Sapphire Material Report

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1. Main properties of sapphire:

Chemical formula	Al_2O_3
Crystal class	Hexagonal system, rhomboidal class 3m
Lattice constants, A	a=4.785, c=12.991
Density, g/cm3	3.98
Melting point, °K	2303
Hardness	Knoop (daN/mm2): 1800 parallel to C-axis, 2200 perpendicular to C-axis, Mohs: 9
Optical transmission range	0.17- 5.5 [µm]
Refractive index at 0.532	n0=1.7717, ne=1.76355 [µm]
Water absorption	nil
Young Modulus, Gpa	345
Shear Modulus, Gpa	145
Bulk Modulus, Gpa	240
Bending Modulus (Modulus of Rupture), Mpa	420 at 20°C, 280 at 500°C
Elastic Coefficient	C11=496, C12=164, C13=115, C33=498, C44=148
Poisson ratio	0.25-0.30
Friction Coefficient	0.15 on steel, 0.10 on sapphire
Tensile strength, MPa	400 at 25°, 275 at 500°, 345 at 1000°
Flexural strength, daN/mm^2	35 to 39
Compressive strength, GPa	2
Young's modulus E, daN/mm^2	3.6 X 10^4 to 4.4 X 10^4
Specific heat, J/(kg x K)	105 at 91°K, 761 at 291 °K
Thermal coefficient of linear expansion, K^{-1}, at323K	6. 66 x 10^{-6} parallel to optical axis, 5 x 10^{-6} perpendicular to optical axis
Thermal conductivity, W/(m x K) at 300K	23.1 parallel to optical axis, 25.2 perpendicular to optical axis
Resistivity, Ohm x cm	10^{16} (25°), 10^{11} (500°), 10^6 (1000°)
Dielectric constant	11.5 (103- 109 Hz, 25°) parallel to C-axis, 9.3 (103- 109 Hz, 25°) perpendicular to C-axis
Dielectric strength, V/cm	4x 10^5
Loss tangent	1 X 10^{-4}
Solubility -in water -in HN03,H2S04, HCI, HF -in alcalis -in melts of metals Mg, AI, Cr, Co, Ni, Na, K, Bi, Zn, Cs	 insoluble insoluble to 300 °C insoluble to 800 °C insoluble to 800-1000 °C
g -radiation stability	No change in transmission above 2.5 mm after exposure to 107 Rads. No visible coloration after exposure to 108 Rads/hr for 60 minutes at- 195°C
Proton radiation stability	No change in transmission below 0.3 m after exposure to 10^{12} proton/cm^2 total dose
Chemical resistance	Sapphire is highly inert and resistant to attack in most process environments including hydrofluoric acid and the fluorine plasma applications commonly found in semiconductor

2. Material purity:

Element	Concentration ppmwt	Element	Concentration ppmwt
Li	<0.05	Ag	<0.5
Be	<0.05	Cd	<0.5
B	<0.05	In	<0.5
0	Matrix	Sn	<0.5
F	<5	Sb	<0.1
Na	0.35	Te	<0.1
Mg	0.22	I	<0.1
Al	Matrix	Cs	<0.1
Si	0.14	Ba	<0.1
p	<0.1	La	<0.1
S	<0.5	Ce	<0.1
Cl	<0.1	Pr	<0.1
K	<0.5	Nd	<0.1
Ca	<0.5	Sm	<0.1
Sc	<0.05	Eu	<0.1
Ti	0.07	Gd	<0.1
V	<0.05	Tb	<0.1
Cr	<0.5	Dy	<0.1
Mn	<0.05	Ho	<0.1
Fe	<1	Er	<0.1
Co	<0.05	Tm	<0.1
Ni	<0.5	Yb	<0.1
Cu	<10	Lu	<0.1
Zn	<0.5	Hf	<0.1
Ga	<0.1	Ta	Electrode
Ge	<1	w	<10
As	<0.1	Re	<0.05
Se	<0.5	Os	<0.05
Br	<0.5	Ir	<0.05
Rb	<0.05	Pt	<0.1
Sr	<0.05	Au	Interference
Y	<0.05	Hg	<0.5
Zr	<0.1	Tl	<0.1
Nb	<50	Pb	<0.1
Mo	<20	Bi	<0.1
Ru	<0.5	Th	<0.01
Rh	<0.5	U	<0.01
Pd	<0.5		

Purity=99.999922%

3. Sapphire quality grades:

Grade 1: free of insertions, block boundaries, twins, microbubbles and scattering centers;

Grade 2: free of insertions, block boundaries, twins; individual scattering centers (microbubbles < 10 µm located not closer than 10 mm) are allowed;

Grade 3: free of insertions, block boundaries, twins; individual bubbles < 20 µm located not closer than 10 mm to each other are allowed;

Grade 4: free of insertions, block boundaries, twins; bubbles < 20 µm located not closer than 2 mm from

one another as well as bubbles clusters (which may include individual bubbles to 50 µm) of size < 200 µm scattered not closer than 10 mm to each other within the effective volume 20x20x20 mm are allowed;

Grade 5: free of insertions, block boundaries, twins; bubbles < 20 µm located not closer than 2 mm from one another as well as bubbles clusters (which may include individual bubbles to 50 µm) of size < 500 µm scattered not closer than 5 mm to each other within the effective volume 20x20x20 mm are allowed;

Grade 6: free of insertions, block boundaries, twins; defective areas with bubbles clusters of size > 500 µm are allowed.

3. Sapphire optical transmittance: