

Contents

Part I General Properties of Dislocation Motion

1	Introduction	3
1.1	Theoretical Yield Strength	4
1.2	Plastic Shear by the Motion of Dislocations	5
2	Experimental Methods	11
2.1	Macroscopic Deformation Tests	11
2.2	Stress Pulse Double Etching Technique	16
2.3	Transmission Electron Microscopy	18
2.4	In Situ Straining Experiments in the Transmission Electron Microscope	20
2.5	Other Methods	26
2.5.1	X-Ray Topography In Situ Deformation Experiments	27
2.5.2	Surface Studies of Slip Lines	27
2.5.3	Internal Friction	29
2.5.4	Nuclear Magnetic Resonance	33
3	Properties of Dislocations	35
3.1	Geometric Properties	35
3.1.1	Burgers Vector	35
3.1.2	Glide and Climb Motion of a Dislocation	37
3.1.3	Relation Between Dislocation Motion and Plastic Strain and Strain Rate	39
3.2	Elastic Properties of Dislocations	40
3.2.1	Stress Fields of Straight Dislocations	41
3.2.2	Dislocation Energy	43
3.2.3	Forces on Dislocations	47
3.2.4	Interaction Between Parallel Dislocations	50
3.2.5	Interaction Between Nonparallel Dislocations	52

3.2.6	Elastic Interaction Between Dislocations and Elastic Inclusions	54
3.2.7	Bowed-Out Dislocations	57
3.3	Dislocations in Crystals	65
3.3.1	Selection of Burgers Vectors	66
3.3.2	Stacking Faults and Partial Dislocations	66
3.3.3	Twins	70
3.3.4	Antiphase Boundaries	71
4	Dislocation Motion	73
4.1	Thermally Activated Overcoming of Barriers	74
4.2	Lattice Friction	78
4.2.1	Peierls–Nabarro Model	79
4.2.2	Double-Kink Model	83
4.2.3	Characteristics and Experimental Evidence of the Double-Kink Model	92
4.3	Slip and Cross Slip	93
4.4	The Locking–Unlocking Mechanism	99
4.5	Overcoming of Localized Obstacles	101
4.5.1	Friedel Statistics	103
4.5.2	Mott Statistics	110
4.6	Transition from the Double-Kink Mechanism to the Overcoming of Localized Obstacles	113
4.7	Overcoming of Extended Obstacles	116
4.8	Dislocation Intersections	126
4.9	Dislocation Motion at High Velocities and Low Temperatures	129
4.10	Dislocation Climb	132
4.10.1	Point Defect Equilibrium Concentrations	132
4.10.2	Climb Forces	134
4.10.3	Emission- or Absorption-controlled Climb	137
4.10.4	Diffusion-controlled Climb	140
4.10.5	Jog Dragging	141
4.11	Drag Forces due to Point Defect Atmospheres	143
4.12	Dynamic Laws of Dislocation Mobility	150
5	Dislocation Kinetics, Work-Hardening, and Recovery	155
5.1	Dislocation Kinetics	155
5.1.1	Models of Dislocation Generation	156
5.1.2	Experimental Evidence of Dislocation Generation	162
5.1.3	Dislocation Immobilization and Annihilation	166
5.2	Work-Hardening and Recovery	171
5.2.1	Work-Hardening Models	172
5.2.2	Thermal and Athermal Components of the Flow Stress	180

5.2.3	Experimental Determination of the Stress Components	187
5.2.4	Steady State Deformation	192
5.3	Plastic Instabilities	196

