

Table of contents

Semiconductors

Subvolume e: Physics of non-tetrahedrally bonded elements and binary compounds I (edited by O. MADELUNG)

A Introduction (O. MADELUNG)

1 List of symbols	1
2 List of abbreviations	5
3 Conversion tables	7

B Physical data of semiconductors III

Data | Figures

8 Non-tetrahedrally bonded elements

8.1 Elements of the IIIId group: Boron(B) (H. WERHEIT)	9	-
8.1.0 Structure, chemical bond	9	263 f.
8.1.1 Electronic properties	10	-
8.1.1.A α -rhombohedral boron	10	265 f.
8.1.1.B β -rhombohedral boron	11	265 ff.
8.1.1.C Amorphous boron	12	-
8.1.2 Impurities and defects	12	-
8.1.2.A β -rhombohedral boron	12	266 ff.
8.1.3 Lattice properties	13	-
8.1.3.A α -rhombohedral boron	13	268 f.
8.1.3.B β -rhombohedral boron	14	267 ff., 283
8.1.3.C α -, β -tetragonal boron, amorphous boron	16	-
8.1.4 Transport properties	16	-
8.1.4.A α -rhombohedral boron	16	266, 271
8.1.4.B β -rhombohedral boron	16	266, 268, 271 ff.
8.1.4.C Amorphous boron	18	276 f.
8.1.5 Optical properties	19	266 ff., 277 ff.
8.1.5.A β -rhombohedral boron	19	273 f., 280 ff.
8.1.5.B Amorphous boron	19	268, 279 f.
8.1.6 Further properties	19	283 ff.
8.1.7 References for 8.1	22	-
8.2 Elements of the Vth group: P, As, Sb, Bi, $\text{Bi}_{1-x}\text{Sb}_x$ (H. LEHMANN)	27	-
8.2.0 Structure, chemical bond	27	285 ff.
References for 8.2.0	28	-
8.2.1 Phosphorus (P)	28	-
8.2.1.1 Electronic properties	28	287 f.
8.2.1.3 Lattice properties	29	288
8.2.1.4 Transport properties	30	288 ff.
8.2.1.5 Optical properties	30	288, 290
8.2.1.6 Further properties	30	291
8.2.1.7 References for 8.2.1	31	-
8.2.2 Arsenic (As)	31	-
8.2.2.1 Electronic properties	31	291 ff.
8.2.2.3 Lattice properties	33	292, 294, 300
8.2.2.4 Transport properties	35	294 f.

	Data	Figures
8.2.2.5 Optical properties	37	292, 295f.
8.2.2.6 Further properties	37	296f.
8.2.2.7 References for 8.2.2	38	–
8.2.3 Antimony (Sb)	39	–
8.2.3.1 Electronic properties	39	292, 298ff.
8.2.3.3 Lattice properties	41	300f.
8.2.3.4 Transport properties	43	295, 302
8.2.3.5 Optical properties	45	299f., 302f.
8.2.3.6 Further properties	45	303f.
8.2.3.7 References for 8.2.3	45	–
8.2.4 Bismuth (Bi)	46	–
8.2.4.1 Electronic properties	46	292, 304ff.
8.2.4.3 Lattice properties	50	300, 307f., 315f.
8.2.4.4 Transport properties	53	295, 307ff.
8.2.4.5 Optical properties	55	304f., 310f.
8.2.4.7 References for 8.2.4	56	–
8.2.5 Solid solutions: $\text{Bi}_{1-x}\text{Sb}_x$	57	–
8.2.5.1 Electronic properties	57	292, 311 ff.
8.2.5.3 Lattice properties	60	292, 308, 314 ff.
8.2.5.4 Transport properties	60	317 ff.
8.2.5.5 Optical properties	61	319f.
8.2.5.6 Further properties	62	320 ff.
8.2.5.7 References for 8.2.5	62	–
8.3 Elements of the IV th group: S, Se, Te, $\text{Se}_x\text{Te}_{1-x}$	63	–
8.3.0 Structure, chemical bond (P. GROSSE, G. WEISER)	63	–
8.3.0.1 Sulfur	63	–
8.3.0.1.A Orthorhombic sulfur (α -S)	63	322
8.3.0.1.B β -monoclinic sulfur	64	323
8.3.0.1.C γ -monoclinic sulfur	64	323
8.3.0.1.D Rhombohedral sulfur (ρ -S)	64	324
8.3.0.1.E Polymeric sulfur S_x	64	323
8.3.0.1.F Orthorhombic lattices of S_{12} , S_{18} and S_{20} molecules	65	323 ff.
8.3.0.2 Selenium	65	–
8.3.0.2.A Trigonal Se	65	325, 344
8.3.0.2.B Monoclinic selenium (α , β , γ)	66	325
8.3.0.2.C Rhombohedral selenium	67	–
8.3.0.2.D Phase transitions under pressure	67	–
8.3.0.3 Tellurium	67	325f.
8.3.0.4 References for 8.3.0	68	–
8.3.1 Sulfur (S) (G. WEISER)	69	–
8.3.1.1 Orthorhombic sulfur (α -S)	69	–
8.3.1.1.1 Electronic properties	69	327, 335
8.3.1.1.3 Lattice properties	70	327 ff., 337
8.3.1.1.4 Transport properties	78	330 ff.
8.3.1.1.5 Optical properties	80	335 ff.
8.3.1.1.6 Further properties	80	337
8.3.1.2 Other sulfur modifications	82	338f.
8.3.1.3 References for 8.3.1	84	–
8.3.2 Selenium (Se) (G. WEISER)	86	–
8.3.2.1 Trigonal selenium	86	–
8.3.2.1.1 Electronic properties	86	340 f., 352 f.
8.3.2.1.3 Lattice properties	89	340 ff., 354 ff.,
8.3.2.1.4 Transport properties	94	344 ff.
8.3.2.1.5 Optical properties	95	350 ff.
8.3.2.1.6 Further properties	96	356

