

## CaF<sub>2</sub>

Calcium Fluoride (CaF<sub>2</sub>) crystal is not only a conventional but also an excellent material for the applications in the ultraviolet and infrared spectra. The crystal covers a very wide transmission range from 130nm to 10μm (UV, VIS and IR). It can be manufactured into windows, lenses, prisms, and mirror substrates.

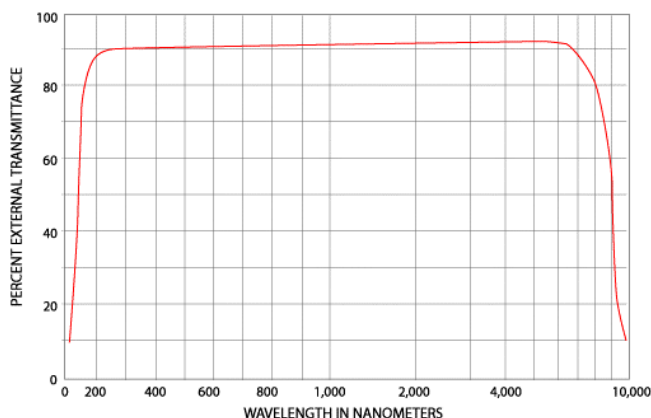
### Basic Properties

Formula	CaF <sub>2</sub>
Structure	Cubic
Growth Method	Stockbarger Technique
Maximum Size	Φ185 mm
Transmission Range	150 - 9000 nm
Density	3.18 g/cm <sup>3</sup>
Melting Point	1418 °C
Mohs Hardness	4
Thermal Expansion Coefficient	16.2-19.4 x 10 <sup>-6</sup> /K
Thermal Conductivity	9.17 W m <sup>-1</sup> K <sup>-1</sup>
Specific Heat Capacity	888 J kg <sup>-1</sup> K <sup>-1</sup>
Solubility in Water	0.0016 g/100cm <sup>3</sup>
Solubility in Acids	unessential
Solubility in Organic Solvents	insoluble in acetone
Absorption Coefficient	0.10 cm <sup>-1</sup> at 200 nm 0.01 cm <sup>-1</sup> at 400 nm 0.03 cm <sup>-1</sup> at 2600-2900 nm

Wavelength (μm)	0.193	0.248	0.257	0.355	0.587	0.65	1.0	1.5	2.0
Refractive Index	1.501	1.468	1.465	1.446	1.433	1.432	1.428	1.426	1.423

Wavelength (μm)	2.5	3.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0
Refractive Index	1.421	1.417	1.409	1.398	1.385	1.369	1.349	1.3002	1.2299

Transmission Spectrum: (Thickness 10 mm)



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MgF<sub>2</sub>

Magnesium Fluoride or MgF<sub>2</sub> is grown by vacuum Stockbarger technique in ingots approximately 120mm in diameter. It is a positive birefringent crystal with high optical transmittance from the vacuum ultraviolet to the infrared spectrum region. It is resistant to mechanical and thermal shock, to radiation, and is chemistry stable.

MgF<sub>2</sub> transmits well into the VUV region at the hydrogen Lyman-alpha line (121nm) and beyond. It is also used for most UV optics and is excellent for Excimer laser application.

## Basic Properties

Structure	Tetragonal
Solubility in 100g water at 18°C	0.0076g
Lattice Constant	a = 4.621Å; c = 3.053Å
Density	3.18g/cm <sup>3</sup>
Mohs Hardness	6
Melting Point	1255°C
Transparency Range	120 ~ 8500nm
Thermal Conductivity	3.14W/m/K
Expansion Coefficient	C: 14.3; C: 9.15 (10 <sup>-6</sup> /K)

## Refraction Index

Wavelength (nm)	n <sub>o</sub>	n <sub>e</sub>	Wavelength (nm)	n <sub>o</sub>	n <sub>e</sub>
178	1.43975	1.45365	656	1.37661	1.38835
436	1.38203	1.39402	1000	1.37964	1.38521
488	1.38016	1.39206	2000	1.36800	1.37922
546	1.37855	1.39039	3000	1.36000	1.37060
588	1.37770	1.38960	5000	1.33020	1.33930

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**BaF<sub>2</sub>**

BaF<sub>2</sub> is relatively hard but is highly sensitive to thermal shock. For its transmission range is 200nm - 11000nm, the material is widely used for making optical windows, lenses and prisms in UV-IR spectra. Besides it can also be used as substrate for some applications. BaF<sub>2</sub> is less resistant to attack by water than CaF<sub>2</sub>. Pronounced water attack occurs at 500°C, but in a dry environment the material can be used up to 800°C. BaF<sub>2</sub> is grown by modified Bridgman technique. Maximum available size: Dia 200 mm x Thickness 50 mm. In addition, BaF<sub>2</sub> is usually used as scintillator for gamma detection. It is the fastest scintillating crystals up to now.

