Single Crystal Products

SHINKOSHA
since 1947
Products

Shinkosha develops and manufactures high-performance single-crystal for optics and various fields with technologies based on its long experience and state of the art appliances.

- **Alumina single-crystals**
  - White sapphire single-crystals ($\text{Al}_2\text{O}_3$)
  - Ruby single-crystals ($\text{Cr}:\text{Al}_2\text{O}_3$)

- **High-function substrates**
  - Sapphire single-crystals ($\text{Al}_2\text{O}_3$)
  - Strontium titanate single-crystals ($\text{SrTiO}_3$)
  - Lanthanum strontium aluminum tantalate single-crystals
    ($\text{LaAlO}_3$)$_{0.5}$ - ($\text{SrAl}_2\text{O}_6\text{Ta}_2\text{O}_5$)$_{0.7}$ [Abbreviation LSAT]
  - Lanthanum aluminate single-crystals ($\text{LaAlO}_3$)
  - Magnesia single-crystals ($\text{MgO}$)
  - Neodymium gallate single-crystals ($\text{NdGaO}_3$)
  - Spinel single-crystals ($\text{MgAl}_2\text{O}_4$)
  - Yttria stabilized zirconia single-crystals ($\text{Y}:\text{ZrO}_2$) [Abbreviation: YSZ]
  - Titania (rutile) single-crystals ($\text{TiO}_2$)

- **Optical crystals**
  - Rutile single-crystals ($\text{TiO}_2$)

We provide crystal growth and precision processing services for special single-crystals.
Introducing single-crystal production methods

**Verneuil method** (Flame fusion method)

Raw material powder is passed through an oxygen-hydrogen flame (about 2,800 degrees Celsius) and melt down. The drips of molten materials are accumulated on a seed crystal and grow into a boule. This method makes it easy to produce crystals in a relatively short time. Since no crucible is used, the crystals have high purity.

**CZ method** (Czochralski method)

Materials are molten in a crucible. A seed crystal is put on the surface of molten materials in a crucible, and pulled up with rotation to grow. The major heating method is high-frequency induction heating or resistance heating. The CZ method is suitable for growing large and high-quality crystals.
Features of alumina single-crystals

Sapphire and Ruby are high-purity alumina (Al₂O₃) single-crystals with excellent resistance to abrasion, heat, and chemicals, as well as high thermal conductivity and insulating functions. They allow a wide range of wavelength, to pass through, from infrared to near-ultraviolet, and are used in a variety of applications including electronic and optical components.

### Characteristics

**Chemical composition**: Al₂O₃ (Sapphire) / Cr: Al₂O₃ (Ruby)

**Crystal systems**: Rhombohedral systems (R3c) (Generally handled as hexagonal crystals)

**Lattice constant**: a=0.47588nm  c=1.2992nm

**Density**: 3.987g/cm³

**Melting point**: 2,040°C (WPOE No. 42-168)

**Thermal conductivity**: 42W/m·K (28°C)

25W/m·K (100°C)

**Specific heat**: 0.755kJ/kg·°C (29°C)

**Thermal expansion coefficient**: (°C axis)

6.8X10⁻⁶°C (200°C)
8.3X10⁻⁶°C (1000°C)

(/°C axis)

7.5X10⁻⁶°C (200°C)
10.0X10⁻⁶°C (1000°C)

**Chemical resistance** (dissolved weight): (In sapphire specimen 25x20x0.0 was put in a solution for 6 days)

No change in weight (Δ=0g).

- HCl (36%, 20°C)
- HNO₃ (50%, 20°C)
- H₂PO₄ (50%, 100°C)
- H₂SO₄ (98%, 100°C)
- NaOH (30%, 100°C)

Micro change in weight

HF (48%, 60°C)

(Δ=0.0009g/day)

**Dielectric constant**: 9.41 (/c-axis, 500Hz)

**Dielectric loss**: 3X10⁻¹ (/c-axis, 300Hz)

**Resistivity**: 10¹⁴Ωcm (28°C)
10¹⁰Ωcm (500°C)
10³Ωcm (100°C)
10³Ωcm (100°C)

**Threshold voltage**: 480 kV/cm (60Hz)

**Hardness**: √Mohs 9 (√Diamond=10, Quartz=7)

√Vickers 1400~2300
(e.g. : a-plane 1750)

**Young’s modulus**: 425GPa (√c)
460GPa (/c)

**Poisson ratio**: 0.30 (√c / √c)
0.18 (/c / /c)
0.18 (√c / /c)

**Bending strength**: 320~930MPa

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### Fig. 1 Transmittance diagram of sapphire

### Fig. 2 Plane orientation drawing of sapphire
Applications of alumina single-crystals

1. Sapphire substrates
Precision-polished substrates of sapphire single-crystals are used in a wide range of applications: blue LED and LD devices, SAW (surface acoustic wave) devices, and SOS (silicon-on-sapphire) wafers which are alternative to SOI (silicon insulators) for semiconductors in high-reliability equipments.

