Germanium

Among other materials for IR applications Tydex uses Germanium showing good transmission in 2-15 µm range. Due to high refractive index Ge lenses became very useful components of IR imaging systems operating in both "atmosphere windows": 3-5 and 8-12 microns.

Both monocrystalline and polycrystalline Ge may be used for manufacturing of optical components. We produce Germanium lenses and windows for infrared thermal imaging applications and pyrometry (see our webpage Germanium windows and lenses for thermography). Also such components for spectroscopy as ATR prisms, detector windows, and IR Polarizers are available.

Ge is also good electromagnetic interference (EMI) shielding material. Its special grade called EMI for its ability to shield against electromagnetic interference has become increasingly important for modern military applications where other signals (within millimeter and centimeter range) can be strong enough to make nearby IR systems ineffective. Typical resistance for EMI grade Germanium is about 4 Ohm x cm but it depends on required level of spurious signal suppression. Using Ge window with such resistance these signals are effectively shorted out and the IR system shows good performance.

Below you can find list of main properties of Germanium as well as its transmission and absorption spectra.

Tab. 1. Physical properties of Germanium

Atom number	32
Atom weight	72.6
Crystal structure	diamond cubic
Lattice constant at 25°C, A	5.657
Density (298 K), g/cm^3	5.323
Atomic density, atoms/cm^3	4.42×10^{22}
Surface tension, liquid at melting point, mN/m	650
Modulus of rupture, MPa PSI	72.4 1.05×10^4
Mohs hardness	6
Vickers hardness, 25 gm load, kg/mm^2	746 (52 Ohm x cm)
Fracture toughness, MPa$^{1/2}$	1.004 (110 fracture plane)
Thermal shock resistance, °C	125
Poisson's ratio , 125-375 K	0.278
Elastic constants, 25°C, cm^2/dyne	S11 = 9.685×10^{-13} S12 = -2.70×10^{-13} S44 = 14.94×10^{-13}
Elastic coefficients, 25°C, dynes/cm^2	C11 = 13.16×10^{11} C12 = 5.09×10^{11} C44 = 6.69×10^{11}
Young's modulii, 25°C, dynes/cm^2	Y100 = 10.33×10^{11} Y110 = 13.80×10^{11} Y111 = 15.55×10^{11}
Shear modulii, 25°C, dynes/cm^2	M100 = 6.69×10^{11} M100 = 4.1×10^{11} M111 = 4.9×10^{11}

Tab. 2. Thermal properties of Germanium

Melting temperature, °C		937
Boiling temperature, °C		2830
Specific thermal capacity (0-100°C), kal/g x degree°C		0.074
Latent heat of fusion:	kal/mol	8100
	J/g	466.5
Latent heat of vaporization, J/g		4602
Coefficient of linear thermal expansion (293 K), cm/degree		6.1×10^{-6}
Heat capacity, 25°C, J/(kg x K)		322

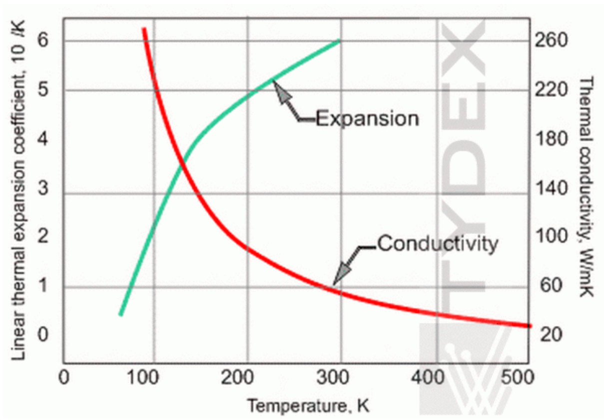

Fig. 1. Linear thermal expansion coefficient and thermal conductivity of Germanium vs temperature.