	Data	Figures
8.3.2.2 Monoclinic selenium	98	-
8.3.2.2.1 Electronic properties	98	357
8.3.2.2.3 Lattice properties	99	357f.
8.3.2.2.4 Transport properties	100	358f.
8.3.2.2.5,6 Optical and further properties	100	359f.
8.3.2.3 References for 8.3.2	101	-
8.3.3 Tellurium (Te) (P. GROSSE, W. RICHTER)	106	-
8.3.3.1 Electronic properties	106	340, 360ff., 366
8.3.3.2 Impurities and defects	108	362
8.3.3.3 Lattice properties	109	325, 362f., 370
8.3.3.4 Transport properties	112	361, 364ff., 368
8.3.3.5 Optical properties	114	340, 366ff.
8.3.3.6 Further properties	115	370
8.3.3.7 References for 8.3.3	116	-
8.3.4 $\text{Se}_x\text{Te}_{1-x}$ (G. WEISER)	118	-
8.3.4.1 Electronic properties	118	371
8.3.4.3 Lattice properties	119	371ff., 377f.
8.3.4.4 Transport properties	120	373ff.
8.3.4.5,6 Optical and further properties	121	377f.
8.3.4.7 References for 8.3.4	122	-
9 Non-tetrahedrally bonded binary compounds	123	-
9.1 IA-IB compounds (W. FREYLAND)	123	-
9.1.0 Structure, chemical bond	123	379
9.1.1 Cesium auride (CsAu)	123	379ff.
9.1.2 Rubidium auride (RbAu)	125	379, 381
9.1.3 References for 9.1	125	-
9.2 $\text{I}_x\text{-V}_y$ compounds (W. FREYLAND)	126	-
9.2.0 Structure, chemical bond	126	382ff.
9.2.1 I-V compounds ($\text{Na-}, \text{K-}, \text{Rb-}, \text{CsSb}$)	129	384, 389
9.2.2 Lithium antimonide, - bismuthide ($\text{Li}_3\text{Sb}, \text{Li}_3\text{Bi}$)	129	384f.
9.2.3 Sodium antimonide (Na_3Sb)	130	385f.
9.2.4 Potassium antimonide (K_3Sb)	130	386ff., 393f.
9.2.5 Rubidium antimonide (Rb_3Sb)	131	389f.
9.2.6 Cesium antimonide (Cs_3Sb)	132	384, 389ff.
9.2.7 Rubidium-, cesium bismuthide ($\text{Rb}_3\text{Bi}, \text{Cs}_3\text{Bi}$)	133	392f.
9.2.8 Sodium-potassium antimonide (Na_2KSb)	133	385f., 393f.
9.2.9 Potassium-cesium antimonide (K_2CsSb)	134	393ff.
9.2.10 Further bialkali antimonides	135	395
9.2.11 References for 9.2	135	-
9.3 $\text{I}_x\text{-VI}_y$ compounds (A. GOLTZENÉ, C. SCHWAB)	137	-
9.3.0 Structure, chemical bond	137	-
9.3.0.1 Cupric and cuprous oxides	137	395, 413
9.3.0.2 Copper chalcogenides Cu_xX	137	396f.
9.3.0.3 Silver oxides	139	422
9.3.0.4 Silver chalcogenides	139	397ff.
9.3.0.5 Other I_xVI_y and $\text{I}_x\text{I}_y\text{VI}_z$ compounds	141	-
9.3.0.6 References for 9.3.0	142	-
9.3.1 Cupric oxide (CuO)	143	400f.
References for 9.3.1	144	-
9.3.2 Cuprous oxide (Cu_2O)	144	-
9.3.2.1 Electronic properties	144	402ff.
9.3.2.3 Lattice properties	146	408f.
9.3.2.4 Transport properties	148	410ff.
9.3.2.5 Optical properties	148	409, 412ff.
9.3.2.6 Further properties	149	413

