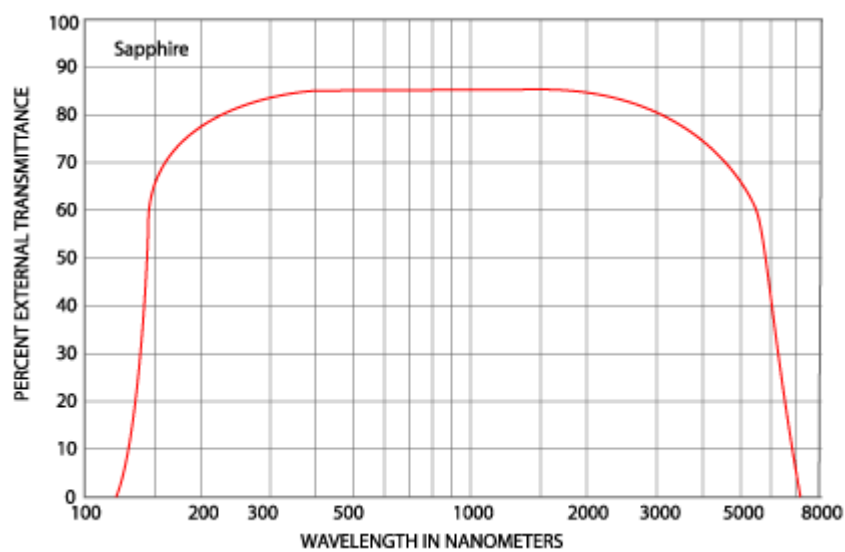


[Home](#)[Optics Guide Contents](#)[Fundamental Optics](#)[Gaussian Beam Optics](#)[Optical Specifications](#)[Material Properties](#)[Optical Coatings](#)[Optics Glossary](#)

Material Properties

Sapphire

Sapphire is a superior window material in many ways. Because of its extreme surface hardness, sapphire can be scratched by only a few substances (such as diamond or boron nitride) other than itself. Chemically inert and insoluble in almost everything except at highly elevated temperatures, sapphire can be cleaned with impunity. For example, even hydrogen fluoride fails to attack sapphire at temperatures below 300°C. Sapphire exhibits high internal transmittance all the way from 150 nm (vacuum ultraviolet) to 6000 nm (middle infrared). The external transmittance of sapphire is shown in the figure below.



External transmittance for 1-mm-thick uncoated sapphire

Because of its great strength, windows made from sapphire can be much thinner than windows of other glass types, and therefore are useful even at wavelengths that are very close to their transmission limits. Because of the exceptionally high thermal conductivity of sapphire, thin windows can be very effectively cooled by forced air or other methods. Conversely, sapphire windows can easily be heated to prevent condensation.

Sapphire is single-crystal aluminum oxide (Al_2O_3). Because of its hexagonal crystalline structure, sapphire exhibits anisotropy in many optical and physical properties. The exact characteristics of an optical component made from sapphire depend on the orientation of the optic axis or c-axis relative to the element surface. Sapphire exhibits birefringence, a difference in index of refraction in orthogonal directions. The difference in index is 0.008 between light traveling along the optic axis and light traveling perpendicular to it. The dispersion relationship for the ordinary ray in sapphire is given by the following equation:

$$n^2 - 1 = \frac{A_1 \lambda^2}{\lambda^2 - \lambda_1^2} + \frac{A_2 \lambda^2}{\lambda^2 - \lambda_2^2} + \frac{A_3 \lambda^2}{\lambda^2 - \lambda_3^2}$$

where

$$A_1 = 1.023798$$

$$A_2 = 1.058264$$

$$A_0 = 5.280792$$

$$\lambda_1^2 = 0.00377588$$

$$\lambda_2^2 = 0.0122544$$

$$\lambda_3^2 = 321.3616$$

The transmission of sapphire is limited primarily by losses caused by surface reflections. The high index of sapphire makes magnesium fluoride almost an ideal single-layer antireflection coating. When a single layer of magnesium fluoride is deposited on sapphire and optimized for 550 nm, total transmission of a sapphire component can be kept above 98% throughout the entire visible spectrum.

Sapphire Constants

Density: 3.98 g-cm⁻³ at 25°C

Young's Modulus*: 3.7 x10¹⁰ dynes/mm²

Poisson's Ratio*: - 0.02

Moh Hardness: 9 (by definition)

Specific Heat at 25°C: 0.18 cal/g-°C

Coefficient of Linear Expansion (0°C to 500°C): 7.7 x 10⁻⁶/°C

Softening Point: 1800°C

** Sapphire is anisotropic in many of its properties which require tensor description. These values are averages over many directions.*

Refractive Index of Sapphire	
Wavelength (nm)	Refractive Index <i>n</i>
265.2	1.8337
351.1	1.7970
404.7	1.7858
488.0	1.7754
514.5	1.7731
532.0	1.7718
546.1	1.7708
632.8	1.7660
1550.0	1.7462
2000.0	1.7377

[Back to Top](#)

[Previous](#) [Next](#)

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