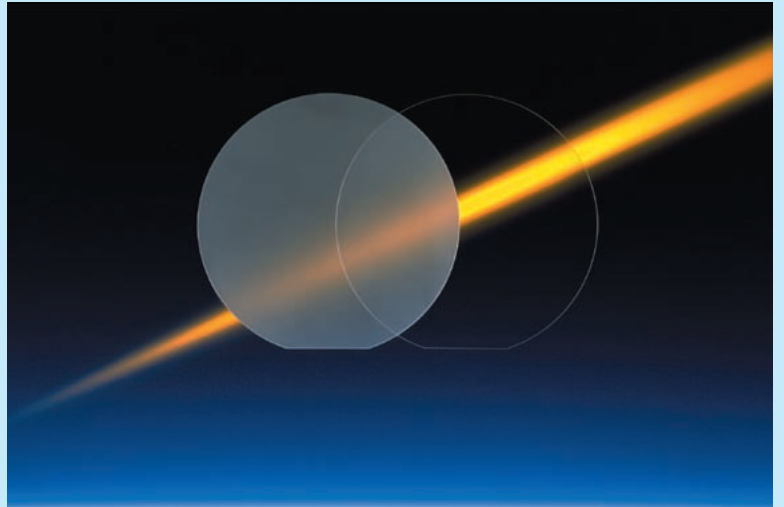


THE NEW VALUE FRONTIER



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# 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**

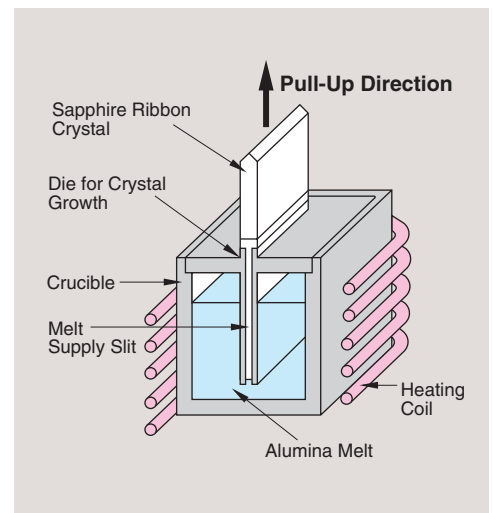
Sizing-up of materials allows for a broader range of applications and uses.

- **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.



EFG Method



## CONTENTS

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| SAPPHIRE MANUFACTURING PROCESS.....             | P3    |
| CHARACTERISTICS OF SINGLE CRYSTAL SAPPHIRE..... | P4    |
| SAPPHIRE PRODUCTS.....                          | P5~P6 |

## 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**

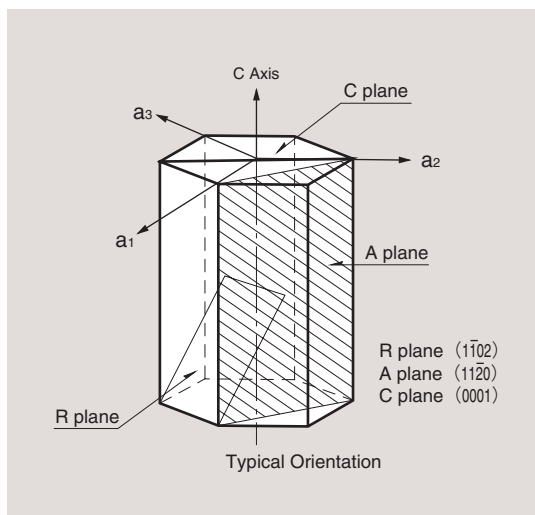
Single Crystal Sapphire is used as a material for substrates in super-high frequency regions. It is also used as an insulation material and microwave window. Single Crystal Sapphire has become indispensable in the Electronics Industries.

- **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.

