PROPERTIES OF SEMICONDUCTORS

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The term *semiconductor* is applied to a material in which electric current is carried by electrons or holes and whose electrical conductivity, when extremely pure, rises exponentially with temperature and may be increased from its low "intrinsic" value by many orders of magnitude by "doping" with electrically active impurities.

Semiconductors are characterized by an energy gap in the allowed energies of electrons in the material which separates the normally filled energy levels of the *valence band* (where "missing" electrons behave like positively charged current carriers "holes") and the *conduction band* (where electrons behave rather like a gas of free negatively charged carriers with an effective mass dependent on the material and the direction of the electrons' motion). This energy gap depends on the nature of the material and varies with direction in anisotropic crystals. It is slightly dependent on temperature and pressure, and this dependence is usually almost linear at normal temperatures and pressures.

Data are presented in five tables. Table 1 lists the main crystallographic and semiconducting properties of a large number of semiconducting materials in three main categories: "Tetrahedral Semiconductors" in which every atom is tetrahedrally coordinated to four nearest neighbor atoms (or atomic sites) as for example in the diamond structure; "Octahedral Semiconductors" in which every atom is octahedrally coordinated to six nearest neighbor atoms—as for example the halite structure; and "Other Semiconductors."

Table 2 gives electrical, magnetic, and optical properties, while Tables 3 and 4 give more details on the semiconducting properties and band structure of the most common semiconductors. Table 5 lists semiconducting minerals with typical resistivity ranges.

TABLE 1. Physico-Chemical Properties of Semiconductors (Listed by Crystal Structure)

Substance	Molecular weight	Average atomic weight	Lattice parameters (Å, room temp.)	Density (g/cm³)	Melting point (K)	Microhardness, N/mm² (M-Mohs Scale)	Specific heat, J/kg·K (300 K)	Debye temp. (K)	Coefficient of thermal linear expansion [10^{-6} K^{-1} (300K)]	Thermal conductivity [mW/cm·K (300K)]
1.1. Adamantine Semiconductors										
1.1.1. Diamond Structure Elements (Strukturbericht symbol A4, Space Group Fd3m-O_h^7)										
C (Diamond)		12.01	3.56683	3.513	≈4713 (12.4 GPa) Transition to graphite > 980	10 (M)	471.5	2340	1.18	9900(I) 23200(IIA) 13600(IIB)
Si		28.09	5.43072	2.329	1687	11270	702	645	2.6	1240
Ge		72.64	5.65754	5.323	1211.35	7644	321.9	374	5.8	640
α-Sn		118.71	6.4912	5.769	505.1 (Tr. 286.4)		213	230	5.4 (220 K)	
1.1.2. Sphalerite (Zinc Blende) Structure Compounds (Strukturbericht symbol B3 Space Group F $\bar{4}$ 3m-T_d^2)										
I-VII Compounds										
CuF	82.54	41.27	4.255		1181					
CuCl	98.99	49.49	5.4057	3.53	695	2.3 (M)	490	240	12.1	8.4
CuBr	143.45	71.73	5.6905	4.98	770	2.5 (M)	381	207	15.4	12.5
CuI	190.45	95.23	6.60427	5.63	878	192	276	181	19.2	16.8
AgBr	187.77	93.89		6.473	>1570 (Tr. 410)	2.5 (M)	270			
AgI	234.77	117.39	6.502	5.67	831	2.5 (M)	232	134	–2.5	4.2
II-VI Compounds										
BeS	41.08	20.54	4.865	2.36	dec.					
BeSe	87.97	43.99	5.139	4.315						
BeTe	136.61	68.31	5.626	5.090						
BePo	(2318)	(109)	5.838	7.3						
ZnO	81.39	40.69	4.63	5.675	2248	5.0 (M)	494	416	2.9	234
ZnS	97.46	48.72	5.4093	4.079	2100 (Tr. 1295)	1780	472	530	6.36	251

Substance	Molecular weight	Average atomic weight	Lattice parameters (Å, room temp.)	Density (g/cm^3)	Melting point (K)	Microhardness, N/mm^2 (M-Mohs Scale)	Specific heat, J/kg·K (300 K)	Debye temp. (K)	Coefficient of thermal linear expansion [10^{-6} K^{-1} (300K)]	Thermal conductivity [mW/cm·K (300K)]
ZnSe	144.34	72.17	5.6676	5.42	1790	1350	339	400	7.2	140
ZnTe	192.99	96.5	6.101	6.34	1568	900	264	223	8.19	108
ZnPo	(274)	(137)	6.309							
CdS	144.48	72.24	5.832	4.826	1750	1250	330	219	4.7	200
CdSe	191.37	95.68	6.05	5.674	1512	1300	255	181	3.8	90
CdTe	240.01	120.00	6.477	5.86	1365	600	205	200	4.9	58.5
CdPo	(321)	(161)	6.665							
HgS	232.66	116.33	5.8517	7.73	1820	3 (M)	210			
HgSe	279.55	139.78	6.084	8.25	1070	2.5 (M)	178	151	5.46	10
HgTe	328.19	164.10	6.4623	8.17	943	300	164	242	4.6	20
III-V Compounds										
BN	24.82	12.41	3.615	3.49	3239	10 (M)	793	≈1900		200
BP(L.T.)	41.78	20.87	4.538	2.9	1398 (dec)	37000		≈980		
BAs	85.73	42.87	4.777		≈2300	19000		≈625		
AlP	57.95	28.98	5.451	2.42	≈2100	5.5 (M)		588		920
AlAs	101.90	50.95	5.6622	3.81	2013	5000		417	3.5	840
AlSb	148.74	74.37	6.1355	4.218	1330	4000		292	4.2	600
GaP	100.70	50.35	5.4905	4.13	1750	9450		446	5.3	752
GaAs	144.64	72.32	5.65315	5.316	1510	7500		344	5.4	560
GaSb	191.48	95.74	6.0954	5.619	980	4480	320	265	6.1	270
InP	145.79	72.90	5.86875	4.787	1330	4100		321	4.6	800
InAs	189.74	94.87	6.05838	5.66	1215	3300	268	249	4.7	290
InSb	236.58	118.29	6.47877	5.775	798	2200	144	202	4.7	160
Other sphalerite structure compounds										
MnS	87.00	43.5	5.011							
MnSe	133.90	66.95	5.82							
β-SiC (3-C SiC)	40.10	20.1	4.348	3.21	3070				2.9	4.9
Ga_2Se_3	376.32	75.26	5.429	4.92	1020	3160			8.9	50
Ga_2Te_3	522.24	104.45	5.899	5.75	1063	2370				47
In_2Te_3(H.T.)	608.44	121.7	6.173	5.8	940	1660				69
$MgGeP_2$	158.84	39.71	5.652							
$ZnSnP_2$	246.00	61.5	5.65		1200					
$ZnSnAs_2$(H.T.)	333.90	82.38	5.851	5.53	1050					76
$ZnSnSb_2$	427.56	106.89	6.281	5.67	870	2500				76

