

CONTENTS

INTRODUCTION	1
Definition of ore mineral, p. 1 -- Occurrence of ore minerals, p. 1 -- Mineral conductivity, p. 4 -- Significance of conductivity, p. 6 -- References, p. 7.	
PART ONE: PRINCIPLES	
CHAPTER 1. ELECTRONIC STRUCTURE	9
Energy units, p. 9 -- Wave mechanics, p. 12 -- Independent-electron approximation, p. 15 -- Atomic structure, p. 15 -- Electronic energy levels in ionic crystals, p. 19 -- Packing of spheres, p. 21 -- Ionic radii, p. 24 -- Transition metal ions, p. 26 -- Covalence, p. 28 -- Delocalized electrons, p. 32 -- Energy bands, p. 34 -- Bond type, p. 37 -- Summary, p. 39 -- References, p. 40.	
CHAPTER 2. CONDUCTION MECHANISM	41
Measurement of conductivity or resistivity, p. 41 -- Electrical anisotropy, p. 44 -- Drude theory, p. 45 -- Electronic units, p. 46 -- Mobility, p. 48 -- Hopping, p. 52 -- Electron-hole equilibrium, p. 55 -- Donors and acceptors, p. 57 -- Native atomic disorder, p. 58 -- Defect association, p. 59 -- Screening, p. 61 -- Defect equilibrium calculations, p. 61 -- Intrinsic semiconduction, p. 63 -- Trapping equilibria, p. 64 -- Compensation, p. 65 -- Nonstoichiometry, p. 66 -- Impurities, p. 70 -- Dielectrics, p. 71 -- Conductivity versus temperature, p. 72 -- Resistivity versus pressure, p. 73 -- Summary, p. 75 -- References, p. 76.	
CHAPTER 3. OTHER ELECTRONIC PROPERTIES	78
Description of alternating-field electrical response, p. 78 -- Conduction versus polarization, p. 82 -- Mechanisms of alternating-field electrical response, p. 84 -- Free-carrier absorption, p. 84 -- Interband transitions, p. 86 -- Lattice polarization, p. 91 -- Dipole orientation, p. 92 -- Magnetic susceptibility, p. 93 -- Diamagnetism, p. 95 -- Paramagnetism, p. 96 -- Magnetic order, p. 99 -- Galvanomagnetic effects, p. 101 -- Thermal conductivity, p. 105 -- Thermoelectricity, p. 110 -- Summary, p. 113 -- References, p. 114.	

CHAPTER 4. HETEROGENEITY AND THE SEMICONDUCTOR-ELECTROLYTE INTERFACE 116

Mixture formulas, p. 117 -- Application to ore conductivity, p. 123 -- Maxwell-Wagner effect, p. 125 -- Observation of the Maxwell-Wagner effect, p. 128 -- P-N junctions, p. 130 -- Other electronic interfaces, p. 134 -- Composition of mineral waters, p. 138 -- Conductivity of mineral waters, p. 141 -- Water in alternating electric fields, p. 143 -- Semiconductor-electrolyte interface, p. 145 -- Interface charge distribution, p. 146 -- Interface capacitance, p. 149 -- Zeta potential and adsorption, p. 150 -- Electrode potential, p. 153 -- Electrode potentials of common sulfides, p. 157 -- Reaction impedance, p. 162 -- Diffusion impedance, p. 164 -- Equivalent circuits, p. 166 -- Induced polarization, p. 167 -- Types of interface reactions, p. 170 -- Summary, p. 172 -- References, p. 173.

PART TWO: ELEMENTS

CHAPTER 5. BISMUTH - Bi 178

Occurrence, p. 178 -- Related minerals, p. 178 -- Resistivity, p. 178 -- Type, p. 179 -- Structure, p. 179 -- Bonding, p. 180 -- Band structure, p. 180 -- Band gap and overlap, p. 182 -- Effective mass, p. 182 -- Mobility, p. 183 -- Impurities, p. 183 -- Summary, p. 184 -- References, p. 185.

CHAPTER 6. COPPER - Cu 187

Occurrence, p. 187 -- Related minerals, p. 187 -- Resistivity and type, p. 187 -- Structure, p. 188 -- Bonding, p. 188 -- Band structure, p. 189 -- Effective mass, p. 189 -- Mobility, p. 190 -- Impurities, p. 190 -- Summary, p. 191 -- References, p. 192.

CHAPTER 7. GRAPHITE - C 193

Occurrence, p. 193 -- Related minerals, p. 193 -- Resistivity, p. 193 -- Type, p. 195 -- Structure, p. 196 -- Bonding, p. 197 -- Band structure, p. 198 -- Band overlap, p. 200 -- Effective mass, p. 200 -- Mobility, p. 200 -- Structural imperfections, p. 201 -- Impurity, p. 201 -- Summary, p. 202 -- References, p. 202.