2. Sapphire laser caps
A laser cap is a window material for airtight packages, which protects semiconductor laser devices from degradation. Sapphire laser caps are used in systems that need high reliability, including submarine optical communications systems. Shinkosha's laser caps have very excellent polished surface precision. We accept orders for special or demanding specifications, too.

3. Alumina single-crystal evaporation material
Alumina single-crystal evaporation material is for forming evaporated films. This material is useful, when a high-quality evaporated film is required, because of its high purity and small amount of gas generation. For this reason, this material is optimal for evaporation coating of semiconductor parts.

4. Alumina single-crystal polisher (Product name: S-Powder)
S-Powder is high-purity alumina powder. The micro particles have an even grain size, and are free of sharp edges, unlike fused alumina polishers. S-Powder is used for ultra-precision finishing of metal products, polishing of lenses and semiconductors, and as chemical catalyst carriers.

5. Windows for watches
Alumina single-crystal is used as window materials for watches because of its scratch resistance owing to its high hardness.

6. Others
Analytic sapphire cells / endoscope glasses for medical use / ultra-microtomes for medical use / erythrocyte measurement disks / sight glasses for high-temperature, pressure furnaces / sight glasses for semiconductor production equipment / sight glasses for vacuum containers / xenon lamp windows / cooling plates for LCD projectors / infrared transmittance windows (gas sensors and fire sensors) / coin sensors / mode selectors / ruby plungers / magnetic tape cleaners / insulator plates / thermocouple protector plates / optical R-processed prisms / ball lenses / sapphire tubes / spinning guides / bearing jewels, etc.

Upon customers' request, we accept orders for special and consigned processing of various single- and poly-crystals.
Features of high-function substrates

Shinkosha supplies oxide single-crystal substrates that are suitable for epitaxial growth of superconductors, compound semiconductors, and dielectrics. Please choose the best substrate material for your requirements - the crystal type, lattice constant and dielectric constant. With high-precision processing technologies, we ensure the high quality of finished substrate surfaces. We can also provide specific substrates by combining standard specifications with a variety of options.

Characteristics

<table>
<thead>
<tr>
<th>Crystal names</th>
<th>Structural lattice constant (A)</th>
<th>Fusing point (°C)</th>
<th>Dielectric constant (300K, 1MHz)</th>
<th>Specific gravity (g/cm³)</th>
<th>Thermal expansion coefficient (10⁻⁶/°C)</th>
<th>Remarks on applications</th>
<th>Standard substrate surface</th>
<th>Maximum shape</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃ (Sapphire)</td>
<td>Trigonal a=4.7688 c=12.992</td>
<td>2040</td>
<td>9.41 (30GHz)</td>
<td>3.99</td>
<td>7.5</td>
<td>Gallium substrates</td>
<td>(0001)</td>
<td>GauN</td>
<td>SAW devices</td>
</tr>
<tr>
<td>MgAl₂O₄ (Spinel)</td>
<td>Cubic a=8.088</td>
<td>2130</td>
<td>8-9</td>
<td>3.61</td>
<td>7.8</td>
<td>Gallium substrates</td>
<td>(111)</td>
<td>GaN</td>
<td>(100)</td>
</tr>
<tr>
<td>(La,Mg)₂O₃ (LSAT)</td>
<td>Cubic a=7.736</td>
<td>1840</td>
<td>22</td>
<td>6.79</td>
<td>10</td>
<td>Superconductor substrates</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(0001)</td>
</tr>
<tr>
<td>LaAlO₃ (LAO)</td>
<td>Rombohedral a=5.365 c=13.11</td>
<td>2100</td>
<td>15-22</td>
<td>6.52</td>
<td>12.6</td>
<td>Superconductor substrates</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(0001)</td>
</tr>
<tr>
<td>NdGaO₃ (NGO)</td>
<td>Orthorhombic a=5.431 b=5.499 c=7.19</td>
<td>1650</td>
<td>20-25</td>
<td>7.56</td>
<td>10</td>
<td>Superconductor substrates</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(0001)</td>
</tr>
<tr>
<td>SrTiO₃ (STO)</td>
<td>Cubic a=3.905</td>
<td>2080</td>
<td>310</td>
<td>11.1</td>
<td>11.1</td>
<td>Superconductor substrates</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(111)</td>
</tr>
<tr>
<td>MgO</td>
<td>Cubic a=4.213</td>
<td>2800</td>
<td>10</td>
<td>3.59</td>
<td>13.5</td>
<td>Superconductor substrates</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(100)</td>
</tr>
<tr>
<td>Y₂Zr₂O₇ (YSZ)</td>
<td>Cubic a=5.139</td>
<td>2500</td>
<td>27</td>
<td>6.05</td>
<td>10.3</td>
<td>Superconductor substrates</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(001)</td>
</tr>
<tr>
<td>TiO₂ (Rutile)</td>
<td>Tetragonal a=4.594 c=2.958</td>
<td>1840</td>
<td>113 (1KHz)</td>
<td>4.25</td>
<td>9.2</td>
<td>Photocatalyst prism polarizers</td>
<td>(100)</td>
<td>Superc conductivity</td>
<td>(001)</td>
</tr>
</tbody>
</table>

