Silver Gallium Sulfide and Silver Gallium Selenide

(Table of Material Properties appears below)

$AgGaSe_2$ (AGSe) has been demonstrated to be an efficient frequency doubling crystal for infrared radiation such as the 10.6μm output of CO_2 lasers(11). It has also been shown to be an excellent crystal for nonlinear three-wave interactions. With suitable pump lasers, AGSe optical parametric oscillators (OPS's) can produce continuously tunable radiation over a wide range of wavelengths in the infrared. Using a 2.05μm pump laser, an optimally designed AGSe OPO is tunable from about 2.5 to 12μm (26). The output range can be extended by sum or difference frequency mixing (SFM/DFM). Residual e ray absorption centered at 2.1μm may limit average power handling.

This crystal has a high nonlinear coefficient, high damage threshold, and a wide transmission range. It also has low optical absorption and scattering and low wavefront distortion. Among commercially available crystals, AGSe has the highest figure of merit for nonlinear interactions in the near and deep infrared. The availability of this crystal has stimulated new activities exploiting its many interesting properties. Potential applications include wavelength selectable medical procedures, LIDAR, a solid-state equivalent of an IR dye laser, and a wide variety of spectroscopic applications. It is useful for high performance IR waveplates.

A closely related crystal, $AgGaS_2$ (AGS), is also available. Its bulk quality is excellent across the transmission range, except for residual e ray absorption centered around 1.8μm. Surface absorption may increase with time, but the behavior is now greatly improved over that of earlier crystals. The phasematching and nonlinear optical properties of AGS allow various SFM/DFM interactions from the visible to mid-IR. these include non-critically phase matched DFM using selected wavelengths (available from tunable dye and Ti:sapphire lasers) and OPO's pumped with commonly available Nd:YAG lasers.

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Properties of $AgGaSe_2$ and $AgGaS_2$[a]

	$AgGaS_2$ (AGS)	$AgGaSe_2$ (AGSe)
Crystal Data		
Structure type[1]	Chalcopyrite	Chalcopyrite
Crystal Symmetry and Class	Tetragonal, 2m	Tetragonal, 2m
Space Group	I 2d	I 2d
Lattice Constants (angstroms)	a=5.7566 +/-0.0008 c=10.3016 +/-0.0013	a=5.99202 +/-0.0018[2] c=10.88626 +/-0.0003[2]
Density, g/cc	4.702	5.700
Cleavage	(112) good	(112) good
Optical Properties		
Optical Transmission (um)[3] **<3cm^{-1}**	0.50 to 13.2	0.78 to 18.0
Energy Gap(eV),Absorption edge(um)		
E perpendicular to c	2.655, 0.467[21]	1.713, 0.724
E parallel to c	2.572, 0.482[22]	1.689, 0.734
Indices of refraction at (um)	n_o[4], n_e[4]	n_o[5], n_e[5]
0.589	2.5834, 2.5406	---
1.064	2.4521, 2.3990	2.7010, 2.6792
3.0	2.4080, 2.3545	2.6245, 2.5925
5.3	2.3945, 2.3408	2.6134, 2.5808
10.6	2.3472, 2.2934	2.5912, 2.5579
12.0	2.3266, 2.2716	---
13.5	---	2.5731, 2.5404
Wavelength where n_o=n_e, um	0.4974[6]	0.811[12]
dn/dT, 10^{-6}/°C		
1.06um	dn_o/dT= 167 dn_e/dT= 176	dn_o/dT= 98[c] dn_e/dT= 66[c]
3.39um	dn_o/dT= 154 dn_e/dT= 155	dn_o/dT= 74 +/-10[30] dn_e/dT= 43 +/-10[30]
10.6um	dn_o/dT= 149[c]	dn_o/dT= 58[c]

