SINGLE CRYSTAL SAPPHIRE
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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.
SINGLE CRYSTAL SAPPHIRE

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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.

- 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.
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><strong>Dimensions</strong></td>
<td><strong>Crystal Orientation</strong></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 Kyocera’s Single Crystal Sapphire

- **Thermal Characteristics**
  - Coefficient of Linear Thermal Expansion
  - Specific Heat Capacity
  - Thermal Conductivity
  - Emittance

- **Electrical Characteristics**
  - Dielectric Constant
  - Volume Resistance
  - Dielectric strength
  - Dielectric Loss
  - Loss Factor
  - Dielectric Loss Angle

- **Mechanical Characteristics**
  - Tensile Strength
  - Flexural Strength
  - Vickers Hardness
  - Reference Density
  - Young's Modulus
  - Compressive Strength
  - Poisson’s Ratio

- **Optical Characteristics**
  - Optical Transmission
  - Index of Reflection
  - Optical Transmission vs. Temperature
  - Dielectric Loss vs. Frequency

<table>
<thead>
<tr>
<th>Wave Length (m)</th>
<th>Transmission (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td>90</td>
</tr>
<tr>
<td>600</td>
<td>80</td>
</tr>
<tr>
<td>700</td>
<td>70</td>
</tr>
<tr>
<td>800</td>
<td>60</td>
</tr>
<tr>
<td>900</td>
<td>50</td>
</tr>
<tr>
<td>1000</td>
<td>40</td>
</tr>
<tr>
<td>1100</td>
<td>30</td>
</tr>
<tr>
<td>1200</td>
<td>20</td>
</tr>
<tr>
<td>1300</td>
<td>10</td>
</tr>
<tr>
<td>1400</td>
<td>0</td>
</tr>
</tbody>
</table>

Hole diameter and standard pitch tolerance 0.25.

As-Grown Materials

Shapes other than above are available.
CHARACTERISTICS OF SINGLE CRYSTAL SAPPHIRE

- **Characteristics of Kyocera's Single Crystal Sapphire**
  - Crystallographic Structure: Hexagonal System, \( a = 4.763 \text{Å} \), \( c = 13.003 \text{Å} \); Rhombohedral Single crystal
  - Reference Density: 3.97 \( \times \) 10^2 kg/m^3
  - Vickers Hardness: 22.5 GPa (HV1 (Load = 9.807N))
  - Flexural Strength: 690 MPa
  - Tensile Strength: 2250 MPa
  - Compressive Strength: (Diameter 0.25mm Filament 25°C)
  - Young’s Modulus: 2.940 MPa
  - Poisson’s Ratio: 0.18 ~ 0.29
  - Melting Point: 2653°C
  - Coefficient of Linear Thermal Expansion:
    - Parallel to C Axis: 40 ~ 400°C (7.7 \( \times \) 10^-6/°C)
    - Perpendicular to C Axis: 7.0 \( \times \) 10^-6/°C
  - Thermal Conductivity: 20°C, 42W/(m°C)
  - Specific Heat Capacity: 0.75 J/(g°C)
  - Emittance: < 0.02 (\( \lambda = 2.6 ~ 3.7 \mu \text{m} 880°C \))
  - Dielectric strength: 48 \( \times \) 10^6 V/m
  - Volume Resistance: 20°C, \( > 10^{14} \Omega \cdot \text{cm} \)
  - Dielectric Constant:
    - Parallel to C Axis: 11.5 \( (1 \text{MHz}) \)
    - Perpendicular to C Axis: 9.3 \( (1 \text{MHz}) \)
  - Dielectric Loss Angle: < 1 \( (\times 10^{-4}) \) \( (1 \text{MHz}) \)
  - Loss Factor: \( > (\times 10^{-3}) \)
  - Dielectric Loss Tangent: \( 10^{-4} \) max.
  - Index of Reflection: \( n_o = 1.768 \), \( n_e = 1.760 \) \( @ 589 \text{nm} \)
  - Optical Transmission: Refer to Fig. 5

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

### Mechanical Characteristics
- **Nominal Dimension**: \( a \)
  - 1 > \( a \) ≤ 4
  - 4 \( < a \) ≤ 25
  - 25 \( < a \) ≤ 102
  - 102 \( < a \) ≤ 190
  - 190 < \( a \)

<table>
<thead>
<tr>
<th>Tolerance (±)</th>
<th>0.05</th>
<th>0.1</th>
<th>0.2</th>
<th>0.25</th>
<th>0.5</th>
<th>1</th>
</tr>
</thead>
</table>

Note: Machining accuracy: Tube 1.4, 10.4, and standard tube thickness tolerance ± 0.2.5. Hole diameter and standard pitch tolerance ± 0.1
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

- Application Examples

<table>
<thead>
<tr>
<th>Size</th>
<th>O.F. Length</th>
<th>Wave length(nm)</th>
<th>Transmission(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8”</td>
<td>φ200±0.25×0.725±0.05</td>
<td>400 450 500 550 600 650 700 750 800</td>
<td>55〜60</td>
</tr>
<tr>
<td>6”</td>
<td>φ150±0.25×0.625±0.05</td>
<td>400 425 450 475 500 525 550 575 600 625 650 675 700</td>
<td>45〜50</td>
</tr>
<tr>
<td>5”</td>
<td>φ125±0.25×0.625±0.05</td>
<td>400 425 450 475 500 525 550 575 600 625 650 675 700</td>
<td>40〜45</td>
</tr>
<tr>
<td>4”</td>
<td>φ100±0.25×0.53±0.05</td>
<td>400 425 450 475 500 525 550 575 600 625 650 675 700</td>
<td>30〜35</td>
</tr>
<tr>
<td>3”</td>
<td>φ76.2±0.25×0.43±0.05</td>
<td>400 425 450 475 500 525 550 575 600 625 650 675 700</td>
<td>19〜25</td>
</tr>
<tr>
<td>2”</td>
<td>φ50.8±0.25×0.33±0.05</td>
<td>400 425 450 475 500 525 550 575 600 625 650 675 700</td>
<td>13〜19</td>
</tr>
</tbody>
</table>

* Specifications other than above are available.
* Available sizes are dependent on a crystal orientation. Sizes and tolerances other than the above table are also available under customer requirements. Please contact or send your requirements to Kyocera.

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.

JP Patent No. 3091183, No.3443549

U.S. Patent No. 6577375, No.6642989
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

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
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

Standard sizes to fit in various LCD panels are available.