	Data	Figures
9.3.2.7 References for 9.3.2	150	-
9.3.3 Copper sulfides (Cu_xS)	151	414 ff.
References for 9.3.3	153	-
9.3.4 Copper selenide (Cu_2Se)	153	418 f.
References for 9.3.4	154	-
9.3.5 Copper telluride (Cu_2Te)	154	420
References for 9.3.5	154	-
9.3.6 Silver oxides (AgO , Ag_2O)	155	421 f.
References for 9.3.6	156	-
9.3.7 Silver sulfide (Ag_2S)	156	423 ff.
References for 9.3.7	159	-
9.3.8 Silver selenide (Ag_2Se)	159	426 ff.
References for 9.3.8	161	-
9.3.9 Silver telluride (Ag_2Te)	161	430 ff.
References for 9.3.9	163	-
9.4 $\text{II}_x\text{-IV}_y$ compounds (O. MADELUNG)	163	-
9.4.0 Structure, chemical bond	163	432
9.4.1 Magnesium silicide (Mg_2Si)	164	433 ff.
9.4.2 Magnesium germanide (Mg_2Ge)	167	433 f., 439 ff.
9.4.3 Magnesium stannide (Mg_2Sn)	170	433 f., 436, 439, 444 ff.
9.4.4 Magnesium plumbide (Mg_2Pb)	174	432 f., 453
9.4.5 Solid solutions $\text{Mg}_2\text{X}_x\text{Y}_{1-x}$	176	453 f.
9.4.6 Calcium compounds: Ca_2Si , Ca_2Sn , Ca_2Pb	176	454 f.
9.4.7 II-IV_2 -compounds: BaSi_2 , BaGe_2 , SrGe_2	176	-
9.4.8 References for 9.4	176	-
9.5 $\text{II}_x\text{-V}_y$ compounds (W. ŻDANOWICZ; sections 9.5.7 and 9.5.9 under assistance of J. WESZKA, sections 9.5.14, 9.5.15 and 9.5.17 under assistance of V. YA. SHEVCHENKO)	178	-
9.5.0 Structure, chemical bond	178	455 ff.
9.5.1 Magnesium arsenide (Mg_3As_2)	182	463
9.5.2 Zinc phosphide (Zn_3P_2)	183	-
9.5.2.1 Electronic properties	183	464
9.5.2.2 Impurities and defects	185	-
9.5.2.3 Lattice properties	185	-
9.5.2.4 Transport properties	186	464 f.
9.5.2.5 Optical properties	186	465 ff.
9.5.2.6 Further properties	187	467
9.5.3 Zinc arsenide (Zn_3As_2)	189	-
9.5.3.1 Electronic properties	189	467 f., 475
9.5.3.3 Lattice properties	190	477
9.5.3.4 Transport properties	191	468 f.
9.5.3.5 Optical properties	191	469
9.5.3.6 Further properties	191	469, 506
9.5.4 Cadmium phosphide (Cd_3P_2)	193	-
9.5.4.1 Electronic properties	193	464, 470
9.5.4.3 Lattice properties	195	-
9.5.4.4 Transport properties	196	471 ff.
9.5.4.5 Optical properties	197	473 f.
9.5.4.6 Further properties	198	467
9.5.5 Cadmium arsenide (Cd_3As_2)	199	-
9.5.5.1 Electronic properties	199	474 ff.
9.5.5.2 Impurities and defects	203	-
9.5.5.3 Lattice properties	203	477 f.
9.5.5.4 Transport properties	204	478 ff.
9.5.5.5 Optical properties	206	475 f., 482 f.
9.5.5.6 Further properties	207	483 ff., 506

