Optischer Saphir:

Optical Sapphire:
· A synthetic sapphire

Major Advantages:
· Hardest natural substance next to diamond
· Much stronger than other optical materials
· Extreme surface hardness
· Highly resistant to scratching and abrasion
· Very wide optical transmission band from UV to near-IR
· Extremely high melt temperature
· High electrical resistance
· Chemically inert
· Totally unaffected by all chemicals except some very hot caustics
· High thermal conductivity for a non-conductor, better than copper at cryogenic temperatures
· High dielectric constant

Optical Properties:
· Refractive Indices:
· Ordinary Ray (No) (C-axis direction): 1.768
· Extraordinary Ray (Ne) (perpendicular to C-axis direction): 1.760
· Birefringence (Ne - No): 0.008
· Temperature Coefficient of Refractive Index: 13x10-6/°C (@ 0.57 µm, 20°C)
· Transmittance: >85% 0.3-4.0 µm (@ 0.1 mm thick) uncorrected
· Emissivity @ 3,4,5 µm: 16%, 25%, 70% (@500°C)
· Absorption @ 0.66 mm @ 1600°C: 0.1 - 0.2 cm-1

Mechanical Properties:
· Hardness (9 Mohs std): 2000 kg/mm2, Knoop
· Coefficient of friction: 0.14 (on steel)
· Young's Modulus: 400 GPa @ 20°C
· Poisson's Ratio: 0.29
· Compressive Strength: 2.0 GPa
· Creep @ 100 Mpa, 1600°C: 1.5x10-4/hr
· Fracture Toughness: 2.0 MPa (m?)
· Flexural Strength: 900 MPa
· Bulk Modulus: 2.4 GPa
· Shear Modulus: 175 GPa (Rigidity Modulus)
· Tensile Strength: 300 to 400 MPa
· Rupture Modulus: 65 - 100,000 psi

Electrical Properties:
· Bulk Resistivity: 1016 ohm-cm @ 25°C, 1011 ohm-cm @ 500°C
· Dielectric Strength: 48 kv/mm, (1.2kv/mil)
· Dielectric Constant 25°C: 9.4 perpendicular to the c-axis, 11.6 parallel to the c-axis between 10Hz and 3x109 Hz
· Loss Tangent 25°C: 3.0 - 8.6x10-5; between 10 Hz and 3x109 Hz
· Magnetic Susceptibility: -0.21x10-6 to -0.25x10-6

Physical Properties:
· Density: 3.98 g/cm3, (0.143 lb/in3)
· Hardness: Knoop microindenter: 1800 FACE perpendicular to c-axis, 2200 FACE parallel to c-axis
· Young's Modulus: 400 GPa @ 20°C
· Tensile Strength: 300 to 400 MPa
· Point Group; Symmetry:3 2/m; [C,1A3, 3A2, 3P]
· Lattice Dimensions: a = 4.748 Angstroms, c = 12.957 Angstroms
· Sound Speed: ~10 km/s

Chemical Properties:
· Non-porous,
· Unaffected by weathering and hydration
· Virtually unaffected by any solvents or acids at room temperature. (Some etching by hot phosphoric acid and strong caustics at temperatures exceeding 600°C - 800°C)

Thermal Properties:
· Melting Point: ~2053°C (3727°F)
· Most properties useful to (maximum): ~1800°C (3272°F)
· Conductivity: 40 W/M°K @ 298°K
· Expansion @ 25°C: 4.5x10-6/K-1 and @ 1000°C: 9.0x10-6/K-1 (90° orientation)
· Specific Heat Capacity: 750 J/K at 300°K
· Viscosity @ 2053°C: 0.0584 Pa·s

Crystal Facts:
The angular relationship between the inherent optical axis of the crystal and the required part is known as orientation. Typical choices for part orientation are:
· Zero Degree: The direction of view is parallel to the optical axis of the crystal
· 90 Degree: The direction of view is perpendicular to the optical axis of the crystal
· C-Axis: In a rod, the direction along its length. In a window, the direction perpendicular to the face
· M-Plane: The plane containing the optic axis (C) and inclined 30 degrees to the A-axis
· A-Plane: The plane that is perpendicular to the A-axis, containing the C-axis
· R-Plane: A plane inclined 57.5667 degrees to the optic axis and in the same zone as the M-plane
· Random: There is no specified relationship between the part and the crystalline orientation. The part is manufactured without concern about orientation

Sapphire Grades:
Sapphire has an infinite number of grades:
Grades are entirely arbitrary and are decided upon after inspection of each synthetic sapphire batch which has been grown.
Synthetic sapphire is graded by what is important for a particular application, either optical or mechanical.
A high grade of sapphire would have little or no light scatter or lattice distortion and be used mainly for the most demanding optical applications.
A lower grade of sapphire may have extensive light scatter or lattice distortion, being used mainly for mechanical and structural uses such as bearings, fixtures, and less demanding optical applications.
An ultraviolet (UV) grade sapphire or non-browning sapphire will not solarize on exposure to UV light.

An infinite number of grades fall between the high and lower synthetic sapphire grades, with each sapphire manufacturer giving a name to their own grades.

Grade 1. Free of insertions, block boundaries, twins, microbubbles and scattering centersl;

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

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

Grade 4. Free of insertions, block boundaries, twins; bubbles < 20um located not closer than 2 mm from one another as well as bubbles clusters (which may include individual bubbles up to 50 um) of size < 200 um scattered not closer than 10mm to each other within the effective volume 20 x 20 x 20mm are allowed;

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

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

We consider 1-4 grades as optical ones; 5-6 as technical ones.

For all optical grades blue and green coloration is not allowed.

For all technical grades coloration is not controlled.

Insertions, block boundaries and twins inside the material are controlled visually between crossed polarizers.