

# Sapphire Products

## Properties and Benefits



Sapphire ( $Al_2O_3$ ) is produced commercially throughout the world and has many industrial uses. Its optical, electrical, chemical, mechanical, and nuclear properties, as described in this brochure, make it an ideal material for hundreds of applications. Frequently it is the combination of two or more properties that make sapphire the only material available to solve complex engineering design problems.

Our engineers can help you determine whether sapphire can solve your particular challenges and if so, help you implement the solution.

### The EFG Process

Saint-Gobain manufactures sapphire products in various sizes and shapes using a proprietary continuous crystal growing process known as EFG (Edge defined Film fed Growth).

Saint-Gobain's patented EFG Process yields "grown-to-shape" material. Most other growth processes form ingots, of various size, which must then be cut to shape by highly skilled workers using expensive diamond impregnated tooling.

With the EFG Process, Saint-Gobain grows tubes, rods and ribbons. Often these can be used "as-grown" and are therefore the most cost effective sapphire parts available anywhere in the world. If machining is required to achieve close dimensional tolerances, or special surface finishes, the cost is kept to a minimum by starting with an EFG-grown blank of "near-net-shape."

### Sapphire Sheet

Crystallographic Orientation: A-Plane (1120) as shown in figure 1.

Special orientation, thickness, polishing and specifications, available upon request

Standard available sheet product features include:

- Unpolished, "As Grown", thickness from .060" to .500" (1.5 to 12.7 mm)
- Polished thickness from .030" to .35" (0.76 to 8.9 mm)
- Widths to 12.0" (304 mm), Lengths to 81.0" (2057 mm)
- Disk diameters 0.125" to 12.0" (3.1 to 304 mm)

### Sapphire Tube

Crystallographic Orientation: C-axis parallel to length (0001).

Standard available tube sizes range from .06" to 1.7" (1.5 mm to 43.0 mm) outside diameter.

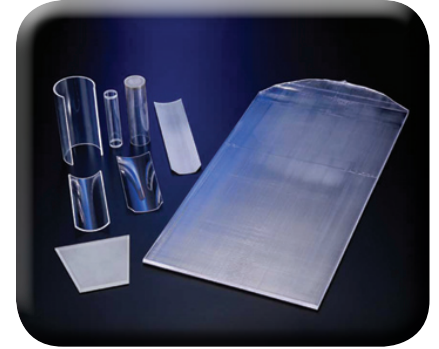
Special ground and finished ends, non-standard tolerances and dimensions are available upon request.

### Sapphire Rod

Crystallographic Orientation: C-axis parallel to length (0001).

Standard available rod sizes up to .30" (7.6 mm) diameter and 40.0" (1016 mm) length

Special, non-standard tolerances and dimensions are available upon request.



Innovative Solutions in the Following Applications:

#### Sheet Products

- Disks and windows
- Bonded assemblies
- Complex shape
- Curved sheets
- Viewports and sight windows
- End effectors
- Gas diffusion plates

#### Tube Products

- Open-end tubes
- Plugged tubes
- Capillary tubes
- Shaped tubes
- Plasma containment tubes
- Process gas injectors
- Thermocouple protection assemblies

#### Rod Products

- Structural rod
- Plugged rod
- Optical rod
- Stiffeners
- Lift pins
- Sensor rod

## Features and Benefits

### Multiple as grown shapes

- Cost-effective, near-net-shape
- Mass production capabilities
- Greatly reduced machining costs

### Single crystal

- Enhanced material properties add to longer operating life and low maintenance costs
- Eliminates grain boundary interface breakdown
- No outgassing

### Withstands high temperatures

- Won't melt until 2053°C — maintains purity in high temperature environments
- High laser damage threshold
- High intensity lighting applications achievable in smaller envelopes

### Hard and Strong

- High processing survival rate
- Scratch resistant to most materials
- Thinner windows and tubes for equivalent strength
- Withstands higher pressures than materials such as polycrystalline alumina and quartz
- Excellent wear surface
- Superior stiffness allows for minimal deflection over a wide temperature range

Chemically inert and insoluble in most common industrial solutions (i.e. hydrofluoric, sulfuric, and hydrochloric acid)

- No outgassing
- Can be used in harsh environments
- Can be easily cleaned
- Does not devitrify
- Longer life
- No system contamination
- Window life up to five times that of quartz in some environments

### Transmits ultraviolet, visible, infrared, and microwaves

- Wide variety of high intensity flash and heat sources
- Excellent waveguide performance at .025-4 microns
- Durable and reliable IR laser transmission

### High thermal conductivity

- Excellent cryogenic conductivity
- Provides rapid heating and cooling capability

### Biocompatible material

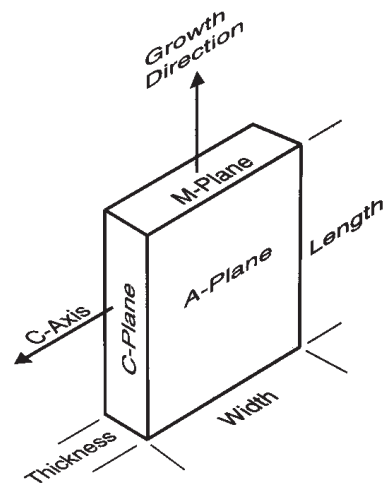
- Non-reactive with body fluids
- Usable in wet field environment

### Patented bonding process

- Bond process allows the bonding of coincident crystal planes thus allowing various sizes of sheet, rod, and tube to be combined.
- Bonded joint shares the same properties as the surrounding sapphire resulting in the ability to create a variety of bonded structures

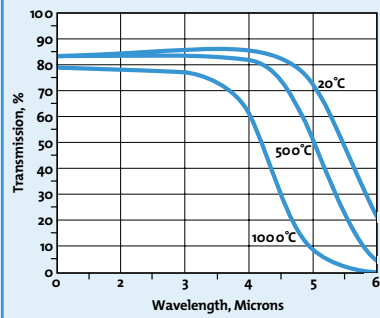


Figure 1: “A-Plane” Crystal Orientation

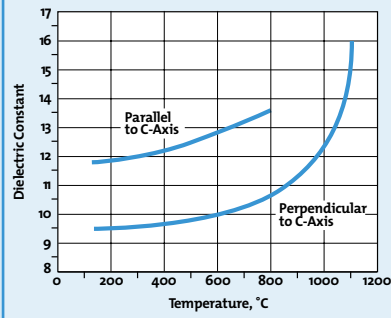


# Optical, Electrical and Thermal Properties of

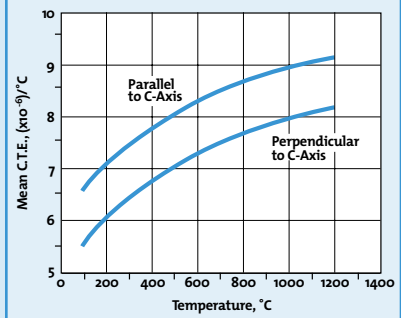
IR Transmission Vs Wavelength



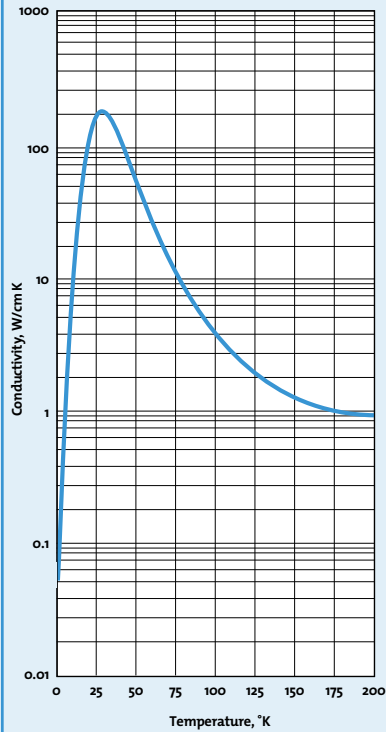
Dielectric Constant Vs Temperature



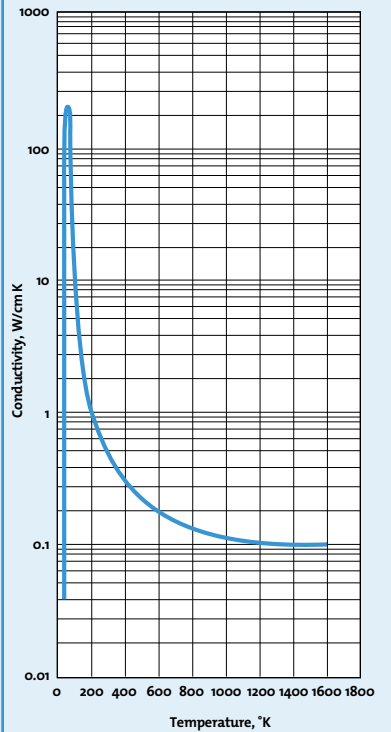
Thermal Expansion Vs Temperature



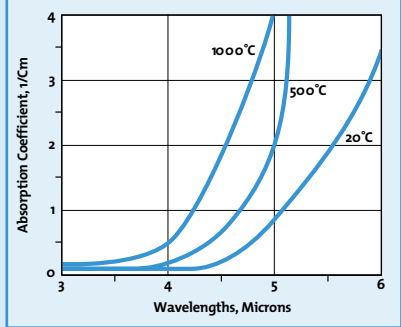
Thermal Conductivity (0° to 200° K)



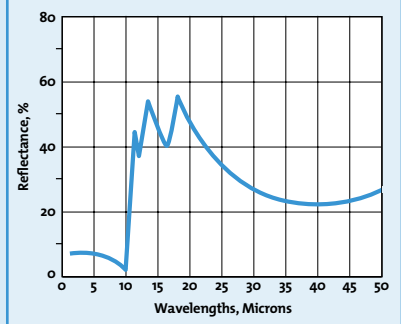
Thermal Conductivity (0° to 1800° K)



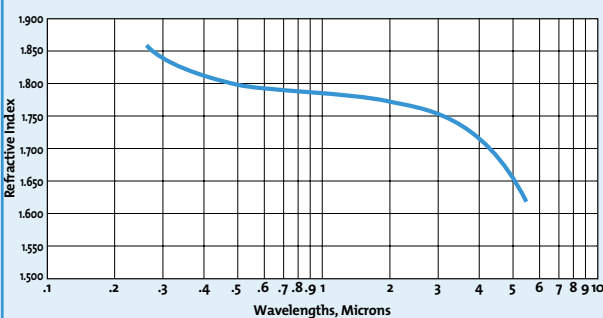
Absorption Coefficient Vs Wavelength



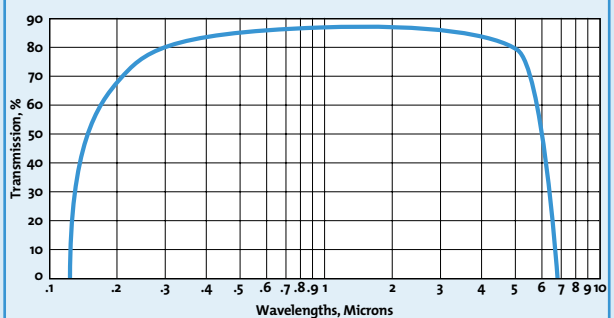
Reflectance Vs Wavelength



Refractive Index Vs Wavelength



Transmission Vs Wavelength @ 0.8 mm Thickness



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## Sapphire Properties

### General Properties

Chemical Formula	Al <sub>2</sub> O <sub>3</sub> (aluminum oxide)
Names	Corundum, Sapphire, Alpha-alumina
Crystal System	Trigonal
Class	Hexagonal-scalenohedral

### Thermal

Melting Point	2053°C (3727°F)
Maximum Useful Temperature	≈2000°C
Specific Heat	0.181 cal/gm°K (25°C) 0.300 cal/gm°K (1000°C)
Thermal Conductivity	0.4 watts/cm°K (25°C) 0.1 watts/cm°K (1000°C)
Thermal Expansion Coefficient	(25 – 1000°C) 8.8 x 10 <sup>-6</sup> ; parallel to C-axis 7.9 x 10 <sup>-6</sup> ; perpendicular to C-axis

### Physical/Mechanical

Density	3.97 gm/cm <sup>3</sup> (0.143 lb/in <sup>3</sup> ) (25°C)
Young's Modulus	435 GPa (63 x 10 <sup>6</sup> psi) parallel to C-axis (25°C) 386 GPa (56 x 10 <sup>6</sup> psi) parallel to C-axis (1000°C)
Modulus of Rigidity (Shear Modulus)	175 GPa (26 x 10 <sup>6</sup> psi)
Poisson's Ratio	0.27 – 0.30 orientation dependent
Flexural Strength	1035 MPa (150 kpsi) parallel to C-axis (25°) 760 MPa (110 kpsi) perpendicular to C-axis (25°)
Compressive Strength	≈2 GPa (300 kpsi) 25°
Hardness 9 Moh's scale (between 20° and 25°C)	1900 Knoop Parallel to C-axis 2200 Knoop Perpendicular to C-axis

### Optical

Uniaxial Negative Refractive Index	Ordinary ray (C-axis) N <sub>o</sub> = 1.768 Extraordinary ray N <sub>e</sub> -1.760 Birefringence: 0.008
Temperature Coefficient of Refractive Index	13 X 10 <sup>-6</sup> /°C (visible range)
Spectral Emittance	0.1 (1600°C)
Spectral Absorption Coefficient	0.1 – 0.2cm <sup>-1</sup> (0.66 μm, 1600°C)

### Electrical

Volume Resistivity	10 <sup>16</sup> ohm-cm (25°) 10 <sup>11</sup> ohm-cm (500°) 10 <sup>6</sup> ohm-cm (1000°)
Dielectric Strength	480,000 volts/cm (1,200 volts/mil)
Dielectric Constant	11.5 (10 <sup>3</sup> – 10 <sup>9</sup> Hz, 25°C) parallel to C-axis 9.3 (10 <sup>3</sup> – 10 <sup>9</sup> Hz, 25°C) perpendicular to C-axis
Loss Tangent	8.6 X 10 <sup>-5</sup> (@10 <sup>10</sup> Hz, 25°C) parallel to C-axis 3.0 X 10 <sup>-5</sup> (@10 <sup>10</sup> Hz, 25°C) perpendicular to C-axis
Magnetic Susceptibility	-0.21 X 10 <sup>-6</sup> parallel to C-axis -0.25 X 10 <sup>-6</sup> perpendicular to C-axis

### Chemical

Weathering Resistance	Unaffected by atmospheric exposure
Sea Water Resistance	Unaffected by marine exposure
Biological Resistance	Unaffected by in-vivo exposure Non-thrombogenic Non-reactive with body fluids

Manufacturer reserves the right to alter specifications.

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