**Main Properties**

Transmission Range	150 ~ 12500 nm
Refractive Index	1.5122~1.3703 @ 150 ~ 12500 nm
Reflection Loss	5.3% @10350nm (2 surfaces)
Absorption Coefficient	3.2×10 <sup>-4</sup> /cm @ 6000nm
Density	4.89 g/cm <sup>3</sup>
Melting Point	< 1280°C
Thermal Conductivity	11.72 W/m/K @ 286K
Thermal Expansion	18.1×10 <sup>-6</sup> /K @ 273K
Knoop Hardness	82 with 500g indenter
Specific Heat	410 J Kg/m <sup>2</sup> /K
Dielectric Constant	7.33 @ 1MHz
Elastic Coefficients	C <sub>11</sub> = 89.2 C <sub>12</sub> = 40.0 C <sub>44</sub> = 25.4
Apparent Elastic Limit	26.9 Mpa (3900psi)
Poisson Ratio	0.343
Solubility in 100g water	0.17 g
Cleavage	[111]

**Main Specifications**

Maximum Size	Single Crystal: φ100×100 mm Poly Crystal: φ200×100 mm (3 ~7 mm boundaries)
Dimension Tolerance	± 0.1mm
Flatness Tolerance	λ/2~λ/10 at 632.8 nm over central 90% of edge dimensional
Parallelism	±1 arc sec ~ ±3 arc min
Surface Quality	10/5 Scratch/Dig

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## LiF

LiF crystal shows excellent transmittance in the VUV region. It is used for optical windows, prisms, and lenses in the visible and infrared in 104nm – 7000nm. LiF crystal is sensitive to thermal shock and would be attacked by atmospheric moisture at 400°C. In addition irradiation produces color centers. Modest precautions should be taken against moisture and high energy radiation damage. Besides LiF softens at 600°C and is slightly plastic that can be bent into radius plates. The material can be cleaved along [100] and less commonly [110]. Although the optical characteristics are good, the structure is not perfect and cleavage is difficult. For good structure LiF is less commonly grown by the Kyropoulos technique (air-grown) specifically for monochromator plates. High quality LiF is usually grown by modified Bridgman technique. Maximum available size in diameters is about 115mm. LiF is slightly plastic and can be bent into radius plates.

## Material and Specifications

Transmission Range	120 ~ 6000 nm
Refractive Index	1.39181 @ 600nm
Reflection Loss	5.2% @ 600nm (2 surfaces)
Absorption Coefficient	$0.74 \times 10^{-3} \text{ cm}^{-1}$ @ 2700 nm
Density	2.639 g/cm <sup>3</sup>
Melting Point	870°C
Thermal Conductivity	4.01 K/W/m @ 314K
Thermal Expansion	$37 \times 10^{-6} / \text{K}$ @ 283K
Knoop Hardness	102 with 600g indenter
Specific Heat Capacity	1562 J. Kg/m <sup>3</sup> K
Elastic Coefficient	$C_{11}=112, C_{12}=46, C_{44}=63.5$
Apparent Elastic Limit	11.2 Mpa (1620 psi)
Poisson Ratio	0.326
Solubility in 100g water at 20°C	0.27g
Cleavage	[100]

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Sapphire (Al<sub>2</sub>O<sub>3</sub>) single crystal has good transmission characteristics over the visible, and near IR spectrum, as well as high mechanical strength, chemical resistance, thermal conductivity and thermal stability. These outstanding properties make sapphire as an ideal window materials operating under extremely offensive conditions such as in aerospace and military equipments. Sapphire is also used as substrates in semiconductor and superconductor fields.

## Main Applications

- UV and IR Optics
- Electrical Insulators
- Thin Film Deposition
- Transparent Electronic Substrate
- Heat Sinders and Thermocouplers; Semiconductor Wafer Carriers
- Silicon on Sapphire Wafers; Superconductor Substrate
- Windows for High Temperature and Pressure, Corrosion Resistance, Abrasion Resistance

## Basic Properties

Transparency Range	170 - 5500 nm
Crystal Structure	Hexagonal
Lattice Constant	a = 4.758Å, c = 12.991 Å
Density	3.98 g/cm <sup>3</sup>
Mohs Hardness	9
Young's Modulus	435 GPa
Melting Point	2030°C
Thermal Conductivity	40 W/m.K
Thermal Expansion Coefficient at 25°C	C: 5.6, ⊥C: 5.0 (10 <sup>-6</sup> /K)
Absorption Coefficient	0.3 × 10 <sup>-3</sup> /cm at 2.4μm
Refractive Indices (n <sub>o</sub> )	1.83 @ 260 nm
	1.76 @ 633 nm
	1.63 @ 5000nm
Transparency Range	170 - 5500 nm

## AOTK Standard Specifications of Sapphire

Orientation	<111> within 5°
Diameter Tolerance	+0.0/-0.2 mm
Thickness Tolerance	±0.2 mm
Surface Quality	Scratch/Dig 60/40 to MIL-O-13830A
Flatness	Better than λ/10 @ 633nm
Transmission Wavefront Distortion	Better than λ/2 per inch @ 1064 nm
Parallelism	Better than 3 arc minutes
Perpendicularity	Better than 5 arc minutes

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## Undoped YAG

Undoped YAG crystal is an excellent material for making UV-IR optical windows, particularly for high temperature and high energy density applications. The mechanical and chemical stability is comparable to sapphire crystal, but YAG is unique with non-birefringence and available with higher optical homogeneity and surface quality.