1.1.3. Wurtzite (Zincite) Structure Compounds (Strukturbericht symbol B4, Space Group P 6_3mc-C^4_{6v})

I-VII Compounds										
CuCl	99.0	49.5	3.91	6.42		703				
CuBr	143.45	71.73	4.06	6.66		770				
CuI	190.45	95.23	4.31	7.09						
AgI	234.77	117.40	4.580	7.494						
II-VI Compounds										
BeO	25.01	12.51	2.698	4.380		2800				
MgTe	151.9	76.0	4.54	7.39	3.85	≈2800				
ZnO	81.37	40.69	3.24950	5.2069	5.66	2250				600
ZnS	97.43	48.72	3.8140	6.2576	4.1	2100				460

Substance	Molecular weight	Average atomic weight	Lattice parameters (Å, room temp.)		Density (g/cm³)	Melting point (K)	Microhardness, N/mm² (M-Mohs Scale)	Specific heat, J/kg·K (300 K)	Debye temp. (K)	Coefficient of thermal linear expansion [10^{-6} K^{-1} (300K)]	Thermal conductivity [mW/cm·K (300K)]
ZnTe	192.99	46.50	4.27	6.99		1568					
CdS	144.48	72.23	4.1348	6.7490	4.82	1748					401
CdSe	191.37	95.68	4.299	7.010	5.66	1512					316
CdTe	240.01	120.00	4.57	7.47							
III-V Compounds											
BP(H.T.)	41.79	20.90	3.562	5.900							
AlN	40.99	20.50	3.111	4.978	3.26	≈2500					823
GaN	83.73	41.87	3.190	5.189	6.10	1500					656
InN	128.83	64.42	3.533	5.693	6.88	1200					556
Other wurtzite structure compounds											
MnS	87.00	43.5	3.985	6.45	3.248						
MnSe	133.90	66.95	4.12	6.72							
SiC	40.10	20.1	3.076	5.048							
MnTe	182.54	91.27	4.078	6.701							
Al_2S_3	150.14	30.03	3.579	5.829	2.55	1400					
Al_2Se_3	290.84	58.17	3.890	6.30	3.91	1250					

1.1.4. Chalcopyrite Structure Compounds (Strukturbericht symbol $E1_1$, Space Group $I\bar{4}$ $2d$-D_{24}^{12})

I-III-VI_2 Compounds											
$CuAlS_2$	154.65	38.66	5.323	10.44	3.47	2500					
$CuAlSe_2$	248.45	62.11	5.617	10.92	4.70	2260					
$CuAlTe_2$	345.73	86.43	5.976	11.80	5.50	2550					
$CuGaS_2$	197.39	49.53	5.360	10.49	4.35	2300					
$CuGaSe_2$	291.19	72.80	5.618	11.01	5.56	1970	4200		275	5.4	42
$CuGaTe_2$	388.47	97.12	6.013	11.93	5.99	2400	3500			6.9	27
$CuInS_2$	242.49	60.62	5.528	11.08	4.75	1400	2550				
$CuInSe_2$	336.29	84.07	5.785	11.56	5.77	1600	2050			6.6	37
$CuInTe_2$	433.57	108.39	6.179	12.365	6.10	1660	400		195	7.1	49
$CuTlS_2$	322.05	83.01	5.580	11.17	6.32						
$CuTlSe_2$(L.T.)	425.85	106.46	5.844	11.65	7.11	900					
$CuFeS_2$	183.51	45.88	5.29	10.32	4.088	1135					
$CuFeSe_2$	277.31	69.33				850					
$CuLaS_2$	266.58	66.65	5.65	10.86							
$AgAlS_2$	198.97	49.74	5.707	10.28	3.94						
$AgAlSe_2$	292.77	73.19	5.968	10.77	5.07	1220					
$AgAlTe_2$	390.05	97.51	6.309	11.85	6.18	1000					
$AgGaS_2$	241.71	60.43	5.755	10.28	4.72						
$AgGaSe_2$	335.51	83.88	5.985	10.90	5.84	1120	4400				
$AgGaTe_2$	432.79	108.2	6.301	11.96	6.05	990	1800		212		10
$AgInS_2$(L.T.)	286.87	71.70	5.828	11.19	5.00		2250				
$AgInSe_2$	380.61	95.15	6.102	11.69	5.81	1053	1850				30
$AgInTe_2$	477.89	119.47	6.42	12.59	6.12	965				9.49, 0.69	
$AgFeS_2$	227.83	56.96	5.66	10.30	4.53						
II-IV-V_2 Compounds											
$ZnSiP_2$	155.40	38.85	5.400	10.441	3.39	1640	1100				
$ZnGeP_2$	199.90	49.98	5.465	10.771	4.17	1295	8100				180
$ZnSnP_2$	246.00	61.5					6500				
$CdSiP_2$	202.43	50.61	5.678	10.431	4.00	≈1470	10500		282		