Tab. 3. Electronic properties of Germanium

Band gap, direct (300 K), eV		0.67
Intrinsic carriers concentration (300 K), cm^{-6}		p, n=5.5×10^{26}
Intrinsic drift mobility (300 K), cm^2/vs:	electrons	3800
	holes	1820
Diffusion coefficient (300 K), cm^2/sec:	electrons	101
	holes	49
Intrinsic resistivity (300 K), Ohm x cm		52
Number of intrinsic electrons, cm^{-3}		2.12×10^{13}
1 Ohm x cm (n-type) is equal to, 10^{15}/cm^{-3}		1.1
1 Ohm x cm (n-type) is equal to, 10^{15}/cm^{-3}		2.3

Tab. 4. Chemical properties of Germanium

Solubility	
In water at 20°C, g/100cm^3	insoluble
In acids	soluble

Thickness of Germanium window required to withstand pressure differential at opposite sides may be calculated by the following equation:

Thk = $\sqrt{(}$ 1.1 x P x r^2 x SF/MR),

where:

P = Pressure difference (PSI),

r = Unsupported radius (mm),

SF = Safety factor (4 to 6) (suggested range, may use other factors),

MR = Modulus of rupture (PSI).

For example window with diameter 100 mm and unsupported radius 45 mm used in environment with pressure differential of 1 atmosphere should have thickness of ~4.0 mm (safety factor 5).

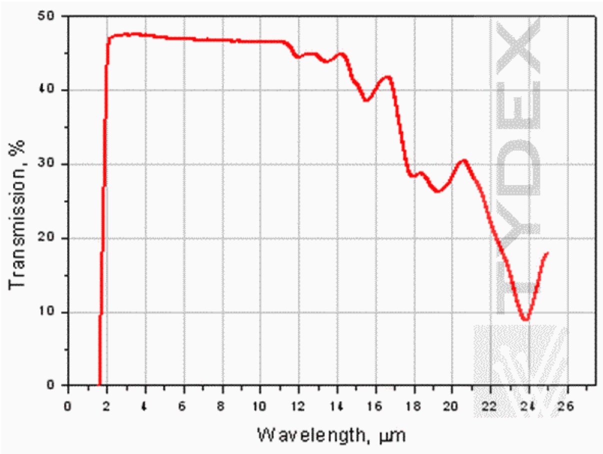

Fig. 2. Typical optical grade Germanium transmission (sample thickness – 2 mm).

Germanium exhibits low absorption of infrared radiation in wavelength range of 2 to 12 µm. The band gap of 0.67 eV in Germanium is responsible for the increase in absorption in the short wavelength range. The lattice (phonon) absorption bands are responsible for the long wavelength absorption.

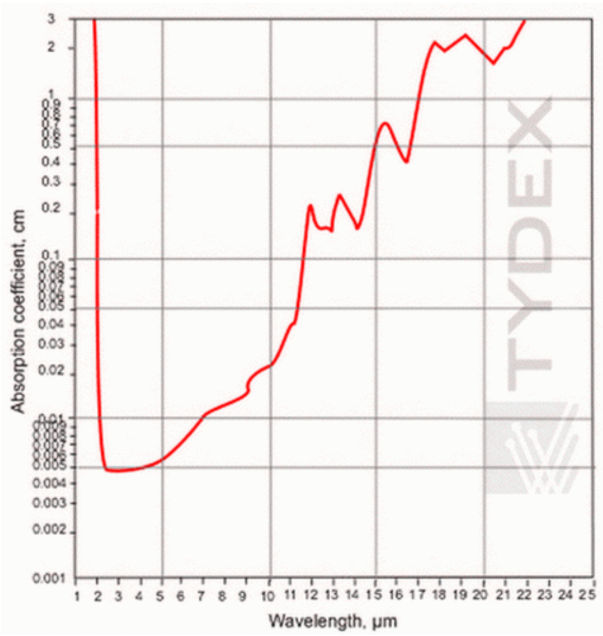

Fig. 3. Typical Germanium coefficient of absorption.