	Data	Figures
9.5.6 Solid solutions between $\text{II}_3\text{-V}_2$ compounds	210	–
9.5.6.A $\text{Cd}_{3-x}\text{Zn}_x\text{As}$	210	486 ff.
9.5.6.B $\text{Cd}_3\text{As}_{2-x}\text{P}_x$	211	492 ff.
9.5.6.C $\text{Cd}_{3-x}\text{Zn}_x\text{P}_2$	212	496 f.
9.5.6.D $\text{Zn}_3\text{As}_{2-x}\text{P}_x$	212	497
9.5.6.E $(\text{Cd}_3\text{As}_2)_{1-x}(\text{Zn}_3\text{P}_2)_x$	213	498 f.
9.5.7 Zinc phosphide (ZnP_2)	213	–
9.5.7.A $\alpha\text{-ZnP}_2$ (tetragonal modification)	213	–
9.5.7.A.1 Electronic properties	213	499 f.
9.5.7.A.2 Impurities and defects	213	–
9.5.7.A.3 Lattice properties	213	500
9.5.7.A.4 Transport properties	214	–
9.5.7.A.5 Optical properties	214	499 ff.
9.5.7.A.6 Further properties	216	467, 500
9.5.7.B $\beta\text{-ZnP}_2$ (monoclinic modification)	216	–
9.5.7.B.1 Electronic properties	216	501, 504
9.5.7.B.2 Impurities and defects	217	–
9.5.7.B.3 Lattice properties	217	–
9.5.7.B.4 Transport properties	217	504
9.5.7.B.6 Further properties	218	467
9.5.8 Zinc arsenide (ZnAs_2)	219	–
9.5.8.1 Electronic properties	219	504 f.
9.5.8.3 Lattice properties	219	–
9.5.8.4 Transport properties	220	505 f.
9.5.8.5 Optical properties	220	–
9.5.8.6 Further properties	221	506
9.5.9 Cadmium phosphide (CdP_2)	222	–
9.5.9.1 Electronic properties	222	499, 507
9.5.9.3 Lattice properties	223	508
9.5.9.5 Optical properties	224	508 f.
9.5.9.6 Further properties	224	467, 508
9.5.10 Cadmium arsenide (CdAs_2)	225	–
9.5.10.1 Electronic properties	225	510
9.5.10.3 Lattice properties	225	–
9.5.10.4 Transport properties	226	510 f.
9.5.10.5 Optical properties	226	510 ff.
9.5.10.6 Further properties	227	506, 512
9.5.11 Solid solutions between II-V_2 compounds	228	–
9.5.12 II-V_4 compounds (MgP_4 , MgAs_4 , CdP_4 , CdAs_4)	228	513 f.
9.5.13 Zinc and cadmium arsenide (ZnAs , CdAs)	230	–
9.5.14 Zinc antimonide (ZnSb)	231	514 ff.
9.5.15 Cadmium antimonide (CdSb)	233	–
9.5.15.1 Electronic properties	233	515 f.
9.5.15.3 Lattice properties	234	–
9.5.15.4 Transport properties	234	516 f.
9.5.15.5,6 Optical and further properties	235	516
9.5.16 Solid solutions between II-V compounds	235	–
9.5.17 Zinc and cadmium antimonide (Zn_4Sb_3 , Cd_4Sb_3)	235	–
9.5.17.A Zn_4Sb_3	235	517 f.
9.5.17.B Cd_4Sb_3	236	518
9.5.17.C Solid solutions	237	518
9.5.18 Cadmium phosphides (Cd_7P_{10} , Cd_6P_7)	237	–
9.5.18.A Cd_7P_{10}	237	457, 460, 518
9.5.18.B Cd_6P_7	238	518
9.5.19 References for 9.5	239	–
9.6 II-VII_2 compounds (G. HARBEKE)	250	–
9.6.0 Structure, chemical bond	250	519

	Data	Figures
9.6.1 Cadmium dichloride (CdCl_2)	250	519 ff.
9.6.2 Cadmium dibromide (CdBr_2)	251	519 ff.
9.6.3 Cadmium diiodide (CdI_2)	252	522 ff.
9.6.4 Mercury dichloride (HgCl_2)	255	526
9.6.5 Mercury dibromide (HgBr_2)	256	526
9.6.6 Mercury diiodide (HgI_2)	256	527 ff.
9.6.7 References for 9.6	262	–