II-VI Crystals

CdS, CdTe, ZnS, ZnSe, ZnTe

(Data apply to high-resistivity, nearly intrinsic material at room temperature unless otherwise noted)

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Items below marked with an asterisk * are shown for reference only and are not currently available from CCI.

	CdS	CdSe	CdTe*	ZnS (Hex)[a]*	ZnS (Cub)*	ZnSe*	ZnTe*
Micron range of >50% transmission (2mm xtal)	0.53 - 15[41]	0.8 - 18	1 - 28	---	0.4 - 14	0.5 - 19	0.6[9] - 25
Absorption coeff. @10.6µm (cm^{-1})	0.01	0.001	[13]	---	---	0.005	0.008
Index of refraction[b]							
	---	---	---	---	2.4208[5]	2.750[52]	---
0.55µm n_o n_e	2.580 2.593[46]	---	---	---	---	2.655[6] 2.670[52]	---
0.589µm n_o n_e	2.525[2]	---	---	2.356 2.378[4]	2.369[4]	2.625[52]	3.054[9]
n_o n_e	2.465 2.483[46]	---	---	---	2.3523[5]	[52]	2.984[9]
0.70µm n_o n_e	2.414 2.432[46]	---	---	---	2.333[5]	---	2.913[9]
0.80µm n_o n_e	2.377 2.394[46]	2.6448 2.6607[5]	---	---	2.3146[5]	---	2.853[9]
1.00µm n_o n_e	2.336 [46]	2.5502 2.5696[5]	2.84[3]	---	2.2932[5]	2.48[3]	2.790[9]
1.40µm n_o	2.304 2.321[46]	2.4929 2.5133[5]	---	---	2.2762[5]	---	2.741[9]

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	CdS	CdSe	CdTe*	ZnS (Hex)[a]*	ZnS (Cub)*	ZnSe*	ZnTe*
n_e							
3.39µm n_o n_e	2.2747 2.2907[2]	2.4562 2.4754[2][d]	---	---	---	---	---
10.6µm n_o n_e	2.226 2.239[2]	2.430 2.448[2][d]	2.6708[50]	---	---	2.392[7] 2.407[51]	2.70[8]
1/n dn/dT RT(10^{-5}/°C)							
0.69µm	10.11	---	---	---	---	---	---
1µm o-ray e-ray	---	12 12	---	---	---	2.655[6] 2.670[52]	---
10.6µm o-ray e-ray	6.0 6.2[48]	---	9.8[49]	---	4.6[49]	5.2[49]	---
Electro-Optic Constants							
r_{41}^T(pm/V) Halfwave Voltage(kV) Wavelength(µm)	---	---	4.5[10] 5 1.0	---	-1.5 9.4 0.436	1.9[54] 9.45 0.633	4.51[9] 2.3 0.589
r_{41}^T(pm/V) Halfwave Voltage(kV) Wavelength(µm)	---	---	6.8[8] 42 10.6	---	-2.1 10.7 0.589	1.9[54] 200 10.6	3.9[10] 69 10.6
r_{41}^S(pm/V) Wavelength(µm)	---	---	---	---	1.6 0.633	2.0[8] 0.633	4.3[8] 0.633
r_{41}^S(pm/V) Wavelength(µm)	---	---	---	---	1.4 3.39	---	---
r_{51}^T(pm/V) Wavelength(µm)	1.6[44] 0.633	---	---	---	---	---	---
r_{13}^T(pm/V) Wavelength(µm)	3.1[44] 1.15	---	---	---	---	---	---
r_{13}^S(pm/V) Wavelength(µm)	1.1[43] 0.633	1.8[43] 3.39	---	0.92[43.45] 0.633	---	---	---

	CdS	CdSe	CdTe*	ZnS (Hex)[a]*	ZnS (Cub)*	ZnSe*	ZnTe*
r_{33}^T(pm/V) Wavelength(µm)	3.2[44] 1.15	1.6[53] 0.8	---	---	---	---	---
r_{33}^S(pm/V) Wavelength(µm)	2.4[43] 0.633	4.3[43] 3.39	---	-1.85[43.45] 0.633	---	---	---
r_c^T(pm/V) Wavelength(µm)	4.8[44] 0.633	---	---	---	---	---	---
r_c^T(pm/V) Wavelength(µm)	5.5[43] 10.6	---	---	---	---	---	---
NLO Susceptibility (pm/V) [8,54]							
d_{14} @28µm	---	---	60	---	---	---	---
d_{14} @10.6µm [f]	---	---	---	---	30	80	90
d_{33} @10.6µm [f]	44 ±13	44 ±13	55 ±13	37 ±13	---	---	---
d_{31} @10.6µm [f]	-26 ±6	-29 +/6	---	-19 ±6	---	---	---
d_{15} @10.6µm [f]	29 ±7	31 ±8	---	21 ±8	---	---	---
d_{14} @1.06µm	---	---	---	---	25	103	108
d_{33} @1.06µm	100	---	---	44	---	---	---
d_{31} @1.06µm	-16 ±1	---	---	-9 ±2	---	---	---
d_{15} @1.06µm	17 ±1	---	---	8 ±1	---	---	---
Piezo-Optic Constants(pm^2/N)							
q_{11} @10.6µm	---	---	-5.91 ±0.21[14]	---	---	---	---
q_{12} @10.6µm	---	---	2.22 ±0.08[14]	---	---	---	---
q_{44}	---	---	-2.85 ±0.33[14] (10.6µm)	---	-1.70 @0.6µm[55]	-1.45 @0.63µm[55]	-1.62 @0.7µm[55]
Pulsed Damage Threshold (MW/cm^2)	---	60[2]	---	---	---	---	---
Structure type[16]	Heaxagon	Heaxagon	Cubic	Heaxagon	Cubic	Cubic	Cubic