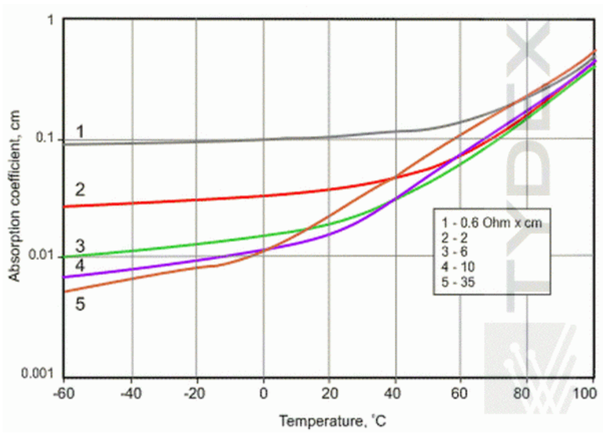

Fig. 4 Absorption vs temperature at 10.6 micron.

At high temperature optical grade germanium is subject to excessive absorption due to increased number of thermally generated holes. As it can be seen from spectra absorption growth becomes important at temperatures over about 45°C.

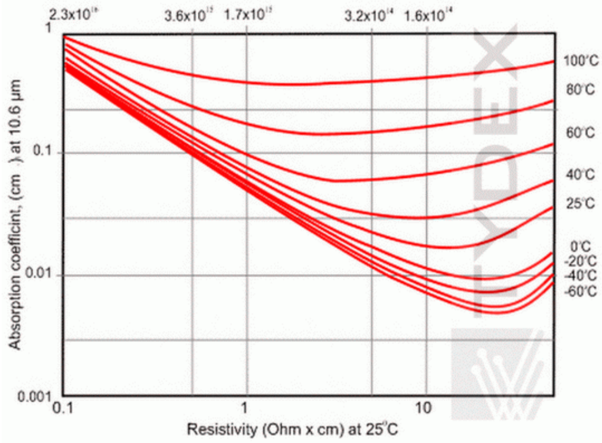

Fig. 5. Absorption vs resistivity of Germanium.

Free carrier (electron and hole) absorption and lattice (phonon) absorption account for the IR absorption in the optical range. Holes in Ge absorb more energy than electrons in this range. For nearly electrically neutral Ge, number of holes times number of electrons is constant. The number of holes present can be reduced by increasing the number of electrons by the addition of group V atoms (donors) to the Ge. This lowers resistivity. Excessive addition of donors leads to excessive electron concentration and increased absorption.

Tab. 5. Refractive index of Germanium.

λ, µm	n(λ)	λ, µm	n(λ)	λ, µm	n(λ)
2.0	4.1079	9.5	4.0056	12.3	4.0038
2.5	4.0653	10.0	4.0052	12.7	4.0036
3.0	4.0446	10.6	4.0048	13.0	4.0035
4.0	4.0255	11.0	4.0045	13.3	4.0034
5.0	4.0170	11.3	4.0043	14.0	4.0032
6.0	4.0122	11.5	4.0042	14.1	4.0031
7.0	4.0092	11.7	4.0041	15.0	4.0029
8.0	4.0074	11.9	4.0040	15.6	4.0027
8.5	4.0067	12.0	4.0039	16.0	4.0026
9.0	4.0061				

Usually material with the following properties is used for optical component manufacturing:

Tab. 6.

Orientation	111
Orientation deviation, arc.deg.	<= 2
Conductivity type	n
Specific resistance, Ohm x cm	5 - 40
Refractive index inhomogeneity, Δn	<= 2 x 10^{-4}
Dislocations density, cm^{-2}	<= 1 x 10^{4}
Transmission of 1 mm thick sample, %	>= 46.8 at 10.6 µm > 46 from 2.5 to 11 µm
Internal scattering coefficient at 2.5 µm, %	<= 5

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Different shapes of optical components are available – spherical, elliptical, rectangular, plano-plano, plano-convex/concave, meniscus, wedges, rods. Overall dimensions available – from 2 mm to 250 mm for monocrystal and to 300 mm for polycrystal.

Please pay attention that this article is only for your information. We do not supply Germanium in blanks or as raw material. Our standard products are finished (polished, coated) parts.

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