SINGLE CRYSTAL SAPPHIRE
**SINGLE CRYSTAL SAPPHIRE**

Single Crystal Sapphire is playing an ever-increasingly important role as a material for high reliability Electronics today due to its excellent mechanical characteristics, chemical stability and light transmission.

Kyocera mass-produces Single Crystal Sapphire in a vertically integrated manner. From “pulling up” the raw material with EFG (Edge-Defined Film-Fed Growth) methods to machining, Kyocera produces and supplies various products with large diameters or specific shape requirements.

**FEATURES OF EFG METHOD**

- **Large Size Material**
  - Sizing-up of materials allows for a broader range of applications and uses.

- **Production of Single Crystal Sapphire in Any Desired Sectional Shape**
  - Since any desired sectional shape can be obtained in the form of ribbons, tubes, rods, and others, cutting processes can be eliminated, allowing for a reduction in cost.

- **Control of Crystal Orientation**
  - Any axis and plane can be produced by instituting proper control during crystal growth.

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**FEATURES OF SINGLE CRYSTAL SAPPHIRE**

  - Because of these characteristics, Single Crystal Sapphire is widely used for precision mechanical parts.

- Stable Dielectric Constant, Very Low Dielectric Loss, Good Electrical Insulation
  - Single Crystal Sapphire is used as a material for substrates in super-high frequency regions. It is also used as an insulation material and microwave window. Single Crystal Sapphire has become indispensable in the Electronics Industries.

- Excellent Light Transmission
  - Single Crystal Sapphire is used for various kinds of vacuum equipment, windows in reaction furnace, scanner windows and caps for optical communication due to its excellent mechanical characteristics and heat resistance.

- Good Thermal Conductivity and High Heat Resistance
  - Excellent thermal conductivity at low temperatures allows Single Crystal Sapphire as a transparent material to be used in many diverse fields requiring thermal conduction and heat radiation.
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**FEATURES OF EFG METHOD**

**FEATURES OF SINGLE CRYSTAL SAPPHIRE**

- **High Strength, High Rigidity, High Anti-Abrasion, High Anti-Heat, High Anti-Corrosion Characteristics, and High Anti-Plasma Characteristics.**
  Because of these characteristics, Single Crystal Sapphire is widely used for precision mechanical parts.

- **Stable Dielectric Constant, Very Low Dielectric Loss, Good Electrical Insulation**
  Single Crystal Sapphire is used as a material for substrates in super-high frequency regions. It is also used as an insulation material and microwave window. Single Crystal Sapphire has become indispensable in the Electronics Industries.

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  Excellent thermal conductivity at low temperatures allows Single Crystal Sapphire as a transparent material to be used in many diverse fields requiring thermal conduction and heat radiation.
SAPPHIRE MANUFACTURING PROCESS

Sapphire Manufacturing Process

Growth of Raw Material

Grinding

Lapping

Polishing

Shape and Specifications

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>Crystal Orientation</td>
</tr>
<tr>
<td>Width: 200max.</td>
<td>R plane ±2deg</td>
</tr>
<tr>
<td>Length: 300max.</td>
<td>A plane ±2deg</td>
</tr>
<tr>
<td>Thickness: 0.1~20</td>
<td>C plane ±2deg</td>
</tr>
</tbody>
</table>

Tube

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Crystal Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Diameter 1.3~50</td>
<td>C Axis in Longitudinal Direction</td>
</tr>
<tr>
<td>Tube Thickness 0.25~5</td>
<td></td>
</tr>
<tr>
<td>Length: 1,000mm max.</td>
<td></td>
</tr>
</tbody>
</table>

Others

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Crystal Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To be Customized</td>
<td>To be Customized</td>
</tr>
</tbody>
</table>

※ Shapes other than above are available.

As-Grown Materials
CHARACTERISTICS OF SINGLE CRYSTAL SAPPHIRE

### Characteristics of Kyocera’s Single Crystal Sapphire

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystallographic Structure</td>
<td>Hexagonal System a = 4.763 Å, c = 13.003 Å</td>
</tr>
<tr>
<td>Reference Density</td>
<td>3.97 x 10^3 kg/m³</td>
</tr>
<tr>
<td>Vickers Hardness</td>
<td>22.5 GPa (HV1 (Load = 9.807 N))</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>690 MPa</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>2250 MPa</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>2.940 MPa</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>470 GPa</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.18 ~ 0.29</td>
</tr>
<tr>
<td>Melting Point</td>
<td>2053 °C</td>
</tr>
<tr>
<td>Coefficient of Linear Thermal Expansion</td>
<td>40 ~ 400 °C C parallel to C axis 7.7 x 10^5°C</td>
</tr>
<tr>
<td></td>
<td>40 ~ 400 °C C perpendicular to C axis 7.0 x 10^5°C</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>20 °C 42 W/(m • K)</td>
</tr>
<tr>
<td>Specific Heat Capacity</td>
<td>0.75 J/(g • K)</td>
</tr>
<tr>
<td>Emissivity</td>
<td>&lt; 0.02</td>
</tr>
<tr>
<td>(λ = 2.6 ~ 3.7 μm880 °C)</td>
<td></td>
</tr>
<tr>
<td>Dielectric strength</td>
<td>48 × 10^9 V/m</td>
</tr>
<tr>
<td>Volume Resistance</td>
<td>20 °C &gt; 10^14 Ω • cm</td>
</tr>
<tr>
<td></td>
<td>500 °C 10^11 Ω • cm</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>C parallel to C axis 11.5 (1MHz)</td>
</tr>
<tr>
<td></td>
<td>C perpendicular to C axis 9.3 (1MHz)</td>
</tr>
<tr>
<td>Dielectric Loss Angle</td>
<td>&lt; 1 (× 10^-4) (1MHz)</td>
</tr>
<tr>
<td>Loss Factor</td>
<td>~ (× 10^-4)</td>
</tr>
<tr>
<td>Dielectric Loss Tangent</td>
<td>10^-4 max.</td>
</tr>
<tr>
<td>Index of Reflection</td>
<td>No = 1.768</td>
</tr>
<tr>
<td></td>
<td>Ne = 1.760</td>
</tr>
<tr>
<td></td>
<td>@589nm</td>
</tr>
<tr>
<td>Optical Transmission</td>
<td>Refer to Fig. 5</td>
</tr>
</tbody>
</table>

