Sapphire (Al_2O_3)

Sapphire is grown by a variety of methods. Verneuil and Czochralski methods are usual for standard grade Sapphire material. Higher quality Sapphire, particularly for electronic substrates is manufactured by Kyropulos growth and this can be very pure with excellent UV transmission. Large thin sheets of Sapphire can be made by ribbon growth. Sapphire is slightly birefringent, general purpose IR windows are usually cut in a random way from crystal but for specific applications where the birefringence is an issue, an orientation is selected. Usually this is with the optic axis at 90 degrees to the surface plane and is known as "zero degree" material. Synthetic optical sapphire has no colouration.

APPLICATIONS: Sapphire is used for its extreme toughness and strength. Sapphire is a very useful optical window material for use in the UV, visible, and near infra-red. Use the QR ink on page 30 for our guide to sapphire.

Transmission Range	0.17 to 5.5µm
Refractive Index	No 1.75449; Ne 1.74663 at 1.06µm (1)
Reflection Loss	14% at 1.06µm
Absorption Coefficient	0.3×10^{-3} cm^{-1} at 2.4µm (2)
Reststrahlen Peak	13.5µm
dn/dT	13.1×10^{-6} at 0.546µm (3)
dn/dµ = 0	1.5µm
Density	3.97 g/cc
Melting Point	2040°C
Thermal Conductivity	27.21 W m^{-1} K^{-1} at 300K
Thermal Expansion	5.6 (para) & 5.0 (perp) x 10^{-6} K^{-1} *
Hardness	Knoop 1800 (para) 2200 (perp)
Specific Heat Capacity	763 J Kg^{-1} K^{-1} at 293K (4)
Dielectric Constant	11.5 (para) 9.4 (perp) at 1MHz
Youngs Modulus (E)	335 GPa
Shear Modulus (G)	148.1 GPa
Bulk Modulus (K)	240 GPa
Elastic Coefficients	C_{11}=496 C_{12}=164 C_{13}=115 C_{33}=498 C_{44}=148
Apparent Elastic Limit	300 MPa (45,000 psi)
Poisson Ratio	0.25
Solubility	98×10^{-6} g/100g water
Molecular Weight	101.96
Class/Structure	Trigonal (hex), R3c

** Note that manufacturers appear to disagree at times on figures for thermal expansion.*

(1) Handbook Optical Constants, ed Palik, V3, ISBN 0-12-544423-0
(2) Harrington et al, Appl.Opt. V15, 1953-1959 (1976)
(3) Malitson, J.Opt.Soc.Am., V52, 1377- 1379 (1962)
(4) Ditmars, et. al., J. Res. Nat. Bur. Stand., 87, (2), 159-163 (1982).

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µm	No	Ne	µm	No	Ne
0.193	1.9288	1.9174	0.213	1.8890	1.8784
0.222	1.8754	1.8650	0.226	1.8702	1.8599
0.244	1.8506	1.8407	0.248	1.8470	1.8372
0.257	1.8393	1.8297	0.266	1.8330	1.8236
0.280	1.8244	1.8151	0.308	1.8110	1.8020
0.325	1.8047	1.7958	0.337	1.8001	1.7921
0.351	1.7969	1.7882	0.355	1.7960	1.7883
0.442	1.7804	1.7721	0.458	1.7784	1.7702
0.488	1.7753	1.7671	0.515	1.7730	1.7649
0.532	1.7717	1.7636	0.590	1.7680	1.7600
0.633	1.7659	1.7579	0.670	1.7643	1.7563
0.694	1.7634	1.7554	0.755	1.7614	1.7535
0.780	1.7607	1.7527	0.800	1.7601	1.7522
0.820	1.7596	1.7517	0.980	1.7561	1.7482
1.064	1.7545	1.7466	1.320	1.7501	1.7423
1.550	1.7462	1.7384	2.010	1.7375	1.7297
2.249	1.7323	1.7243	2.703	1.719	1.711
2.941	1.712	1.711	3.333	1.701	1.693
3.704	1.687	1.679	4.000	1.674	1.666
4.348	1.658	1.65	4.762	1.636	1.628
5.000	1.623	1.615	5.263	1.607	1.599