

Contents

Narrow-Gap Lead Salts

By G. Nimtz and B. Schlicht (With 111 Figures)

1. Introduction	1
2. The Crystal	1
2.1 Basic Properties	2
2.2 Phase Diagrams and Crystal Growth	11
2.2.1 $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$	12
2.2.2 $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$	12
2.2.3 $\text{PbS}_{1-x}\text{Se}_x$	13
2.2.4 $\text{PbTe}_{1-x}\text{S}_x$	14
2.2.5 Crystal Growth	14
2.3 Imperfections	14
2.3.1 Native Defects	14
2.3.2 Chemical Impurities	20
3. Band Structure	26
3.1 Band-Structure Calculations	27
3.1.1 Lead Chalcogenides	27
3.1.2 SnTe	33
3.2 Temperature, Pressure, and Composition Dependence of the Fundamental Gap	35
3.2.1 Lead Chalcogenides	35
3.2.2 SnTe	40
3.2.3 Ternary Compounds	41
3.2.3.1 $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$	41
3.2.3.2 $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$	43
3.2.3.3 $\text{PbS}_{1-x}\text{Se}_x$	44
3.3 Band-Edge Characteristics	45
3.3.1 $k \cdot p$ Models	45
3.3.2 Statistics	49
3.3.3 Effective Masses	55
3.3.3.1 $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$	55
3.3.3.2 $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$	57
	VII

3.3.3.3 $\text{PbS}_{1-x}\text{Se}_x$	58
3.3.4 Energy Levels in a Magnetic Field, g Factors	58
4. Transport Properties	63
4.1 Hall Coefficient, Carrier Concentration	64
4.2 Carrier Mobility, Scattering Mechanisms	67
4.3 Magnetotransport	73
4.3.1 Magnetoresistance	74
4.3.2 Shubnikov - de Haas Effect	75
4.3.3 Magnetophonon Effect	78
4.3.4 Magneto-optical Properties	79
4.4 Warm and Hot Carrier Effects, Impact Ionization	80
4.5 Thermal Conductivity and Thermoelectric Effects	83
4.6 Magnetic Susceptibility	84
5. Optical Properties	85
5.1 General Remarks	85
5.2 Absorption, Reflexion and Emission near the Fundamental Energy Gap ...	85
5.3 Optical Properties at Energies Above the Fundamental Energy Gap	89
5.4 Dielectric Properties, Phonons	90
6. Recombination of Carriers	100
6.1 General Remarks	100
6.2 Experimental Data	100
6.3 Theoretical Investigations	103
6.3.1 Radiative and Plasmon Recombination	104
6.3.2 Auger Recombination	106
References	107
Combined Subject Index	305

The Properties and Applications of the $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ Alloy System

By R. Dornhaus and G. Nimtz (With 133 Figures)

1. Introduction	119
2. The Crystal	121
2.1 Basic Properties	121
2.2 Phase Diagram and Crystal Growth	126
2.3 Imperfections	130
2.3.1 Dislocations and Native Point Defects; Radiation Defects	131
2.3.2 Foreign Atoms	135
2.3.3 Long-Term Instability of n-Type $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$, Diffusion Effects at Room Temperature, Effects of Annealing on the Electrical Properties	138

3. Band Structure	141
3.1 Band Structure Calculations	142
3.1.1 KKR Model Calculations	143
3.1.2 Pseudopotential Calculations	145
3.1.3 Tight-Binding Model	150
3.2 The Semimetal-Semiconductor Transition (SM-SC Transition)	152
3.3 The Band Edge Characteristics	153
3.3.1 The Three Level Model of a Small-Gap Semiconductor	153
3.3.2 Statistics	156
3.3.3 Comparison Between Theoretical and Experimental Results	158
3.3.3.1 The Dependence of the Energy Gap E_g on Compositons x , Temperature T and Pressure p	158
3.3.3.2 Effective Masses	163
3.3.3.3 g Factor of Conduction Electrons	167
3.3.3.4 E_1 and $E_1 + \Delta$ Gaps	167
3.4 Temperature Dependence of the Band Gap	172
3.5 Pressure Effects on the Band Structure	175
3.6 The Disorder Problem in Pseudo Binary Alloys	179
3.7 Band Structure and Dielectric Function	185
3.7.1 Dielectric Function	185
3.7.1.1 Static Dielectric Function $\epsilon(0,q)$	186
3.7.1.2 Dynamic Dielectric Function	187
3.7.1.3 Phonon Contribution $\Delta\epsilon_{ph}$	188
3.7.2 Magnetooptics and Band Structure in a Magnetic Field	189
3.7.2.1 Band Structure in a Magnetic Field	190
3.7.2.2 Magnetooptics	195
3.7.3 Impurity States	197
4. Transport Properties	202
4.1 Hall Coefficient, Intrinsic Carrier Density	203
4.2 Carrier Mobility, Scattering Mechanisms	208
4.3 Magnetoresistance	217
4.4 Magnetic Quantum Effects	221
4.4.1 Shubnikov-de Haas Effect	222
4.4.2 Magnetophonon Effect	227
4.4.3 Cyclotron Resonance	228
4.4.4 Electron-Spin and Combined Resonance	230
4.4.5 Spin-Flip Raman Scattering	232
4.4.6 Various Other Quantum Effects	234
4.5 Hot Carrier Properties	235
4.6 Thermoelectric Effects	240
4.7 Magnetic Susceptibility	242

5. Optical Properties	244
5.1 Fundamental Reflectivity and Absorption	244
5.1.1 Reflectance and Absorption	244
5.1.2 Magnetorefectance	246
5.1.3 Electroreflectance	247
5.2 Optical Phonons	247
5.3 Free Carrier Absorption and Reflectance	252
5.4 Photoluminescence and Deep Level Transient Spectroscopy	253
6. Infrared Devices	254
6.1 Recombination Mechanisms and Carrier Lifetime	255
6.2 Photoconductivity	262
6.2.1 Photoconductive Infrared and Microwave Devices	265
6.3 Photovoltaic Effects	265
6.4 Infrared Radiation Sources	269
6.5 Charge Transfer Devices and Field-Effect Transistors	270
7. Surfaces, Interfaces, Graded-Gap Materials	271
7.1 HgCdTe Surfaces	272
7.1.1 Free HgCdTe Surfaces	272
7.1.2 Native Oxides, Production and Composition	275
7.1.3 Electronic Properties of the Native Oxide-HgCdTe Interface	277
7.2 MOS and MIS Devices	277
7.3 Transport and Optical Studies of Inversion Layers	278
7.4 CdTe-HgTe Superlattices	279
7.5 Tunneling Spectroscopy of HgCdTe Crystals	280
7.6 Metal-HgCdTe Contacts	280
7.7 Homogeneous and Graded-Gap Epitaxial HgCdTe Layers	281
References	287
List of Important Symbols	301
Numerical Values of Important Quantities	304
Combined Subject Index	305