※ These figures are representative.
※ Each Crystal Orientation has different characteristics.

### Standard Dimensional Tolerance

<table>
<thead>
<tr>
<th>Nominal Dimension (a)</th>
<th>1 &gt; a</th>
<th>1 ≤ a ≤ 4</th>
<th>4 &lt; a ≤ 25</th>
<th>25 &lt; a ≤ 102</th>
<th>102 &lt; a ≤ 190</th>
<th>190 &lt; a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tolerance (±)</td>
<td>0.05</td>
<td>0.1</td>
<td>0.2</td>
<td>0.25</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

※ Machining accuracy: Tube 1.A, 10.A, and standard tube thickness tolerance: ± 0.25.
※ Hole diameter and standard pitch tolerance: ± 0.1

### Figures

- Fig. 1: Thermal Expansion vs. Temperature
- Fig. 2: Thermal Conductivity vs. Temperature
- Fig. 3: Dielectric Constant vs. Temperature
- Fig. 4: Dielectric Loss vs. Frequency
- Fig. 5: Transmission vs. Wave Length
SAPPHIRE PRODUCTS

Substrate

Application
(1) High Brightness LED
(2) HB-LED Semiconductor, Piezoelectric Semiconductor, Superconductor, Thin Film Substrate.
(3) MR Sensor, Precision Resistor
(4) Optical Devices
(5) Thin Film HIC

Single Crystal Sapphire is widely used substrate material for blue, green, ultraviolet and white LEDs. It has excellent features as a base substrate for GaN deposition and great mass-productivity. In addition, it can meet future larger-size demand.

Single Crystal Sapphire is used as a base substrate in thin film deposition because of its lattice alignment match with a variety of semiconductor materials combined with excellent thermal and chemical stability.

2"-8" substrate for Optical Devices

Standard Dimension and Tolerance

<table>
<thead>
<tr>
<th>Size</th>
<th>Ø Diameter (mm)</th>
<th>O.F. Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8&quot;</td>
<td>200 ± 0.25 x 0.725 ± 0.05</td>
<td>55~60</td>
</tr>
<tr>
<td>6&quot;</td>
<td>150 ± 0.25 x 0.625 ± 0.05</td>
<td>45~50</td>
</tr>
<tr>
<td>5&quot;</td>
<td>125 ± 0.25 x 0.625 ± 0.05</td>
<td>40~45</td>
</tr>
<tr>
<td>4&quot;</td>
<td>100 ± 0.25 x 0.53 ± 0.05</td>
<td>30~35</td>
</tr>
<tr>
<td>3&quot;</td>
<td>76.2 ± 0.25 x 0.43 ± 0.05</td>
<td>19~25</td>
</tr>
<tr>
<td>2&quot;</td>
<td>50.8 ± 0.25 x 0.33 ± 0.05</td>
<td>13~19</td>
</tr>
</tbody>
</table>

※ Specifications other than above are available.
※ Available sizes are dependent on a crystal orientation.

Semiconductor Process Equipment Parts

Application
(1) Carrier Plate
(2) Microwave Entrance Tube
(3) Dummy Water
(4) Handling Arm
(5) Vacuum Chuck
(6) Window

It is used as various Semiconductor Process Equipment due to its high anti-plasma and high anti-heat characteristics.

Application Examples

Optical Products for LCD Projectors

Characteristic values are subjected to change due to each specs or conditions.

Optical Products

Others
Optical Products for LCD Projectors

- **Application**
  1. Sapphire Plate
  - Polarizing Film Attached
  - Holder Assembled
  - Dichroic Filter
  2. LCD Projector
     - Dust Control Plate

- Sapphire material realizes high brightness and high picture quality for LCD projectors due to its high thermal conductivity and optical properties.

- Coating such as Dichroic Filter, to prevent reflection features is available.

- Standard sizes to fit in various LCD panels are available.

- **Selected Transmission Layer for Wave Length**

- **Optical Transmission**

- **AR Coat External Transmission**

- Characteristic values are subjected to change due to each specs or conditions.

Optical Products for LCD Projectors

- **Application**
  1. POS Scanner Window (SOG)
  2. Window
  3. Cap for Optical Communication
  4. Infrared Measuring Device Window
  5. Coin Sensor
  6. Lamp External Tube
     - High Pressure Sodium, Xenon, Ultra Pressure mercury
     - Metallic Halide
     - Light Emitting Window Accelerating Tube
  7. Light Receiving Window Accelerating Tube

- **Others**

- **Application**
  1. Fiber Bar Guide
  2. Insulating Plate and Rod
  3. Single Crystal Material Sheel Holder
  4. Biomaterial (BIOCERAM®)
  5. Watch Window
  6. NMR Protection Tube
  7. Thermocouple Protection Tube
  8. HDC Resonator Rod

Characters and measurements values are subjected to change due to each specs or conditions.