Substance	Molecular weight	Average atomic weight	Lattice parameters (Å, room temp.)		Density (g/cm^3)	Melting point (K)	Microhardness, N/mm^2 (M-Mohs Scale)	Specific heat, J/kg·K (300 K)	Debye temp. (K)	Coefficient of thermal linear expansion [10^{-6} K^{-1} (300K)]	Thermal conductivity [mW/cm·K (300K)]
$CdGeP_2$	246.94	61.74	5.741	10.775	4.48	1049	5650				110
$CdSnP_2$	243.03	73.26	5.900	11.518		840	5000		195		140
$ZnSiAs_2$	242.20	60.55	5.61	10.88	4.70	1311	9200				
$ZnGeAs_2$	287.80	71.95	5.672	11.153	5.32	1150	6800		263		110
$ZnSnAs_2$	333.90	83.48	5.8515	11.704	5.53	1048	4550		271		150
$CdSiAs_2$	290.34	72.58	5.884	10.882		>1120	6850				
$CdGeAs_2$	334.83	83.71	5.9427	11.2172	5.60	938	4700				48
$CdSnAs_2$	380.93	95.23	6.0944	11.9182	5.72	880	3450				40

1.1.5. Other Ternary Semiconductors with Tetrahedral Coordination

I_2-IV-VI_3 Compounds

Cu_2SiS_3(H.T.)	251.36	41.89	3.684	6.004	3.81	1200					23
Cu_2SiS_3(L.T.)			5.290	10.156	3.63						
Cu_2SiTe_3	537.98	89.66	5.93		5.47						
Cu_2GeS_3(H.T.)	295.88	49.31	5.317		4.45	1210	4550	510	254	7.2	12
Cu_2GeS_3(L.T.)			5.327	5.215	4.46						
Cu_2GeSe_3	436.56	72.76	5.589	5.485	5.57	1030	3840	340	168	8.4	24
Cu_2GeTe_3	582.51	97.09	5.958	5.935	5.92		2890				130
Cu_2SnS_3	341.98	57.00	5.436		5.02	1110	2770	440	214	7.8	28
$CuSnSe_3$	482.66	80.44	5.687		5.94	960	2510	310	148	8.9	35
Cu_2SnTe_3	628.61	104.77	6.048		6.51	680	1970				144
Ag_2GeSe_3	525.21	87.54				810					
Ag_2SnSe_3	571.31	95.22									
Ag_2GeTe_3	671.13	111.86				600					
Ag_2SnTe_3	717.23	119.54									

I_3-V -VI_4-Compounds

Cu_3PS_4	349.85	40.73	7.44	6.19							
Cu_3AsS_4	393.79	49.22	6.43	6.14	4.37	931				3.2	30.2
Cu_3AsSe_4	581.37	72.67	5.570	10.957	5.61	733			169	9.5	19
Cu_3SbS_4	440.64	55.08	5.38	16.76	4.90	830					
Cu_3SbSe_4	628.22	78.53	5.654	11.256	6.0	700			131	12.4	14.6

I-IV_2-V_3 Compounds

$CuSi_2P_3$	212.64	35.44	5.25								
$CuGe_2P_3$	301.65	50.28	5.375		4.318	1113	8500	429	8.21	37.6	
$AgGe_2P_3$	345.97	57.66				1015	6150				

1.1.6. "Defect Chalcopyrite" Structure Compounds (Strukturbericht symbol E3, Space Group $I\bar{4}$-S_4^2)

$ZnAl_2Se_4$	435.18	62.17	5.503	10.90	4.37						
$ZnAl_2Te_4$(?)	629.74	84.96	5.904	12.05	4.95						
$ZnGa_2S_4$(?)	333.06	47.58	5.274	10.44	3.80						
$ZnGa_2Se_4$(?)	520.66	74.38	5.496	10.99	5.21						
$ZnGa_2Te_4$(?)	715.22	102.17	5.937	11.87	5.67						
$ZnIn_2Se_4$	610.86	87.27	5.711	11.42	5.44	1250					
$ZnIn_2Te_4$	805.42	115.06	6.122	12.24	5.83	1075					
$CdAl_2S_4$	294.61	42.09	5.564	10.32	3.06						
$CdAl_2Se_4$	482.21	68.89	5.747	10.68	4.54						
$CdAl_2Te_4$(?)	676.77	97.68	6.011	12.21	5.10						