Part II Dislocation Motion in Particular Materials

6	Semiconductors	207
6.1	Crystal Structure and Slip Geometry	207
6.2	Microscopic Observations	209
6.3	Dislocation Dynamics	213
6.4	Recombination-enhanced Dislocation Mobility	217
6.5	Macroscopic Deformation Properties	218
6.6	Summary	220
7	Ceramic Single Crystals	221
7.1	Alkali Halides	221
7.1.1	Crystal Structure and Slip Geometry	222
7.1.2	Dislocation Dynamics	223
7.1.3	Macroscopic Deformation Properties	223
7.1.4	Summary	229
7.2	Magnesium Oxide	231
7.2.1	Microscopic Observations	231
7.2.2	Statistics of Overcoming Localized Obstacles	234
7.2.3	Kinematics of Overcoming Localized Obstacles	239
7.2.4	Dislocation Dynamics	242
7.2.5	Macroscopic Deformation Properties and Discussion ..	243
7.2.6	Dislocations in the Plastic Zone of a Crack	249
7.2.7	Summary	252
7.3	Zirconia Single Crystals	253
7.3.1	Crystal Structure and Slip Geometry of $\text{ZrO}_2\text{-Y}_2\text{O}_3$ alloys	253
7.3.2	Microscopic Observations in Cubic ZrO_2	254
7.3.3	Dislocation Dynamics in Cubic ZrO_2	260
7.3.4	Macroscopic Deformation Properties of Cubic ZrO_2 ...	261
7.3.5	Deformation Mechanisms	263
7.3.6	Summary of Cubic ZrO_2	273
7.3.7	Tetragonal ZrO_2	273
8	Metallic Alloys	281
8.1	Precipitation Hardened Aluminium Alloys	281
8.1.1	Al-Zn-Mg	282
8.1.2	Al-Ag	285
8.1.3	Al-Li	287
8.1.4	Summary	293

8.2	Dislocation Generation in Metals	293
8.3	Oxide Dispersion Strengthened Materials	297
8.3.1	Microscopic Observations in Oxide Dispersion Strengthened Alloys	298
8.3.2	Macroscopic Deformation Properties	303
8.3.3	Deformation Mechanisms	304
8.3.4	Summary.....	308
8.4	Plastic Deformation During Fracture of $\text{Al}_2\text{O}_3/\text{Nb}$ Sandwich Specimens	309
9	Intermetallic Alloys.....	313
9.1	Introduction	313
9.2	Ni_3Al	316
9.2.1	Microscopic Observations and Dislocation Dynamics ...	316
9.2.2	Models of the Flow Stress Anomaly	319
9.3	$\gamma\text{-TiAl}$	322
9.3.1	Crystal Structure and Slip Geometry	323
9.3.2	Microscopic Observations.....	324
9.3.3	Macroscopic Deformation Parameters	331
9.3.4	Deformation Mechanisms	333
9.3.5	Summary.....	340
9.4	NiAl	340
9.4.1	Crystal Structure and Slip Geometry	340
9.4.2	Microscopic Observations.....	341
9.4.3	Macroscopic Deformation Parameters	346
9.4.4	Deformation Mechanisms	348
9.4.5	Summary.....	355
9.5	FeAl	355
9.5.1	Microscopic Observations.....	355
9.5.2	Macroscopic Deformation Parameters	360
9.5.3	Deformation Mechanisms	362
9.5.4	Summary.....	368
9.6	Molybdenum Disilicide	369
9.6.1	Crystal Structure and Slip Geometry	369
9.6.2	Microscopic Observations.....	370
9.6.3	Macroscopic Deformation Parameters	380
9.6.4	Deformation Mechanisms	383
9.6.5	Summary.....	389
9.7	Conclusions on Intermetallics	390
10	Quasicrystals	393
10.1	Structure of Quasicrystals	394
10.1.1	Quasicrystals with Icosahedral Symmetry.....	396
10.1.2	Quasicrystals with Decagonal Symmetry	398

10.2 Defects in Quasicrystals	400
10.2.1 Vacancies	400
10.2.2 Phason Defects	400
10.2.3 Dislocations	403
10.3 Microscopic Observations of Dislocations	408
10.3.1 i-Al-Pd-Mn	408
10.3.2 d-Al-Ni-Co	422
10.4 Macroscopic Deformation Parameters	431
10.4.1 i-Al-Pd-Mn	432
10.4.2 d-Al-Ni-Co	438
10.5 Mechanisms of Dislocation Motion and Plastic Deformation ..	440
10.5.1 Glide or Climb Motion of Dislocations	441
10.5.2 Components of the Flow Stress	443
10.5.3 Formation of Phason Faults	443
10.5.4 Long-Range Dislocation Interactions	445
10.5.5 Activation Parameters of Plastic Deformation	446
10.5.6 Friction Mechanisms of Dislocation Motion	448
10.5.7 Dislocation Kinetics in the High-Temperature Range ..	453
10.5.8 The Climb-Exchange Model	455
10.6 Conclusions on Quasicrystals	459
11 Conclusion	463
List of Abbreviations and Symbols	465
List of Video Clips	471
References	475
Index	499