PART THREE: SULFIDES

CHAPTER 8. ARSENOPYRITE - FeAsS 205

Occurrence, p. 205 -- Related minerals, p. 205 -- Resistivity and type, p. 205 -- Marcasite structure, p. 206 -- Arsenopyrite structure, p. 207 -- Magnetism, p. 208 -- Bonding, p. 209 -- Band structure, p. 211 -- Conductivity activation energy, p. 212 -- Energy gap, p. 213 -- Mobility, p. 214 -- Nonstoichiometry, p. 214 -- Impurities, p. 216 -- L8llingite, p. 216 -- Safflorite, p. 217 -- Summary, p. 218 -- References, p. 218.

CHAPTER 9. BORNITE - Cu_5FeS_4 221

Occurrence, p. 221 -- Related minerals, p. 221 -- Resistivity, p. 221 -- Type, p. 222 -- Structure, p. 223 -- High temperature resistivity, p. 224 -- Bonding, p. 224 -- Magnetism, p. 225 -- Band structure, p. 226 -- Defect ionization, p. 226 -- Nonstoichiometry, p. 227 -- Impurity, p. 227 -- Summary, p. 228 -- References, p. 228.

CHAPTER 10. CHALCOCITE - Cu_{2-x}S 230

Occurrence, p. 230 -- Mineralogy, p. 230 -- Resistivity and type, p. 231 -- Structure, p. 232 -- Ionic mobility p. 233 -- Bonding, p. 234 -- Band structure, p. 234 -- Hole mobility, p. 235 -- Effective mass, p. 236 -- Defect ionization, p. 237 -- Nonstoichiometry and carrier concentration, p. 237 -- Summary, p. 238 -- References, p. 239.

CHAPTER 11. CHALCOPYRITE - CuFeS_2 242

Occurrence, p. 242 -- Related minerals, p. 242 -- Resistivity and type, p. 243 -- Structure, p. 244 -- Magnetic structure, p. 245 -- Bonding, p. 245 -- Band gap, p. 246 -- Band structure, p. 246 -- Mobility, p. 247 -- Defect ionization, p. 247 -- Nonstoichiometry: metal/sulfur ratio, p. 248 -- Nonstoichiometry: Cu/Fe ratio, p. 249 -- Impurities, p. 249 -- Cubanite, p. 250 -- Summary, p. 251 -- References, p. 251.

CHAPTER 12. COVELLITE - CuS 254

Occurrence, p. 254 -- Related minerals, p. 254 -- Resistivity, p. 254 -- Structure, p. 255 -- Bonding, p. 255 -- Band structure, p. 256 -- Nonstoichiometry and impurity, p. 258 -- Summary, p. 258 -- References, p. 259.

CHAPTER 13. GALENA - PbS 260

Occurrence, p. 260 -- Related minerals, p. 260 -- Resistivity and type, p. 261 -- Structure, p. 262 -- Bonding, p. 262 -- Band structure, p. 263 -- Energy gap, p. 263 -- Fourfold degeneracy of electronic states, p. 264 -- Effective mass, p. 264 -- Mobility, p. 265 -- Carrier concentration, p. 266 -- Nonstoichiometry, p. 268 -- Impurities, p. 270 -- Summary, p. 272 -- References, p. 273.

CHAPTER 14. MOLYBDENITE - MoS_2 276

Occurrence, p. 276 -- Related minerals, p. 276 -- Resistivity, p. 276 -- Type, p. 277 -- Anisotropy, p. 277 -- Frequency effect, p. 278 -- Structure, p. 278 -- Bonding, p. 279 -- Energy gap, p. 280 -- Band structure, p. 281 -- Effective mass, p. 282 -- Hole mobility, p. 282 -- Electron mobility, p. 284 -- Defect ionization, p. 285 -- Nonstoichiometry, p. 285 -- Impurities, p. 286 -- Summary, p. 286 -- References, p. 287.

CHAPTER 15. PYRRHOTITE - Fe_{1-x}S 290

Occurrence, p. 290 -- Related minerals, p. 290 -- Composition, p. 290 -- Resistivity, p. 292 -- Anisotropy, p. 292 -- Type, p. 293 -- Crystal structure, p. 294 -- Magnetic structure, p. 296 -- Bonding, p. 297 -- Band structure, p. 298 -- Impurities, p. 300 -- Summary, p. 300 -- References, p. 301.