	dn_e/dT= 156[c]	dn_e/dT= 46[c]
$d(n_e^2 - n_o)/dT$ @ pm for type I SHG 10.6um	---	+/- 1.1[9], -1.2[c]
Fresnel Refection Loss per surface		
1.06um	17%	21%
10.6um	16%	19%
Absorption Coeff. (cm^{-1})[g]		
1.06um (random)	< 0.01	< 0.02
1.8um (e ray)	< 0.10	< 0.02
2.1um (e-ray)	< 0.02	< 0.05
10.6um (random)	0.6[b]	< 0.02
Laser Damage Threshold[g,h]		
1.06um, ~10ns pulse (MW/cm^2)	sfc 25; bulk >500	sfc 25
2.09um, ~50ns pulse (J/cm^2)[25]	---	sfc 0.5-3.0
10.6um, ~10ns pulse (MW/cm^2)[25]	---	sfc 20-30
10-20ns pulse (J/cm^2)[25]	---	sfc 0.1-0.2; bulk ~0.2
200ns pulse (J/cm^2)[31]	---	sfc ~1
NLO Susceptibility d_{36}, pm/V		
SHG at 1.064um	17.5[28]	---
SHG at 10.6um	11.2[28]	33[28]
Phasematching Range (,um)		
Type I SHG	1.8 to 11.2[4]	3.1 to 12.8[5]
Type II SHG	2.5 to 7.7[4]	4.7 to 8.1[5]
Phasematching Angle 10.6um Type I SHG	71.5 [4]	57.0 [c]
Birefringence Walkoff @5.3um	0.76 [27,c]	0.67 [11]
Pockels Coeffs. (Linear Electro-Optic)		
r_{41}^T (pm/V)	4.0 +/-0.2[10]	4.5 at 1.15um[12]
r_{63}^T (pm/V)	3.0 +/-0.1[10]	3.9 at 1.15um[12]
Optical Gyration Coeff. (10^{-3} deg)		
0.4974um	3.88[6]	---
0.5045um	3.63[13]	---
Electrogyration Coeff	2.03[14]	---

$_{41}(10^{-12})$ at 0.498um		
Mechanical Properties		
Elastic Compliances, (TPa^{-1})[10,29]		
s_{11}	26.2	26.6
s_{12}	-7.7	-14.9
s_{13}	-14.5	-9.1
s_{33}	35.9	31.4
s_{44}	41.5	46.1
s_{66}	32.5	75.2
Young's Modulus, $1/s_{11}^E$(GPa)	38.2	37.6
Poisson's Ratio, $-s_{12}/s_{11}$	0.29	0.56
Elastic Stiffnesses, (GPa)[10,29]		
c_{11}	87.9	89.8
c_{12}	58.4	65.7
c_{13}	59.2	45.1
c_{33}	75.8	58.0
c_{44}	24.1	21.7
c_{66}	30.8	13.3
Thermal Properties		
Melting point (°C)	997	851[11]
Thermal Expansion Coeff.(10^{-6}/°C)		
Along c axis	12.5[15]	16.8[16]
Perpendicular to c axis	-13.2[15]	-7.8[16]
Phase transitions	none >RT	none >RT
Heat Capacity (J/mole/°C)	99.8[17]	97 +/-5
Specific Heat (J/cc/°C)	1.9	1.7
H_{melt} (KJ/mole)	53.6[18]	58.6[18]
Thermal Conductivity (W/cm/°C) (nearly isotropic)	0.015	0.011
Electrical Properties		
Typical dark Resistivity (ohm-cm)	$>10^{11}$	$>10^{10}$

Relative dielectric constant @25MHz		
$_{11}^{S}/\ _{o}$	10[10]	10.5[7]
$_{33}^{S}/\ _{o}$	14[10]	12.0[7]
Piezoelectric Coefficients, (pC/N)		
d_{14}	+ [10]	9.0[7]
d_{36}	+ [10]	3.7[7]
Electromechanical Coupling Factors		
k_{14}	---	0.098[7]
k_{36}	---	0.040[7]
	;	;

Footnotes

a) Unreferenced data were determined at Cleveland Crystals, Inc.

b) AGS has a high transmission to 8.3um.

c) Calculated from a combination of Cleveland Crystals data, and data referenced herein.

d) The indicies of refraction for AGS[4] were fitted to Sellmeier equations after ref.(24)

e) The indicies of refraction for AGSe[5] were fitted to Sellmeier equations after ref.(27)

f) Calculated value.

g) Recent experimental data, subject to change with crystal development.

h) NOTE: All damage threshold information is provided as a guide **only**. NO warranty, expressed or implied, is made with regard to damage threshold. Users are encouraged to establish safe operating conditions for their laser system components.

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