Substance	Molecular weight	Average atomic weight	Lattice parameters (Å, room temp.)		Density (g/cm^3)	Melting point (K)	Microhardness, N/mm^2 (M-Mohs Scale)	Specific heat, J/kg·K (300 K)	Debye temp. (K)	Coefficient of thermal linear expansion [10^{-6} K^{-1} (300K)]	Thermal conductivity [mW/cm·K (300K)]
$CdGa_2S_4$	380.09	54.30	5.577	10.08	4.03						
$CdGa_2Se_4$	567.69	81.10	5.743	10.73	5.32						
$CdGa_2Te_4$	762.25	108.89	6.093	11.81	5.77						
$CdIn_2Te_4$	852.45	121.78	6.205	12.41	5.9	1060					
$HgAl_2S_4$	382.79	54.68	5.488	10.26	4.11						
$HgAl_2Se_4$	570.39	82.48	5.708	10.74	5.05						
$HgAl_2Te_4$(?)	764.48	109.28	6.004	12.11	5.81						
$HgGa_2S_4$	468.27	66.90	5.507	10.23	5.00						
$HgGa_2Se_4$	655.87	93.70	5.715	10.78	6.18						
$HgIn_2Se_4$	746.07	106.58	5.764	11.80	6.3	1100					
$HgIn_2Te_4$(?)	940.63	134.38	6.186	12.37	6.3	980					
1.1.7. Other Adamantine Compounds											
α–SiC	40.10	20.10	3.0817	15.12	3.21	3070					
$Hg_5Ga_2Te_8$	2163.19	144.21	6.235								
$Hg_5In_2Te_8$	2253.39	150.23	6.328								
$CdIn_2Se_4$	657.89	93.98	a = c = 5.823								
1.2. Octahedral Semiconductors											
1.2.1. Halite Structure Semiconductors (Strukturbericht symbol B1, Space Group $Fm3m$-O_h^5)											
GeTe	200.21	100.10	5.98		6.14						
SnSe	197.67	98.83	6.020			1133					
SnTe	246.31	123.15	6.313		6.45	1080 (max)					91
PbS	239.3	119.63	5.9362		7.61	1390					23
PbSe	286.2	143.08	6.1243		8.15	1340					17
PbTe	334.8	167.4	6.454		8.16	1180					23
1.2.2. Selected Other Binary Halites											
BiSe	287.94	143.97	5.99		7.98	880					
BiTe	336.58	168.29	6.47								
EuSe	230.92	115.46	6.191			2300					2.4
GdSe	236.21	118.11	5.771			2400					
NiO	74.69	37.35	4.1684		6.6	2260					
CdO	128.41	64.21	4.6953			1700					7
SrS	119.69	59.84	6.0199		3.643	3000					
1.3. Other Semiconductors											
1.3.1. Antifluorite Structure Compounds ($Fm3m$–O_h^5)											
Mg_2Si	76.70	25.57	6.338		1.88	1375				11.5	
Mg_2Ge	121.22	40.4	6.380		3.08	1388				15.0	
Mg_2Sn	167.32	55.77	6.765		3.53	1051				9.9	92
Mg_2Pb	225.81	85.27	6.836		5.1	823				10.0	
1.3.2. Tetradymite Structure Compounds ($\bar{R}3m$–D_{3d}^5)											
Sb_2Te_3	626.3	125.26	4.25	30.3	6.44	895					
Bi_2Se_3	654.84	130.97	4.14	28.7	7.51	979	167				24
Bi_2Te_3	800.76	160.15	4.38	30.45	7.73	858	155	16			30

Substance	Molecular weight	Average atomic weight	Lattice parameters (Å, room temp.)	Density (g/cm³)	Melting point (K)	Microhardness, N/mm² (M-Mohs Scale)	Specific heat, J/kg·K (300 K)	Debye temp. (K)	Coefficient of thermal linear expansion [10^{-6} K^{-1} (300K)]	Thermal conductivity [mW/cm·K (300K)]
1.3.3. Skutterudite Structure Compounds (Im3–T_h^5)										
CoP_3	151.85	37.96	7.7073		>1270					
$CoAs_3$	286.70	71.65	8.2060	6.73	1230					
$CoSb_3$	424.18	106.05	9.0385		1123			307		50
$NiAs_3$	283.45	70.86	8.330	6.43						
RhP_3	195.83	48.96	7.9951		>1470					
$RhAs_3$	327.67	81.92	8.4427		>1270					100
$RhSb_3$	468.16	117.04	9.2322		1170					
IrP_3	285.14	71.29	8.0151	7.36	>1470					
$IrAs_3$	416.98	104.25	8.4673	9.12	>1470					90
$IrSb_3$	557.47	139.37	9.2533	9.35	1170			303		
1.3.4. Selected Multinary Compounds										
$AgSbSe_2$	387.54	96.88	5.786	6.60	910					10.5
$AgSbTe_2$ (or $Ag_{19}Sb_{29}Te_{52}$)	484.82	121.2	6.078	7.12	830					86
$AgBiS_2$(H.T.)	380.97	95.24	5.648							
$AgBiSe_2$(H.T.)	474.77	118.69	5.82							
$AgBiTe_2$(H.T.)	572.05	143.01	6.155							
Cu_2CdSnS_4	486.43	60.80	5.586	10.83						
1.3.5. Some Elemental Semiconductors										
B		10.81	4.91	12.6	2.34	2348	9.5 (M)	1277	1370	8.3	600
Se(gray)		78.96	4.36	4.95	4.81	493	350	292.6		(||C) 17.89	(||C) 45.2
										(⊥C) 74.09	(⊥C) 13.1
Te		127.60	4.45	5.91	6.23	723		196.5		16.8	(||C) 33.8
											(⊥C) 19.7

TABLE 2. Basic Thermodynamic, Electrical, and Magnetic Properties of Semiconductors (Listed by Crystal Structure)

Substance	Heat of formation [kJ/mol (300K)]	Volume compressibility (10^{-10}m²/N)	Static dielectric constant	Atomic magnetic susceptibility (10^{-6} cgs)	Index of refraction	Miniumum room temperature energy gap (eV)	Mobility (room temp.) (cm²/V·s) Electrons	Mobility (room temp.) (cm²/V·s) Holes	Optical transition	Breakdown voltage kV/mm	Remarks
2.1. Adamantine Semiconductors											
2.1.1. Diamond Structure Elements (Strukturbericht symbol A4, Space Group Fd 3m–O_h^7)											
C	714.4	18	5.7	–5.88	2.419 (589 nm)	5.4	1800	1400	i*	500	
Si	324	0.306	11.9	–3.9	3.49 (589 nm)	1.12	1900	500	i	30	
Ge	291	0.768	16	–0.12	3.99 (589 nm)	0.67	3800	1820	i		
α-Sn	267.5		24		2.75 (589 nm)	0.0; 0.8	2500	2400			
2.1.2. Sphalerite (Zinc Blende) Structure Compounds (Strukturbericht symbol B3 Space Group F $\bar{4}$ 3m–T_d^2)											
I-VII Compounds											
CuF											
CuCl	481	0.26	7.9		1.93	3.17			d		Nantokite