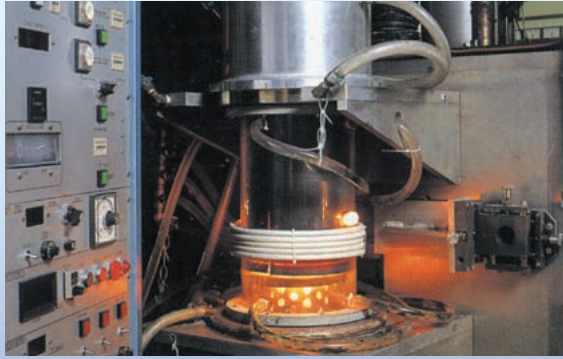


Unit Cell of Sapphire

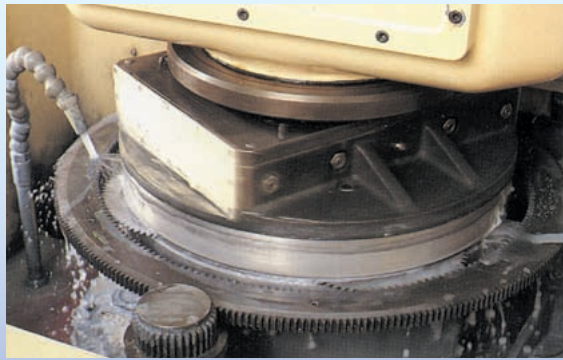
## SAPPHIRE MANUFACTURING PROCESS

### Sapphire Manufacturing Process

#### Growth of Raw Material



#### Grinding

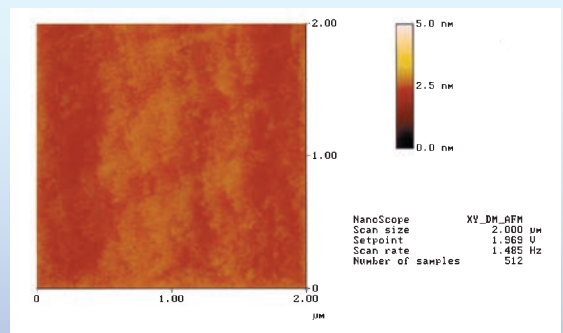


#### Lapping



#### Polishing

(Ra:  $\leq 1 \text{ \AA}$ )



### Shape and Specifications

(unit: mm)

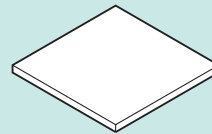
#### Substrate

##### Dimensions

Width 200max.  
Length 300max.  
Thickness 0.1~20

##### Crystal Orientation

R plane  $\pm 2^\circ$   
A plane  $\pm 2^\circ$   
C plane  $\pm 2^\circ$



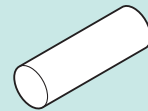
#### Rod

##### Dimensions

Diameter 0.5~20  
Length 1,000max.

##### Crystal Orientation

C Axis in  
Longitudinal  
Direction



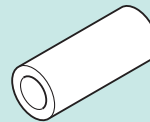
#### Tube

##### Dimensions

Inner Diameter 1.3~50  
Tube Thickness 0.25~5  
Length: 1,000mm max.

##### Crystal Orientation

C Axis in  
Longitudinal  
Direction



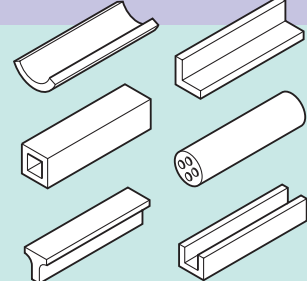
#### Others

##### Dimensions

To be  
Customized

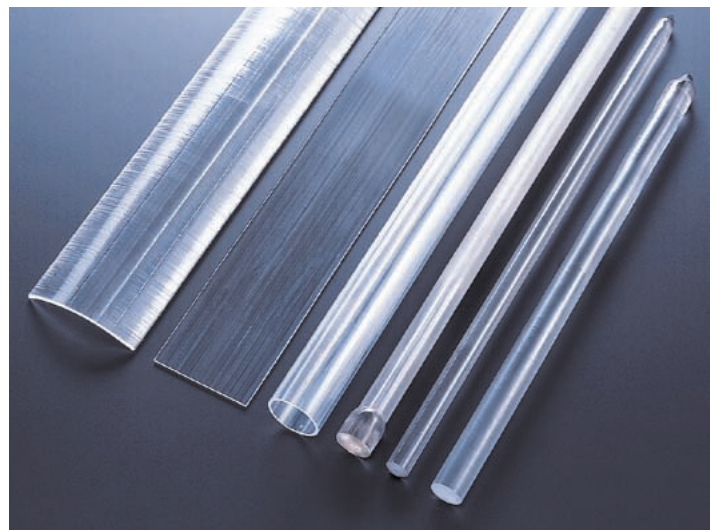
##### Crystal Orientation

To be  
Customized



※Shapes other than above are available.