	CdS	CdSe	CdTe*	ZnS (Hex)[a]*	ZnS (Cub)*	ZnSe*	ZnTe*
	al Wurtzite	al Wurtzite	Sphalerite	al Wurtzite	Sphalerite	Sphalerite	Sphalerite
Space Group[16]	P6mc	P6mc	F 3m	P6mc[a]	F 3m	F 3m	F 3m
Wurtzite Parameter u (ideal=0.375)[17]	0.378	0.377	---	0.374	---	---	---
Lattice Constants Å, 25°C	Ref (18)	Ref (18)		Ref (19)	Ref (20)		
a_o c_o	4.1367 ±0.0003 6.7161 ±0.0005	4.2972 ±0.0003 7.0064 ±0.0005	6.4830 ±0.0004 ------ ------	3.8218 ±0.0004 6.25875 ±0.0001	5.4094 ±0.0002 ------ ------	5.6687 ±0.0003 ------ ------	6.1034 ±0.0003 ------ ------
Calc'd Density g/cc, 25°C	4.819	5.670	5.849	4.087	4.088	5.262	5.636
Cleavage	---	---	[110]	[11 0] [10 0]	[110]	[110]	[110]
Thermal Expansion (10^{-6}/°C) Perp. to c Along c Temp range°C	---	---	4.5[21] --- 50	6.5[22] 4.6[22] 25	5.9 --- 25-100	7.1[7] --- 29	8.36 --- 25-100
Thermal Conductivity (W/cm/°C), 25°C	---	---	0.06	---	---	0.19[56]	--
Heat Capacity (J/mole/°C)	---	---	54[40]	---	47[24]	51[40]	51
Melting Point,°C	1397 ±2[18]	1258 ±2[18]	1097 ±2	1718 ±10[25]	---	1526 ±10[25]	1292 ±5
Flexural Strength (psi)	~4000	~3000	~3000	~10000	---	~8500	~3500
Estimated max. safe operating temp,°C	---	---	>200	>200	>200	>200	>200
Dark resistivity							

	CdS	CdSe	CdTe*	ZnS (Hex)[a]*	ZnS (Cub)*	ZnSe*	ZnTe*
(ohm-cm)							
Typical As-Grown	~2000	~2000	~1000	---	10^8	10^8	~10
Max. (compensated)	$>10^9$	$>10^9$	$>10^7$	---	10^9-10^{10}[11]	10^8-10^9[23]	10^8-10^9
Minimum	$<10^{-2}$	$<10^{-2}$	$<10^{-2}$	---	---	$<10^{-1}$	<10
Type	n	n	p or n	p	p	n	p
Hall Mobilties (cm^2/V-sec) (highest measured)							
300°K	350(e)	650(e)	1000(e)	---	100(e)	400(e)	130(h)
80°K	5200(e)	5000(e)	10000(e)	---	---	5000(e)	2600(h)
Energy Gap(eV)300°K	2.42[28]	1.72[29]	1.44[39]	---	---	2.7	2.23[32]
dE_G/dT (eV/°K)	-5E-4[27]	-4E-4[30]	---	3.6	---	---	-5.5E-4[32]
Effective carrier mass							
Electrons	$0.205m_e$[33]	$0.130m_e$	$0.11m_e$	$0.27m_e$	---	$0.17m_e$	---
Holes	$2.1m_e$[33]	$0.7m_e$	$0.63m_e$	---	---	---	$0.6m_e$
Sound velocities,25°C(m/s)							
Longitudinal Waves							
propagation along c particle motion along c	4470	3860	---	---	---	---	---
propagation perp. to c particle motion perp. to c	4340	3610	3020	---	5060	4040	3560
Transverse Waves							