### Main Features

- Transmission in 250-5000 nm, no absorption in 2000-3000 nm
- Extremely hard and durable
- High thermal conductivity
- High bulk damage threshold.
- High index of refraction and Non-birefringence

### Basic Properties

Crystal structure	Cubic
Density	4.5g/cm <sup>3</sup>
Transmission Range	250-5000nm
Melting Point	1970°C
Specific Heat	0.59 W.s/g/K
Thermal Conductivity	14 W/m/K
Thermal Shock Resistance	790 W/m
Thermal Expansion	6.9x10 <sup>-6</sup> /K
dn/dt @ 633nm	7.3x10 <sup>-6</sup> /K <sup>-1</sup>
Mohs Hardness	8.5
Refractive Index	1.8245 @0.8 μm, 1.8197 @1.0 μm, 1.8121 @1.4 μm

### AOTK Standard Specifications of YAG Windows and Mirrors

Orientation	<111> within 5°
Diameter Tolerance	+0.0/-0.2 mm
Thickness Tolerance	±0.2 mm
Surface Quality	Scratch/Dig 10/5 to MIL-O-13830A
Flatness	Better than λ/8 @ 633nm
Transmission Wavefront Distortion	Better than λ/2 per inch @ 1064 nm
Parallelism	Better than 30 arc seconds
Perpendicularity	Better than 5 arc minutes

### Note

- AR and HR Coatings are available upon request.

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**AOTK** can provide a large number of optical components made from various materials. It is very important to select a suitable material for an optical component, and many characteristics should be considered, such as transmission range, index of refraction, thermal, chemical, mechanical characteristics and also the cost.

There are two instances in which you might need to know more about optical materials. First, you may need to determine the performance of a catalog component in a particular application. Second, you may need specific information when selecting the material for a custom component. The data in the following is intended to assist in these situations.

If you can not confirm which material is the right one, please let us know your applications,. Our engineers can select the most suitable one for you.

Some of the materials that AOTK uses include:

<b>General Optical Glass:</b>	Schott glass, Ohara glass
<b>Special Glass;</b>	Fused Silica, Dynasil fused silica, Color glass, Float glass...
	Sapphire, CaF <sub>2</sub> , BaF <sub>2</sub> , MgF <sub>2</sub> , NaCl, MgO...
<b>Optical Crystalline:</b>	Quartz, Si, Ge, ZnSe, ZnS...
	Calcite, YVO <sub>4</sub> , $\alpha$ -BBO, LiNbO <sub>3</sub> , TeO <sub>2</sub> , PbMoO <sub>4</sub> , KTP, YAG...

Materials	Refractive Index	Transmission Range ( $\mu\text{m}$ )	Thermal Expansion Coefficient ( $10^{-6}/\text{K}$ )
BK7	1.5164 (588 nm)	0.330 - 2.1	7.1
SF11	1.78472 (588nm)	0.370 - 2.5	6.1
SF14	1.76182 (588 nm)	0.420 - 2.0	6.6
Fused Silica	1.4858 (308 nm)	0.185 - 2.5	0.50
CaF <sub>2</sub>	1.399 (5.0 $\mu\text{m}$ )	0.170 - 7.8	18.85
Sapphire	1.755 (1.0 $\mu\text{m}$ )	0.180 - 4.5	8.4
Si	3.4179 (10 $\mu\text{m}$ )	1.200 - 7.0	2.23
Ge	4.003 (10 $\mu\text{m}$ )	1.900 - 16	5.7
ZnSe	2.40 (10 $\mu\text{m}$ )	0.630 - 18	7.1
ZnS	2.2 (10 $\mu\text{m}$ )	0.380 - 14	6.5
MgF <sub>2</sub>	$n_o=1.3836, n_e=1.3957$ (405nm)	0.130 - 7.0	8.8  c; 13.1  a
YVO <sub>4</sub>	$n_o=1.9500, n_e=2.1554$ (1.3 $\mu\text{m}$ )	0.400 - 5.0	11.37  c; 4.43  a
Calcite	$n_o=1.6557, n_e=1.4852$ (633nm)	0.210 - 2.3	24.39  c; 5.68  a
Quartz	$n_o=1.5427, n_e=1.5518$ (633nm)	0.200 - 2.3	6.88  c; 12.38  a
$\alpha$ -BBO	$n_o=1.6749, n_e=1.5555$ (532nm)	0.190 - 3.5	33.3  c; 0.5  a
LiNbO <sub>3</sub>	$n_o=2.2863, n_e=2.2027$ (633nm)	0.370 - 4.5	4.1  c; 14.8  a

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