
Contents

1	Dislocations in Germanium: Mechanical Properties	1
1.1	Introduction	1
1.2	Elastic Properties of Germanium	2
1.2.1	Definitions	2
1.2.2	Linear Expansion Coefficient of Ge	4
1.2.3	The First-Order Elastic Constants	6
1.2.4	Third-Order Elastic Constants	7
1.2.5	Internal Friction of Ge	8
1.3	Dislocation: Definitions and Structures	11
1.4	Creation and Observation of Dislocations	15
1.4.1	Grown-In Dislocations	17
1.4.2	Deformation-Induced Dislocations	18
1.4.3	Observation of Dislocations	19
1.5	Hardness and Plasticity of Ge at Room Temperature	24
1.6	High Temperature Plasticity of Germanium	30
1.6.1	Dislocation Velocity: Experimental Facts	31
1.6.2	Dislocation Velocity: Fundamental Understanding	41
1.6.3	Static Flow Tests or Creep Curve	42
1.6.4	Dynamic Testing: Stress–Strain Yield Curves in Ge	46
1.7	Impact of Dislocations on Dopant Diffusion	54
1.8	Conclusions	57
	References	58
2	Electrical and Optical Properties	65
2.1	Introduction	65
2.2	Electronic States of Dislocations	67
2.2.1	Read’s Acceptor Level Model	67
2.2.2	Schröter’s 1D Band Model	70
2.2.3	First Principles Calculations and EPR Results: Do DBs Exist in Split Dislocations?	75
2.2.4	One Dimensional Conduction Along Dislocations	77

2.2.5	Deformation-Induced Point Defects	83
2.2.6	Electrical Activity of Grown-In Dislocations	85
2.3	Impact of Dislocations on Carrier Mobility	89
2.4	Impact of Dislocations on Lifetime, Trapping, and Noise	93
2.4.1	Impact on Carrier Recombination	93
2.4.2	Impact on Low Frequency Noise	99
2.5	Impact of Dislocations on Ge Junction Devices	100
2.6	Impact of Dislocations on Optical Properties	104
2.6.1	Absorption and Recombination	107
2.6.2	Optical Recombination	110
2.6.3	Photoconductivity	113
2.6.4	Photoluminescence	126
2.7	Conclusions	131
	References	132
3	Grain Boundaries in Germanium	137
3.1	Introduction	137
3.2	Structure and Observation of Grain Boundaries	137
3.3	Electrical Properties of Grain Boundaries	141
3.4	Optical Properties of Grain Boundaries	150
3.5	Conclusions	151
	References	151
4	Germanium-Based Substrate Defects	153
4.1	Introduction	153
4.2	Epitaxial Deposition: Definitions	154
4.2.1	Modern Epitaxial Techniques	154
4.2.2	Epitaxial Growth Modes	158
4.3	Heteroepitaxial Strained Layers	159
4.3.1	Equilibrium Critical Thickness	160
4.3.2	Metastable Critical Thickness	163
4.3.3	Misfit and Threading Dislocation Densities	165
4.3.4	Strained Layer Dislocation Nucleation Mechanism	166
4.3.5	Dislocation Glide and Climb in Strained Layers	169
4.3.6	Dislocation Interaction Mechanisms	172
4.3.7	Elastic Relaxation by Surface Roughening	175
4.3.8	Strain Relaxation in Local Epitaxial Growth	178
4.4	Homoeptaxy of Germanium	180
4.4.1	Growth Modes	180
4.4.2	Growth Roughness and Epitaxial Breakdown at Low Temperatures	184
4.5	Heteroepitaxial Growth of Ge on Si	193
4.5.1	Initial Growth Mechanisms	195
4.5.2	Direct Layer-By-Layer Growth of Ge on Si	198
4.5.3	Growth of Thick Relaxed Ge Layers Directly on Si	203

4.5.4	Growth of Thick Relaxed Ge Layers by Means of a Graded Virtual Substrate.....	206
4.5.5	Selective Epitaxial Growth of Relaxed Ge on Si	210
4.5.6	Growth of Strained Ge and Si Layers and Si/Ge Superlattices	215
4.6	Defects in Germanium-On-Insulator Substrates.....	216
4.7	Summary and Conclusions	227
	References	228
5	Process-Induced Defects in Germanium	241
5.1	Introduction	241
5.2	Fundamental Ion Implantation Damage Mechanisms	242
5.3	Heavy Ion Induced Void Formation	254
5.4	Damage Annealing and Solid Phase Epitaxial Regrowth	257
5.5	Implantation Damage and Removal by Standard Dopant Ions	265
5.5.1	Lattice Site and Damage of Implanted Species in Ge ...	265
5.5.2	Boron Implantation in Ge	268
5.5.3	Al Implantation in Ge	277
5.5.4	P and As Implantation in Ge	278
5.5.5	{311} Interstitial Clusters in Ge	282
5.6	Oxygen Implantation in Ge and Ion Beam Mixing	283
5.7	Hydrogen-Related Extended Defects in Germanium	285
5.8	Conclusions.....	287
	References	288
	Index	293

Extended Defects in Germanium
Fundamental and Technological Aspects

Claeys, C.; Simoen, E.

2009, XX, 300 p., Hardcover

ISBN: 978-3-540-85611-5