Substance	Heat of formation [kJ/mol (300K)]	Volume compressibility (10^{-10}m^2/N)	Static dielectric constant	Atomic magnetic susceptibility (10^{-6} cgs)	Index of refraction	Miniumum room temperature energy gap (eV)	Mobility (room temp.) (cm^2/V·s) Electrons	Mobility (room temp.) (cm^2/V·s) Holes	Optical transition	Breakdown voltage kV/mm	Remarks
CuBr	481	0.26	7.9		2.12	2.91			d		
CuI	439	0.27	6.5		2.346	2.95			d		Marshite
AgBr	486		12.4		2.253	2.50	4000		i		Bromirite
AgI	389	0.41	10		2.22	2.22	30		d		Miersite
					II-VI Compounds						
BeS					4.17				i		
BeSe					3.61				i		
BeTe					1.45		20		d		
BePo											
ZnO											See 2.1.3.
ZnS	477		8.9	−9.9	2.356	3.54	180	5(400°C)	d		See also 2.1.3.
ZnSe	422		9.2		2.89	2.58	540	28	d		
ZnTe	376		10.4		3.56	2.26	340	100	d		
ZnP											
CdS											See 2.1.3.
CdSe											See 2.1.3.
CdTe	339		7.2		2.50	1.44	1200	50	d		
CdPo											
HgS					2.85		250		d		Metacinnabarite
HgSe	247					2.10 (α)	20000	≈1.5	s		Tiemannite
HgTe	242					−0.06	25000	350	s		Coloradoite
					III-V Compounds						
BN	815					4.6					Borazone
BP(L.T.)						≈2.1	500	70			Ignites 470K
BAs						≈1.5					
AlP						2.45	80		i		
AlAs	627		10.9			2.16	1200	420	i		
AlSb	585	0.571	11		3.2	1.60	200–400	550	i		
GaP	635	0.110	11.1	−13.8	3.2	2.24	300	150	i		
GaAs	535	0.771	13.2	−16.2	3.30	1.35	8800	400	d		
GaSb	493	0.457	15.7	−14.2	3.8	0.67	4000	1400	d		
InP	560	0.735	12.4	−22.8	3.1	1.27	4600	150	d		
InAs	477	0.549	14.6	−27.7	3.5	0.36	33000	460	d		
InSb	447	0.442	17.7	−32.9	3.96	0.163	78000	750	d		

* i = indirect, d = direct, s = semimetal.

Other sphalerite structure compounds

MnS											See also 2.1.3.
MnSe											See also 2.1.3.
β-SiC					2.697	2.3	4000				
Ga_2Te_3	271			−13.5		1.35	50				
In_2Te_3(H.T.)	198			−13.6		1.04	50				
$MgGeP_2$											El–T^{d12}
$ZnSnP_2$						2.1					Same
$ZnSnAs_2$(H. T.)						≈0.7					Same
$ZnSnSb_2$						0.4					Same

2.1.3. Wurtzite (Zincite) Structure Compounds (Strukturbericht symbol B4, Space Group P 6$_3$ mc-C_{6v}^4)

					I-VII Compounds						
CuCl											
CuBr											
CuI											
AgI						2.63					Iodargirite
					II-VI Compounds						
BeO											
MgTe											
ZnO	−350					3.2	180				
ZnS	−206					3.67					
ZnTe	−163										

Substance	Heat of formation [kJ/mol (300K)]	Volume compressibility ($10^{-10}m^2/N$)	Static dielectric constant	Atomic magnetic susceptibility (10^{-6}cgs)	Index of refraction	Miniumum room temperature energy gap (eV)	Mobility (room temp.) ($cm^2/V{\cdot}s$) Electrons	Holes	Optical transition	Breakdown voltage kV/mm	Remarks
CdS				8.45; 9.12	2.32	2.42	350	40	d		Greenockide
CdSe						1.74	900	50	d		Cadmoselite
CdTe						1.50	650				
III-V Compounds											
BP(H.T.)											
AlN						6.02					
GaN						3.34					
InN						2.0					
Other wurtzite structure compounds											
MnS											
MnSe											
SiC					2.654						
MnTe						≈1.0					
Al_2S_3	426					4.1					
Al_2Se_3	367					3.1					

2.1.4 Chalcopyrite Structure Compounds (Strukturbericht symbol E1$_1$, Space Group I $\bar{4}$ 2d-D^{12}_{2d})

I-III-VI$_2$ Compounds											
$CuAlS_2$		0.106				2.5					
$CuAlSe_2$						2.67					
$CuAlTe_2$						0.88					
$CuCaS_2$		0.106				2.38					
$CuGaSe_2$		0.141				0.96, 1.63					
$CuGaTe_2$		0.227				0.82, 1.0					
$CuInS_2$		0.141				1.2					
$CuInSe_2$		0.187				0.86, 0.92					
$CuInTe_2$		0.278				0.95					
$CuTlS_2$											
$CuTlSe_2$ (L.T.)						1.07					
$CuFeS_2$						0.53					Chalcopyrite
$CuFeSe_2$						0.16					
$CuLaS_2$											
$AgAlS_2$											
$AgAlSe_2$						0.7					
$AgAlTe_2$						0.56					
$AgGaS_2$		0.150				1.66					
$AgGaSe_2$		0.182				1.1					
$AgGaTe_2$		0.280				1.9					
$AgInS_2$ (L.T.)		0.185				1.18					
$AgInSe_2$		0.238				0.96, 0.52					
$AgInTe_2$		0.338									
$AgFeS_2$											
II-IV-V$_2$ Compounds											
$ZnSiP_2$	312					2.3	1000				
$ZnGeP_2$	293					2.2					
$ZnSnP_2$	275					1.45					
$CdSiP_2$		0.103				2.2	1000				
$CdGeP_2$	289					1.8					
$CdSnP_2$	270					1.5					
$ZnSiAs_2$	290					1.7		50			
$ZnGeAs_2$	271			−14.4		0.85					
$ZnSnAs_2$	252			−18.4		0.65		300			Disorders at 910 K
$CdSiAs_2$		0.143				1.6					
$CdGeAs_2$	266			−23.4		0.53	70	25			Disorders at 903 K
$CdSnAs_2$	247		13.7	−21.5		0.26	22000	250			