### As-Grown Materials



## CHARACTERISTICS OF SINGLE CRYSTAL SAPPHIRE

### Characteristics of Kyocera's Single Crystal Sapphire

|                            |                                         |                                                                                                                                   |
|----------------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| Mechanical Characteristics | Crystallographic Structure              | Hexagonal System $a=4.763\text{\AA}$<br>$c=13.003\text{\AA}$<br>Rhombohedral Single crystal                                       |
|                            | Reference Density                       | $3.97 \times 10^3 \text{ kg/m}^3$                                                                                                 |
|                            | Vickers Hardness                        | 22.5GPa (HV1 (Load=9.807N))                                                                                                       |
|                            | Flexural Strength                       | 690MPa                                                                                                                            |
|                            | Tensile Strength                        | 2250MPa<br>(Diameter 0.25mm Filament 25°C)                                                                                        |
|                            | Compressive Strength                    | 2,940MPa                                                                                                                          |
|                            | Young's Modulus                         | 470GPa                                                                                                                            |
|                            | Poisson's Ratio                         | 0.18~0.29                                                                                                                         |
| Thermal Characteristics    | Melting Point                           | 2,053°C                                                                                                                           |
|                            | Coefficient of Linear Thermal Expansion | 40~400°C C parallel to C axis $7.7 \times 10^{-6}/\text{°C}$<br>40~400°C C perpendicular to C axis $7.0 \times 10^{-6}/\text{°C}$ |
|                            | Thermal Conductivity                    | 20°C 42W/(m·K)                                                                                                                    |
|                            | Specific Heat                           | $0.75 \times 10^3 \text{ J/(kg·K)}$                                                                                               |
|                            | Emittance                               | <0.02<br>( $\lambda=2.6\sim 3.7\mu\text{m}$ 880°C)                                                                                |
| Electrical Characteristics | Dielectric strength                     | $48 \times 10^6 \text{ V/m}$                                                                                                      |
|                            | Volume Resistance                       | 20°C $>10^{14} \Omega \cdot \text{cm}$<br>500°C $10^{11} \Omega \cdot \text{cm}$                                                  |
|                            | Dielectric Constant                     | C parallel to C axis 11.5 (1MHz)<br>C perpendicular to C axis 9.3 (1MHz)                                                          |
|                            | Dielectric Loss Angle                   | $<1 (\times 10^{-4})$ (1MHz)                                                                                                      |
|                            | Loss Factor                             | $— (\times 10^{-4})$                                                                                                              |
|                            | Dielectric Loss Tangent                 | $10^{-4}$ max.                                                                                                                    |
| Optical Characteristics    | Index of Refraction                     | No=1.768<br>Ne=1.760 @589nm                                                                                                       |
|                            | Optical Transmission                    | Refer to Fig.5                                                                                                                    |

※ These figures are representative.

※ Each Crystal Orientation has different characteristics.

