
Contents

Acknowledgements	ix
Introduction	xi
Chapter 1. Continuous Dislocation Modeling	1
1.1. Introduction	1
1.2. Lattice incompatibility	2
1.3. Burgers vector	5
1.4. Compatibility conditions	8
1.5. Dislocation fields	10
1.6. Tangential continuity at interfaces	13
1.7. Curvatures and rotational incompatibility	19
1.8. Incompatibility tensor	22
1.9. Conclusion	23
1.10. Problems	23
1.10.1. Discrete versus continuous modeling of crystal defects	23
1.10.2. Incompatibility in simple shear	25
1.10.3. Frank's relation	26
1.11. Solutions	27
1.11.1. Discrete versus continuous modeling of crystal defects	27
1.11.2. Incompatibility in simple shear	28
1.11.3. Frank's relation	29

Chapter 2. Elasto-static Field Equations	31
2.1. Introduction	31
2.2. Elasto-static solution to field equations	31
2.2.1. Stokes-Helmholtz decomposition and Poisson-type equations	32
2.2.2. Navier-type equations for compatible elastic distortion fields	34
2.3. Straight screw dislocation in a linear isotropic elastic medium	35
2.4. Straight edge dislocation in a linear isotropic elastic medium	37
2.5. Conclusion	38
2.6. Problems	39
2.6.1. Screw dislocation	39
2.6.2. Twist boundary	39
2.6.3. Tilt boundary	41
2.6.4. Zero-stress everywhere dislocation fields	41
2.7. Solutions	42
2.7.1. Screw dislocation	42
2.7.2. Twist boundary	43
2.7.3. Tilt boundary	45
2.7.4. Zero-stress everywhere dislocation fields	46
Chapter 3. Dislocation Transport	49
3.1. Introduction	49
3.2. Dislocation flux and plastic distortion rate	50
3.3. Coarse graining	52
3.4. Compatibility versus incompatibility of plasticity	54
3.5. Tangential continuity of plastic distortion rate	57
3.6. Transport equations	60
3.6.1. Small transformations	60
3.6.2. Finite transformations	62
3.7. Transport waves	64
3.7.1. Annihilation	66
3.7.2. Expansion of dislocation loops	68
3.7.3. Initiation of a Frank–Read source	69
3.8. Numerical algorithms for dislocation transport	71
3.9. Conclusion	76

3.10. Problems	76
3.10.1. Propagation of a discontinuous dislocation density	76
3.10.2. Dislocation loop expansion	78
3.10.3. Stability / instability of homogeneous dislocation distributions	79
3.10.4. Dislocation nucleation	80
3.11. Solutions	81
3.11.1. Propagation of a discontinuous dislocation density	81
3.11.2. Expansion of dislocation loops	84
3.11.3. Stability / instability of homogeneous dislocation distributions	85
3.11.4. Dislocation nucleation	86
Chapter 4. Constitutive Relations	89
4.1. Introduction	89
4.2. Dissipation	90
4.3. Pressure independence	92
4.4. Dislocation climb versus dislocation glide	93
4.5. Viscoplastic relationships	94
4.6. Coarse graining	96
4.7. Contact with conventional crystal plasticity	97
Chapter 5. Elasto-plastic Field Equations	99
5.1. Introduction	99
5.2. Fundamental field equations	99
5.3. Boundary conditions	101
5.4. Coarse graining	102
5.5. Resolution algorithm	104
5.6. Reduced field equations	105
5.6.1. Plane dislocations	107
5.7. Augmented crystal plasticity	109
5.8. Dynamics of a twist boundary	111
5.9. Conclusion	116
5.10. Problems	117
5.10.1. Helical dislocations	117
5.11. Solutions	118
5.11.1. Helical dislocations	118

Chapter 6. Case Studies	121
6.1. Introduction	121
6.2. Dislocation core structure	123
6.3. Piezoelectricity and dislocations	132
6.3.1. Coupling piezoelectricity, lattice incompatibility and transport	132
6.3.2. Piezoelectric polarization and dislocations in GaN layers	134
6.3.3. Dislocation transport and electric displacement in GaN layers	137
6.4. Intermittent plasticity	139
6.5. Effects of size on mechanical response	150
6.6. Complex loading paths	159
6.7. Strain localization	170
6.7.1. Experimental data in Al–Cu–Li alloys	171
6.7.2. Simulation results	174
Chapter 7. Review and Conclusions	181
7.1. Comparisons with conventional crystal plasticity	181
7.2. Alternative approaches	183
7.2.1. Peierls-Nabarro model	183
7.2.2. Atomistic simulations	184
7.2.3. Phase field methods	186
7.2.4. Discrete dislocation dynamics	187
7.3. Shortcomings and extensions	190
7.3.1. Fracture and disconnections	190
7.3.2. Rotational incompatibility and disclinations	191
7.3.3. Phase transformation and generalized disclinations	193
7.4. Final remarks	196
Appendix	197
Bibliography	203
Index	217