Substance	Heat of formation [kJ/mol (300K)]	Volume compressibility ($10^{-10}m^2/N$)	Static dielectric constant	Atomic magnetic susceptibility (10^{-6} cgs)	Index of refraction	Miniumum room temperature energy gap (eV)	Mobility (room temp.) ($cm^2/V{\cdot}s$) Electrons	Holes	Optical transition	Breakdown voltage kV/mm	Remarks
2.1.5. Other Ternary Semiconductors with Tetrahedral Coordination											
II_2-IV-VI_3 Compounds											
Cu_2SiS_3 (H.T.)											Wurtzite
Cu_2SiS_3 (L.T.)											Tetragonal
Cu_2SiTe_3											Cubic
Cu_2GeS_3 (H.T.)				–18.7							Cubic
Cu_2GeS_3 (L.T.)							360				Tetragonal
Cu_2GeSe_3	211.5			–21.3		0.94	238				Same
Cu_2GeTe_3	190.2			–23.4							Same
Cu_2SnS_3				–18.2		0.91	405				Cubic
$CuSnSe_3$				–21.0		0.66	870				Cubic
Cu_2SnTe_3				–28.4							Cubic
Ag_2GeSe_3				–29.6		0.91 (77K)					
Ag_2SnSe_3				–29.5		0.81					
Ag_2GeTe_3				–31.4		0.25					
Ag_2SnTe_3				–31.0		0.08					
II_3-V-VI_4 Compounds											
Cu_3PS_4											Enargite
Cu_3AsS_4	269.6			–15.8		1.24					
Cu_3AsSe_4	161.3			–13.1		0.88					Famatinite
Cu_3SbS_4				–8.3		0.74					Famatinite
Cu_3SbSe_4	127.1			–20.5		0.31					
II-IV_2-V_3 Compounds											
$CuSi_2P_3$											El
$CuGe_2P_3$		0.12				0.90					El
$AgGe_2P_3$											
2.1.6. "Defect Chalcopyrite" Structure Compounds (Strukturbericht symbol E3, Space Group $I\bar{4}$-S_4^2)											
$ZnAl_2Se_4$											
$ZnAl_2Te_4$(?)											
$ZnGa_2S_4$ (?)						≈3.4					
$ZnGa_2Se_4$(?)						≈2.2					
$ZnGa_2Te_4$(?)						1.35					
$ZnIn_2Se_4$	206					1.82	35				
$ZnIn_2Te_4$	198					1.2					
$CdAl_2S_4$											
$CdAl_2Se_4$											
$CdAl_2Te_4$(?)											
$CdGa_2S_4$	256					3.44	60				
$CdGa_2Se_4$	216					2.43	33				
$CdGa_2Te_4$											
$CdIn_2Te_4$	195					(1.26 or 0.9)	4000				
$HgAl_2S_4$											
$HgAl_2Se_4$											
$HgAl_2Te_4$(?)											
$HgGa_2S_4$	249					2.84					
$HgGa_2Se_4$	204					1.95	400				
$HgIn_2Se_4$	196					0.6	290				
$HgIn_2Te_4$(?)	188					0.86	200				
2.1.7. Other Adamantine Compounds											
α–SiC			10.2	–6.4	2.67	2.86	400				6H structure
$Hg_5Ga_2Te_8$											B3 with superlattice
$Hg_5In_2Te_8$						0.7	2000				B3 with superlattice
$CdIn_2Se_4$						1.55					

Substance	Heat of formation [kJ/mol (300K)]	Volume compressibility (10^{-10}m²/N)	Static dielectric constant	Atomic magnetic susceptibility (10^{-6} cgs)	Index of refraction	Miniumum room temperature energy gap (eV)	Mobility (room temp.) (cm²/V·s) Electrons	Holes	Optical transition	Breakdown voltage kV/mm	Remarks
2.2. Octahedral Semiconductors											
2.2.1. Halite Structure Semiconductors (Strukturbericht symbol B1, Space Group Fm3m-O_h^5)											
GeTe											
SnSe											
SnTe											
PbS	435					0.5	600	600			
PbSe	393		161			0.37	1000	900			
PbTe	393		280			0.26	1600	600			Altaite
			360			0.25					
2.2.2. Selected Other Binary Halites											
BiSe											
BiTe						0.4					
EuSe											
GdSe						1.8	4				
NiO						2.0 or 3.7	100				
CdO	531					2.5					
SrS						4.1					
2.3. Other Semiconductors											
2.3.1. Antifluorite Structure Compounds (Fm3m-O_h^5)											
Mg_2Si	79.08					0.77	405	70			
Mg_2Ge						0.74	520	110			
Mg_2Sn	76.57					0.36	320	260			
Mg_2Pb	52.72					0.1					
2.3.2. Tetradymite Structure Compounds ($R\bar{3}m$-D_{3d}^5)											
Sb_2Te_3						0.3		360			
Bi_2Se_3						0.35	600				
Bi_2Te_3						0.21	1140	680			R3m (166)
2.3.3. Skutterudite Structure Compounds (Im3-T_h^5)											
CoP_3						0.43					
$CoAs_3$						0.69		~4000			
$CoSb_3$						0.63	70	~3000			
RhP_3								700			
$RhAs_3$						0.85		~3000			
$RhSb_3$						0.80		~7000			
$IrSb_3$						1.18		1500			
2.3.4. Selected Multinary Compounds											
$AgSbSe_2$						0.58					
$AgSbTe_2$ (or$Ag_{19}Sb_{29}Te_{52}$)						0.7, 0.27					
$AgBiS_2$ (H.T.)											
$AgBiSe_2$ (H.T.)											
$AgBiTe_2$ (H.T.)											
Cu_2CdSnS_4						1.16	<2				
2.3.5. Some Elemental Semiconductors											
B	397.1			−6.7	3.4	1.55	10				
Se(gray)			6.6 (0.1 GHz)	−22.1	2.5	1.5		5			$P3_121$(152)
Te				−39.5	3.3	0.33	1700	1200			Same