	CdS	CdSe	CdTe*	ZnS (Hex)[(a)*]	ZnS (Cub)*	ZnSe*	ZnTe*
propagation along c particle motion perp. to c	1770	1520	1850	---	3360	2780	2350
propagation perp. to c particle motion along to c	1800	1530	---	---	---	---	---
propagation perp. to c particle motion perp. to c	1700	1590	---	---	---	---	---
Relative dielectric constant 25°C[(34)]							
$_{33}^{T}/\ _{o}$	10.33	10.65	---	8.00[(41)]	---	---	---
$_{11}^{T}/\ _{o}$	9.35	9.70	11.0[(39)]	8.58[(41)]	8.37	9.25[(39)]	10.10
$_{33}^{T}/\ _{o}$	9.53	10.20	---	---	---	---	---
$_{11}^{T}/\ _{o}$	9.02	9.53	---	---	8.32	9.12	10.10
Piezoelectric Coefficients,25°C							
d_{31} (pC/N)	-5.18	-3.92	---	-1.1[(12)]	---	---	---
d_{33} (pC/N)	10.32	7.87	---	3.2[(12)]	---	---	---
d_{15} (pC/N)	-13.98	-10.51	---	-2.8[(12)]	---	---	---
d_{14} (pC/N)	---	---	1.54	---	3.18	1.10	0.91
d_h (pC/N)	0.0	0.0	---	1.1[(12)]	---	---	---
e_{31} (C/m^2)	-0.244	-0.160	---	0.10[(26)]	---	---	---
e_{33} (C/m^2)	0.440	0.347	---	0.35[(26)]	---	---	---
e_{15} (C/m^2)	-0.210	-0.138	---	-0.08[(26)]	---	---	---
e_{14} (C/m^2)	---	---	~0.304	---	0.147	0.049	0.0284
Piezoelectric Coupling Factors[(34)]							
k_{33}	0.262	0.194	---	0.127[(12)]	---	---	---
k_{31}	0.1191	0.0836	---	0.039[(12)]	---	---	---

	CdS	CdSe	CdTe*	ZnS (Hex)[a]*	ZnS (Cub)*	ZnSe*	ZnTe*
k_{15}	0.1885	0.1305	---	0.052[12]	---	---	---
k_t	0.154	0.124	---	---	---	---	---
k_{14}	---	---	~0.023	---	0.0795	0.026	0.017
Elastic Constants[34] ($10^{-11}m^2/N$)							
s_{11}^E	2.069	2.338	---	---	1.839	2.26	2.40
s_{33}^E	1.697	1.735	---	---	---	---	---
s_{12}^E	-0.999	-1.122	---	---	-0.707	-0.85	-0.873
s_{13}^E	-0.581	-0.572	---	---	---	---	---
s_{44}^E	6.649	7.595	---	---	2.168	2.27	3.21
s_{66}	6.136	6.920	---	~3.12?[35]	---	---	---
s_{11}^D	2.040	2.322	---	~1.10?[35]	---	---	---
s_{33}^D	1.581	1.670	---	~0.85?[35]	---	---	---
s_{12}^D	-1.028	-1.138	---	~ -0.46[35]	---	---	---
s_{13}^D	-0.523	-0.539	---	~ -0.21[35]	---	---	---
s_{44}^D	6.412	7.466	---	~3.51[35]	2.154	2.27	3.21
c_{11}^E	9.07	7.41	5.351[36]	---	10.46	8.59[37]	7.13
c_{33}^E	9.38	8.36	---	---	---	---	---
c_{12}^E	5.81	4.52	3.681[36]	---	6.53	5.06(37)	4.07
c_{13}^E	5.10	3.93	---	---	---	---	---
c_{44}^E	1.504	1.317	1.994[36]	---	4.613	4.06[37]	3.12
c_{66}	1.630	1.445	---	~3.2[35]	---	---	---
c_{11}^D	9.13	7.42	---	~12.4[35]	---	8.59[37]	---
c_{33}^D	9.623	8.477	---	~14.0[35]	---	---	---
c_{12}^D	5.888	4.53	---	~6.0[35]	---	5.06[37]	---
c_{13}^D	4.97	3.86	---	~4.5[35]	---	---	---
c_{44}^D	1.560	1.340	---	~2.85[7]	4.643	4.06[37]	3.12

We have attempted to be as accurate as possible in gathering data and noting sources, but no guarantees can be made. In general, non-referenced data was internally generated, but it is possible that errors may appear. Apologies are offered to anyone whose data are miscredited. Any suggestions for corrections or additions will be considered for the next revision.

Mixed crystals are available in the systems CdS-CdSe, with properties intermediate between the end members. Inquiries are welcomed. Other mixed crystals are occasionally available, but are more difficult to grow due to lattice and volatility mismatch.

FOOTNOTES

(a) Much of the data in the literature on the "hexagonal" form of ZnS is on polytypes that vary only slightly in bulk properties from the cubic form, although such is frequently not disclosed. We have attempted to evaluate the data on the internal evidence to eliminate those which obviously do not apply to pure wurtzite. The attempt may not have been completely successful. Examples of information on polytypes may be found in reference 12, and refernce 8. The data on the cubic form of ZnS are usually on material which is free of polytypes.

(b) Refernces 15 and 50 give formulae for calculating indicies of refraction vs. wavelength for CdSe and CdTe. Cleveland Crystals has determined single resonance dispersion curve-fits to existing data for ZnS and ZnSe and ZnTe. Contact us for more information.

(c) Claculated values.

(d) Indicies of refraction of uncompensated crystals tend to be lower.

(e) See refernence 49.

(f) These values are taken from two refernces (8 and 54), so may not be completely self-consistent.

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