Light catalytic polymers
Standard specifications of high-function substrates

Standard shape: (depends on material)
- 10×10×0.5 mm
- 15×15×0.5 mm
- 50.8×50.8 mm
- Others: 50.8×0.33 mm

Standard outline tolerance: ±0.10 mm or more
Standard thickness tolerance: ±0.05 mm
Crystal axis tolerance: ±0.5°
Orientation flat surface tolerance: ±1°
Polishing: Single- and double-side polishing

(Circular substrate)

Substrate surface
Orientation flat direction

(Rectangular substrate)

Substrate surface
C 1.0 (Both-side polish, OFF substrates)
C 0.5 (Single-side polish substrates)
Orientation flat direction

Flatness: 10λ/λ/10 (λ=528.8 nm)
* Depends on substrate size and material.

Surface roughness: (Guaranteed value) Ra ≤ 1.0 nm, Rmax ≤ 5.0 nm
(Typical value) Ra ≤ 0.2 nm, Rmax ≤ 1.0 nm
* Measurement range: 1 μm²

Sapphire (0001)
Microscopic image of 10×10×0.5t substrate laser interference

Sapphire
AFM (atomic force microscope) photo of substrate surface
**Special specifications**

**SPECIAL SPECIFICATIONS** Molecular layer STEP substrates

The surface of a STEP substrate is composed of molecular layer steps and atomic level flat terraces. For Perovskite-type crystals, outermost atomic layers have a uniform site in either A or B with high cleanliness.

**Model of molecular layer steps**

**Cross-section profile of sapphire c-plane molecular layer step substrates**

<table>
<thead>
<tr>
<th>Types</th>
<th>Orientation</th>
<th>Crystal axis precision (degrees)</th>
<th>Size (mm)</th>
<th>Roughness on terrace surface (Ry, nm)</th>
<th>Step height (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al_{2}O_{3}</td>
<td>(0001) (1120) (0112)</td>
<td>$\leq 0.5$</td>
<td>$\leq 0.1016$</td>
<td>$\leq 0.05$</td>
<td>0.21 0.25 0.35</td>
</tr>
<tr>
<td>LaAlO_{3}</td>
<td>(100)</td>
<td>$\leq 0.5$</td>
<td>$\leq 0.508$</td>
<td>$\leq 0.05$</td>
<td>0.4</td>
</tr>
<tr>
<td>SrTiO_{3}</td>
<td>(100)</td>
<td>$\leq 0.5$</td>
<td>$\leq 0.20$</td>
<td>$\leq 0.05$</td>
<td>0.4</td>
</tr>
</tbody>
</table>
**Sapphire laser caps**

- Optimal strength for high-reliable component (five times stronger than glass).
- No deterioration caused by high power laser output.
- Excellent radiation performance (thermal conductivity) by 40 times of glass.
- No variation in extinction ratio by strict control of c-axis.
- Specially shaped items are available including box-shaped windows and tapered types.
- High transmission by superb AR coating.
- High airtightness and strength by superb metalization coating.
- Available to join with the Kovar ring.