TABLE 3. Semiconducting Properties of Selected Materials

Substance	Minimum energy gap (eV) R.T.	Minimum energy gap (eV) 0 K	$dE_g/dT \times 10^4$ eV/°C	$dE_g/dP \times 10^6$ eV·cm²/kg	Density of states electron effective mass m_{da} (m_o)	Electron mobility and temperature dependence μ_n (cm²/V·s)	Electron mobility and temperature dependence $-x$	Density of states hole effective Mass m_{dp} (m_n)	Hole mobility and temperature dependence μ_p (cm²/V·s)	Hole mobility and temperature dependence $-x$
Elements										
Si	1.107	1.153	−2.3	−2.0	1.1	1900	2.6	0.56	500	2.3
Ge	0.67	0.744	−3.7	+7.3	0.55	3800	1.66	0.3	1820	2.33
α–Sn	0.08	0.094	−0.5		0.02	2500	1.65	0.3	2400	2.0
Te	0.33				0.08	1100		0.19	560	
III-V Compounds										
AlAs	2.2	2.3				1200			420	
AlSb	1.6	1.7	−3.5	−1.6	0.09	200	1.5	0.4	500	1.8
GaP	2.24	2.40	−5.4	−1.7	0.35	300	1.5	0.5	150	1.5
GaAs	1.35	1.53	−5.0	+9.4	0.068	9000	1.0	0.5	500	2.1
GaSb	0.67	0.78	−3.5	+12	0.050	5000	2.0	0.23	1400	0.9
InP	1.27	1.41	−4.6	+4.6	0.067	5000	2.0		200	2.4
InAs	0.36	0.43	−2.8	+8	0.022	33,000	1.2	0.41	460	2.3
InSb	0.165	0.23	−2.8	+15	0.014	78,000	1.6	0.4	750	2.1
II-VI Compounds										
ZnO	3.2		−9.5	+0.6	0.38	180	1.5			
ZnS	3.54		−5.3	+5.7		180			5(400°C)	
ZnSe	2.58	2.80	−7.2	+6		540			28	
ZnTe	2.26			+6		340			100	
CdO	2.5 ± .1		−6		0.1	120				
CdS	2.4		−5	+3.3	0.165	400		0.8		
CdSe	1.74	1.85	−4.6		0.13	650	1.0	0.6		
GdTe	1.44	1.56	−4.1	+8	0.14	1200		0.35	50	
HgSe	0.30				0.030	20,000	2.0			
HgTe	0.15		−1		0.017	25,000		0.5	350	
Halite Structure Compounds										
PbS	0.37	0.28	+4		0.16	800		0.1	1000	2.2
PbSe	0.26	0.16	+4		0.3	1500		0.34	1500	2.2
PbTe	0.25	0.19	+4	−7	0.21	1600		0.14	750	2.2
Others										
ZnSb	0.50	0.56			0.15	10				1.5
CdSb	0.45	0.57	−5.4		0.15	300			2000	1.5
Bi_2S_3	1.3					200			1100	
Bi_2Se_3	0.27					600			675	
Bi_2Te_3	0.13		−0.95		0.58	1200	1.68	1.07	510	1.95
Mg_2Si		0.77	−6.4		0.46	400	2.5		70	
Mg_2Ge		0.74	−9			280	2		110	
Mg_2Sn	0.21	0.33	−3.5		0.37	320			260	
Mg_3Sb_2		0.32				20			82	
Zn_3As_2	0.93					10	1.1		10	
Cd_3As_2	0.55				0.046	100,000	0.88			
GaSe	2.05		−3.8						20	
GaTe	1.66	1.80	−3.6			14				
InSe	1.8					900				
TlSe	0.57		−3.9		0.3	30		0.6	20	1.5
$CdSnAs_2$	0.23				0.05	25,000	1.7			
Ga_2Te_2	1.1	1.55	−4.8							
α-In_2Te_2	1.1	1.2			0.7				50	1.1
β-In_2Te_2	1.0								5	
$Hg_5In_2Te_8$	0.5								11,000	
SnO_2									78	

TABLE 4. Band Properties of Semiconductors

4.1. Data on Valence Bands of Semiconductors (Room Temperature)

Substance	Band curvature effective mass (Expressed as fraction of free electron mass)			Energy separation of "split-off" band (eV)	Measured (light) hole mobility ($cm^2/V{\cdot}s$)
	Heavy holes	Light holes	"Split-off" band holes		
4.1.1. Semiconductors with Valence Band Maximum at the Center of the Brillouin Zone ("F")					
Si	0.52	0.16	0.25	0.044	500
Ge	0.34	0.043	0.08	0.3	1820
Sn	0.3				2400
AlAs					
AlSb	0.4			0.7	550
GaP				0.13	100
GaAs	0.8	0.12	0.20	0.34	400
GaSb	0.23	0.06		0.7	1400
InP				0.21	150
InAs	0.41	0.025	0.083	0.43	460
InSb	0.4	0.015		0.85	750
CdTe	0.35				50
HgTe	0.5				350

4.1.2. Semiconductors with Multiple Band Maxima

Substance	Number of equivalent valleys and direction	Band curvature effective masses		Anistrophy $K = m_L/m_T$	Measured (light) hole mobility ($cm^2/V{\cdot}s$)
		Longitudinal m_L	Transverse m_T		
PbSe	4 "L" [111]	0.095	0.047	2.0	1500
PbTe	4 "L" [111]	0.27	0.02	10	750
Bi_2Te_3	6	0.207	~0.045	4.5	515

4.2. Data on Conduction Bands of Semiconductors (Room Temperature Data)

4.2.1. Single Valley Semiconductors

Substance	Energy gap (eV)	Effective mass (m_o)	Mobility ($cm^2/V{\cdot}s$)	Comments
GaAs	1.35	0.067	8500	3(or 6?) equivalent [100] valleys 0.36 eV above this maximum with a mobility of ~50.
InP	1.27	0.067	5000	3(or 6?) equivalent [100] valleys 0.4 eV above this minimum.
InAs	0.36	0.022	33,000	Equivalent valleys ~1.0 eV above this minimum.
InSb	0.165	0.014	78,000	
CdTe	1.44	0.11	1000	4(or 8?) equivalent [111] valleys 0.51 eV above this minimum.

