
   2.1.1 Explanation based on phase diagram 52
   2.1.2 Morphology of precipitates, structure of interfaces . 53

2.1.3 Sequence of precipitation, G.P. zone and metastable precipitates 56
2.1.4 Reversion 59
2.1.5 Precipitation hardening 59
2.1.6 Spinodal decomposition 62
2.2 Heat Treatment in Steels 66
2.2.1 Fe-C phase diagram 66
2.2.2 Quenching and martensite 69
2.2.3 Other martensitic transformations 77
2.2.4 Tempering of martensite, Temperature-time-transformation (TTT) diagram, Continuous cooling transformation (CCT) diagram 81
2.2.5 Improvement of hardenability of steel 88
2.2.6 Case hardening 89

3. Thermodynamics of Binary Phase Diagrams 92
3.1 Equilibrium Between Different Phases 92
3.1.1 Chemical potential 92
3.1.2 Simple phase diagram and free energy 97
3.1.3 Free energy of substitutional solid solution 99
3.1.4 Free energy of a liquid 110
3.2 Thermodynamics of Nucleation 112
3.2.1 Spinodal decomposition 112
3.2.2 Homogeneous nucleation 114
3.2.3 Heterogeneous nucleation 116
3.2.4 Precipitation of intermediate phases 118
3.2.5 Martensitic transformation 119

4. Ternary Phase Diagram 121
4.1 Fundamentals of Ternary Phase Diagrams 121
4.1.1 How to represent — The Gibbs triangle 121
4.1.2 Tie-lines and lever principle 122
4.1.3 Phase rule in the ternary system 125
4.1.4 Space diagram and sectional diagram 125
4.2 Relatively Simple Ternary Systems 128
4.2.1 Solidification of an isomorphous (complete) ternary solid solution 128
4.2.2 Simple eutectic system 129
4.2.3 Simple peritectic system 138

4.3 Complex Ternary Systems 144
4.3.1 Ternary eutectic system (Class I) 144
4.3.2 Peritecto-eutectic system (Class II) 152
4.3.3 Peritecto-eutectic system (Class III) 157
4.3.4 Summary 166
4.4 Ternary Systems Containing Intermetallic Compound 168
4.4.1 Quasi-binary system 168
4.4.2 Quasi-binary systems are not formed 168

Appendix: Conversion of indices between three and four indices in HCP 171

Index 173