**Sapphire axis specification**

<table>
<thead>
<tr>
<th>Method</th>
<th>Diameter</th>
<th>Thickness</th>
<th>Type of Metalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>V:Verneuil</td>
<td>36</td>
<td>30</td>
<td>Thin film (Cr-Ni-Au)</td>
</tr>
<tr>
<td>C:CZ</td>
<td></td>
<td></td>
<td>Mo/Mn Metalization (Mo/Mn-Ni-Au)</td>
</tr>
<tr>
<td>A:Random</td>
<td></td>
<td></td>
<td>No coating</td>
</tr>
</tbody>
</table>

**For your reference**

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>OD (D)</th>
<th>Thickness (T)</th>
<th>Metalized ID (M)</th>
<th>AR OD (A)</th>
<th>AR OD (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2828</td>
<td>ø2.8±0.05</td>
<td>0.28±0.05</td>
<td>ø2.0±0.15</td>
<td>ø1.70±0.1</td>
<td>ø2.2±0.1</td>
</tr>
<tr>
<td>3328</td>
<td>ø3.3±0.05</td>
<td>0.28±0.06</td>
<td>ø2.3±0.15</td>
<td>ø2.00±0.1</td>
<td>ø2.5±0.1</td>
</tr>
<tr>
<td>3928</td>
<td>ø3.5±0.05</td>
<td>0.28±0.05</td>
<td>ø2.5±0.15</td>
<td>ø2.25±0.1</td>
<td>ø2.8±0.1</td>
</tr>
<tr>
<td>3628</td>
<td>ø3.6±0.05</td>
<td>0.28±0.05</td>
<td>ø2.5±0.15</td>
<td>ø2.25±0.1</td>
<td>ø2.8±0.1</td>
</tr>
<tr>
<td>3630</td>
<td>ø3.6±0.05</td>
<td>0.30±0.05</td>
<td>ø2.5±0.15</td>
<td>ø2.25±0.1</td>
<td>ø2.8±0.1</td>
</tr>
<tr>
<td>4228</td>
<td>ø4.2±0.05</td>
<td>0.28±0.05</td>
<td>ø3.3±0.15</td>
<td>ø3.00±0.1</td>
<td>ø3.4±0.1</td>
</tr>
</tbody>
</table>
Optical crystals

Features of rutile single-crystals

Rutile single-crystals have a large refractive index and high birefringence, and are therefore suitable for optical applications including polarizers and polarizing prisms. The rutile single-crystals also exhibit high thermal and chemical stability. We produce and process high-quality rutile single-crystals with few crystal defects. We meet customers’ demands for a wide range of rutile single-crystal applications, including AR coating, specific products and large products.

[Rutile features]

- Crystal system: Tetragonal system
- Lattice constant: $a=4.594\,\text{Å}$
  
  $c=2.958\,\text{Å}$

  $a=0.1\,\text{mm}$

- Density: $4.26\,\text{g/cm}^3$
- Fusing point: $1840\,\text{°C}$
- Hardness (Mohs): 6.5

<table>
<thead>
<tr>
<th>Birefringence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rutile refractive index</td>
</tr>
<tr>
<td>Approximate polynomial in Wavelength (nm)</td>
</tr>
<tr>
<td>$n = A_1 + A_2 \lambda + A_3 \lambda^2 + A_4 \lambda^3 + A_5 \lambda^4 + A_6 \lambda^5$</td>
</tr>
<tr>
<td>Coefficient value</td>
</tr>
<tr>
<td>$A_1 = 7.240917163 \times 10^{-1}$</td>
</tr>
<tr>
<td>$A_2 = 2.938424313 \times 10^{-3}$</td>
</tr>
<tr>
<td>$A_3 = -2.70507824 \times 10^{-6}$</td>
</tr>
<tr>
<td>$A_4 = -3.944927718 \times 10^{-9}$</td>
</tr>
<tr>
<td>$A_5 = 2.77526405 \times 10^{-12}$</td>
</tr>
<tr>
<td>$A_6 = -2.904206886 \times 10^{-15}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Refractive index</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_{o}$: Ordinary ray (o-ray)</td>
</tr>
<tr>
<td>$n_{e}$: Extraordinary ray (e-ray)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison with other crystals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Thermal expansion coefficient (°C)</td>
</tr>
<tr>
<td>c-axis</td>
</tr>
<tr>
<td>a-axis</td>
</tr>
<tr>
<td>Refractive index @1.55μm</td>
</tr>
<tr>
<td>$n_{o}$</td>
</tr>
<tr>
<td>$n_{e}$</td>
</tr>
<tr>
<td>Birefringence @1.55μm</td>
</tr>
<tr>
<td>0.250</td>
</tr>
<tr>
<td>Hardness in mohs</td>
</tr>
<tr>
<td>6.5</td>
</tr>
</tbody>
</table>