Contents

List of contributors *page* xi
Preface xiii

1 Introduction 1
K. Otsuka and C. M. Wayman
1.1 Invitation to shape memory effect and the notion of martensitic transformation 1
1.2 Martensitic transformations: crystallography 5
1.3 Martensitic transformations: thermodynamic aspects 21

2 Mechanism of shape memory effect and superelasticity 27
K. Otsuka and C. M. Wayman
2.1 Stress-induced martensitic transformation and superelasticity 27
2.2 Shape memory effect 36
2.3 Rubber-like behavior 44

3 Ti–Ni shape memory alloys 49
T. Saburi
3.1 Structure and transformations 49
3.2 Mechanical behavior of Ti–Ni alloys 58
3.3 Ternary alloying 73
3.4 Self-accommodation in martensites 79
3.5 All-round shape memory (Two-way shape memory) 84
3.6 Effects of irradiation on the shape memory behavior 87
3.7 Sputter-deposited films of Ti–Ni alloys 87
3.8 Melt-spun ribbons of Ti–Ni alloys 93

4 Cu-based shape memory alloys 97
T. Tadaki
4.1 Phase diagrams of typical Cu-based shape memory alloys 97
4.2 Mechanical behavior 100

4.3 Aging effects of shape memory alloys 105
4.4 Thermal cycling effects 109
4.5 Improvements of shape memory alloys 112
5 Ferrous shape memory alloys 117
T. Maki
5.1 Morphology and substructure of ferrous martensite 117
5.2 Ferrous alloys exhibiting shape memory effect 118
5.3 Shape memory effect associated with α' thin plate martensite 121
5.4 Shape memory effect associated with ε martensite in Fe–Mn–Si alloys 126
6 Fabrication of shape memory alloys 133
Y. Suzuki
6.1 Fabrication of Ti–Ni based alloys 134
6.2 Fabrication of Cu–Al–Zn based alloys 143
6.3 Powder metallurgy and miscellaneous methods 145
7 Characteristics of shape memory alloys 149
J. Van Humbeeck and R. Stalmans
7.1 Summary of the functional properties 149
7.2 A generalized thermodynamic description of shape memory behaviour 151
7.3 Two-way memory behaviour 159
7.4 Constrained recovery – generation of recovery stresses 162
7.5 The high damping capacity of shape memory alloys 165
7.6 Cycling effects, fatigue and degradation of shape memory alloys 168
7.7 Property values 178
8 Shape memory ceramics 184
K. Uchino
8.1 Development trends of new principle actuators 184
8.2 Shape memory ceramics 185
8.3 Sample preparation and experiments 189
8.4 Fundamental properties of the electric field-induced phase transition 190
8.5 Comparison with shape memory alloys 198
8.6 Applications of shape memory ceramics 199
8.7 Conclusions 202
9 Shape memory polymers 203
M. Irie
9.1 Shape memory effect of polymer materials 203

9.2 Thermal-responsive shape memory effect 206
9.3 Photo-responsive shape memory effect 212
9.4 Chemo-responsive shape memory effect 218
10 General applications of SMA's and smart materials 220
K. N. Melton
10.1 Introduction 220
10.2 History of applications of SMA 221
10.3 SMA couplings 222
10.4 Electrical connectors 226
10.5 Fastener type applications 230
10.6 History of applications of superelasticity 232
10.7 Selection criteria for SMA applications 234
10.8 Smart materials 237
11 The design of shape memory alloy actuators and their applications 240
I. Ohkata and Y. Suzuki
11.1 Characteristics of shape memory alloy actuators 240
11.2 The design of shape memory alloy springs 242
11.3 The design of two-way actuators 247
11.4 Shape memory alloy actuator applications 254
12 Medical and dental applications of shape memory alloys 267
S. Miyazaki
12.1 Introduction 267
12.2 Application examples 267
12.3 Corrosion resistance 276
12.4 Elution test 278
12.5 Biocompatibility 279

Index 282