CHAPTER 16. PYRITE - FeS_2 304

Occurrence, p. 304 -- Related minerals, p. 304 -- Resistivity and type, p. 305 -- Structure, p. 306 -- Bonding, p. 307 -- Band structure, p. 307 -- Energy gap, p. 308 -- Mobility, p. 308 -- Carrier concentration, p. 309 -- Defect ionization, p. 310 -- Nonstoichiometry, p. 310 -- Pyrite geothermometer, p. 312 -- Impurities, p. 312 -- Electrical properties of related minerals, p. 313 -- Summary, p. 315 -- References, p. 316.

CHAPTER 17. SPHALERITE - ZnS 319

Occurrence, p. 319 -- Related minerals, p. 319 -- Resistivity, p. 319 -- Structure, p. 320 -- Bonding, p. 320 -- Band structure, p. 321 -- Effective mass, p. 322 -- Mobility, p. 322 -- Defect chemistry, p. 323 -- Impurity conduction, p. 324 -- Summary, p. 325 -- References, p. 325.

CHAPTER 18. MISCELLANEOUS SULFIDES 328

Argentite - Ag_2S , p. 328 -- Cinnabar - HgS , p. 330 -- Enargite - Cu_3AsS_4 , p. 331 -- Pyrargyrite - Ag_3SbS_3 , Proustite - Ag_3AsS_3 , p. 332 -- Skutterudite - CoAs_3 , p. 333 -- Stibnite - Sb_2S_3 , Bismuthinite - Bi_2S_3 , p. 334 -- Tetrahedrite - $\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$, Tennantite - $\text{Cu}_{12}\text{As}_4\text{S}_{13}$, p. 336 -- References, p. 337.

PART FOUR: OXIDES

CHAPTER 19. CASSITERITE - SnO_2 340

Occurrence, p. 340 -- Related minerals, p. 340 -- Resistivity, p. 340 -- Type, p. 341 -- Structure, p. 341 -- Bonding, p. 342 -- Band structure, p. 343 -- Effective mass, p. 344 -- Mobility, p. 344 -- Nonstoichiometry, p. 345 -- Impurities, p. 345 -- Summary, p. 346 -- References, p. 346.

CHAPTER 20. CUPRITE - Cu_2O 349

Occurrence, p. 349 -- Type and resistivity, p. 349 -- Structure, p. 349 -- Bonding, p. 350 -- Band structure, p. 350 -- Mobility, p. 351 -- Nonstoichiometry, p. 353 -- Impurities, p. 354 -- Summary, p. 354 -- References, p. 354.

CHAPTER 21. HEMATITE - $\alpha\text{-Fe}_2\text{O}_3$ 357

Occurrence, p. 357 -- Related minerals, p. 357 -- Resistivity, p. 357 -- Type and anisotropy, p. 358 -- Structure, p. 358 -- Magnetic structure, p. 359 -- Bonding, p. 360 -- Band structure, p. 360 -- Resistivity activation energy, p. 361 -- Mobility, p. 363 -- Nonstoichiometry, p. 364 -- Impurities, p. 365 -- Ilmenite, p. 367 -- Summary, p. 368 -- References, p. 368.

CHAPTER 22. MAGNETITE - Fe_3O_4 371

Occurrence, p. 371 -- Related minerals, p. 371 -- Resistivity, p. 371 -- Type, p. 373 -- Structure, p. 373 -- Magnetic structure, p. 375 -- Bonding, p. 375 -- Band structure, p. 376 -- Mobility, p. 377 -- Nonstoichiometry and maghemite, p. 378 -- Titanomagnetite, p. 379 -- Exsolution, p. 380 -- Other impurities, p. 382 -- Verwey's rule, p. 383 -- Jacobsite and hausmannite, p. 383 -- Chromite, p. 384 -- Summary, p. 384 -- References, p. 385.

CHAPTER 23. PYROLUSITE - MnO_2	389
Occurrence, p. 389 -- Related minerals, p. 389 -- Resistivity and type, p. 389 -- Structure, p. 390 -- Magnetic structure, p. 391 -- Electric order (?), p. 391 -- Bonding, p. 392 -- Band structure, p. 392 -- Mobility, p. 393 -- Nonstoichiometry, p. 393 -- Impurities, p. 394 -- Summary, p. 395 -- References, p. 395.	
CHAPTER 24. RUTILE - TiO_2	397
Occurrence, p. 397 -- Related minerals, p. 397 -- Resistivity, type and anisotropy, p. 397 -- Structure, p. 398 -- Bonding, p. 399 -- Band structure, p. 399 -- Mobility, p. 400 -- Nonstoichiometry, p. 401 -- Impurity, p. 403 -- Summary, p. 405 -- References, p. 405.	
SUBJECT INDEX	408
MINERAL INDEX	412