4.2.2. Multivalley Semiconductors

Substance	Energy gap	Number of equivalent valleys and direction	Band curvature effective mass		Anisotropy $K = m_L/m_T$
			Longitudinal m_L	Transverse m_T	
Si	1.107	6 in [100] "Δ"	0.00	0.192	4.7
Ge	0.67	4 in [111] at "L"	1.588	0.0815	19.5
GaSb	0.67	as Ge (?)	~1.0	~0.2	~5
PbSe	0.26	4 in [111] at "L"	0.085	0.05	1.7
PbTe	0.25	4 in [111] at "L"	0.21	0.029	5.5
Bi_2Te_2	0.13	6			~0.05

TABLE 5. Resistivity of Semiconducting Minerals

Mineral	ρ (ohm · m)	Mineral	ρ (ohm · m)
Diamond (C)	2.7	Pentlandite, $(Fe, Ni)_4S_4$	1 to 11×10^{-6}
Sulfides		Pyrrhotite, Fe_7S_4	2 to 160×10^{-6}
Argentite, Ag_2S	1.5 to 2.0×10^{-3}	Pyrite, FeS_2	1.2 to 600×10^{-3}
Bismuthinite, Bi_2S_3	3 to 570	Sphalerite, ZnS	2.7×10^{-3} to 1.2×10^{4}
Bornite, $Fe_2S_3 \cdot nCu_2S$	1.6 to 6000×10^{-6}	Antimony-sulfur compounds	
Chalcocite, Cu_2S	80 to 100×10^{-6}	Berthierite, $FeSb_2S_4$	0.0083 to 2.0
Chalcopyrite, $Fe_2S_3 \cdot Cu_2S$	150 to 9000×10^{-6}	Boulangerite, $Pb_5Sb_3S_{11}$	2×10^3 to 4×10^4
Covellite, CuS	0.30 to 83×10^{-6}	Cylindrite, $Pb_3Sn_4Sb_2S_{14}$	2.5 to 60
Galena, PbS	6.8×10^{-6} to 9.0×10^{-2}	Franckeite, $Pb_5Sn_3Sb_2S_{14}$	1.2 to 4
Haverite, MnS_2	10 to 20	Hauchecornite, $Ni_4(Bi, Sb)_2S_{14}$	1 to 83×10^{-6}
Marcasite, FeS_2	1 to 150×10^{-3}	Jamesonite, $Pb_4FeSb_6S_{14}$	0.020 to 0.15
Metacinnabarite, HgS	2×10^{-6} to 1×10^{-3}	Tetrahedrite, Cu_3SbS_3	0.30 to 30,000
Millerite, NiS	2 to 4×10^{-7}	Arsenic-sulfur compounds	
Molybdenite, MoS_2	0.12 to 7.5	Arsenopyrite, FeAsS	20 to 300×10^{-6}

Cobaltite, CoAsS	$6.5 \text{ to } 130 \times 10^{-3}$
Enargite, Cu_3AsS_4	$0.2 \text{ to } 40 \times 10^{-3}$
Gersdorfite, NiAsS	$1 \text{ to } 160 \times 10^{-6}$
Glaucodote, (Co, Fe)AsS	$5 \text{ to } 100 \times 10^{-6}$
Antimonide	
Dyscrasite, Ag_3Sb	$0.12 \text{ to } 1.2 \times 10^{-6}$
Arsenides	
Allemonite, $SbAs_3$	70 to 60,000
Lollingite, $FeAs_2$	$2 \text{ to } 270 \times 10^{-6}$
Nicollite, NiAs	$0.1 \text{ to } 2 \times 10^{-6}$
Skutterudite, $CoAs_3$	$1 \text{ to } 400 \times 10^{-6}$
Smaltite, $CoAs_2$	$1 \text{ to } 12 \times 10^{-6}$
Tellurides	
Altaite, PbTe	$20 \text{ to } 200 \times 10^{-6}$
Calavarite, $AuTe_2$	$6 \text{ to } 12 \times 10^{-6}$
Coloradoite, HgTe	$4 \text{ to } 100 \times 10^{-6}$
Hessite, Ag_2Te	$4 \text{ to } 100 \times 10^{-6}$
Nagyagite, $Pb_6Au(S,Te)_{14}$	$20 \text{ to } 80 \times 10^{-6}$
Sylvanite, $AgAuTe_4$	$4 \text{ to } 20 \times 10^{-6}$
Oxides	
Braunite, Mn_2O_3	0.16 to 1.0
Cassiterite, SnO_2	4.5×10^{-4} to 10,000
Cuprite, Cu_2O	10 to 50
Hollandite, (Ba, Na, K) Mn_8O_{16}	$2 \text{ to } 100 \times 10^{-3}$
Ilmenite, $FeTiO_3$	0.001 to 4
Magnetite, Fe_3O_4	52×10^{-6}
Manganite, $MnO \cdot OH$	0.018 to 0.5
Melaconite, CuO	6000
Psilomelane, $BaMn_9O_{18} \cdot 2H_2O$	0.04 to 6000
Pyrolusite, MnO_2	0.007 to 30
Rutile, TiO_2	29 to 910
Uraninite, UO_2	1.5 to 200

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