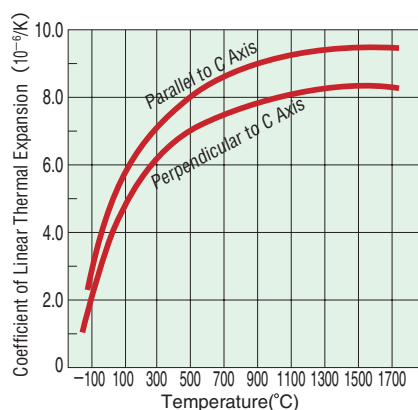


Fig. 1 Thermal Expansion vs. Temperature

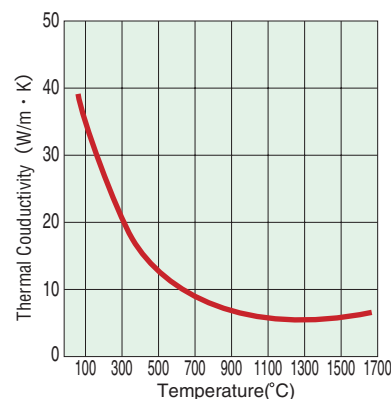


Fig. 2 Thermal Conductivity vs. Temperature

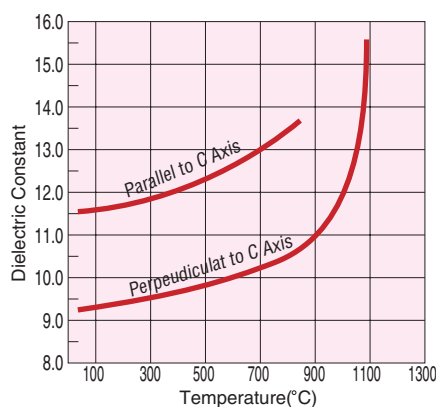


Fig. 3 Dielectric Constant vs. Temperature

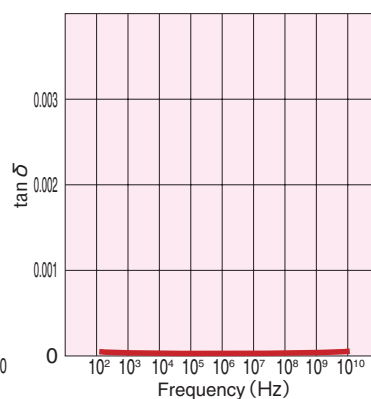


Fig. 4 Dielectric Loss vs. Frequency

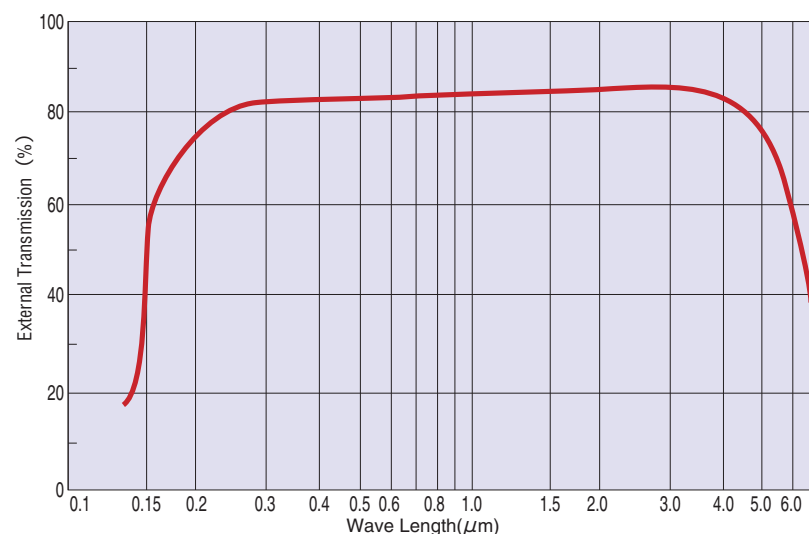


Fig. 5 Transmission vs. Wave Length

NOTE: • Transmittance range varies depending on thickness of Sapphire Products.

• Interfacial Reflection included

• Thickness 1mm.

(Unit:mm)

### Standard Dimensional Tolerance

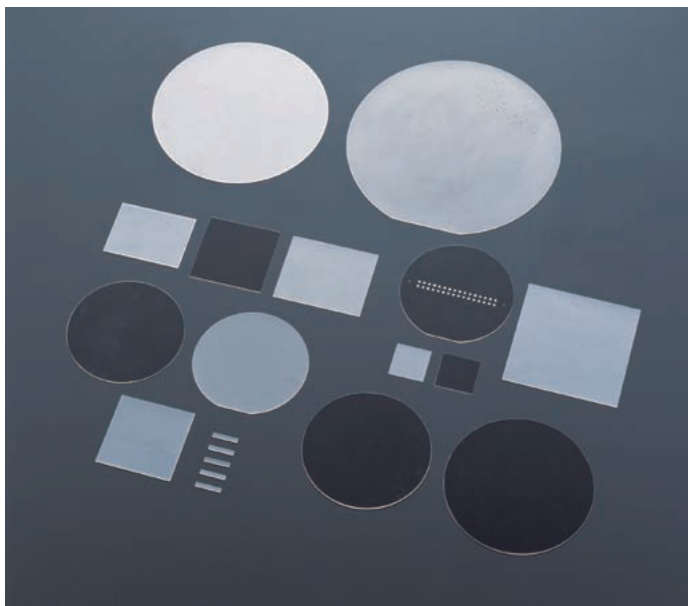
| Nominal Dimension<br>: a | $1 > a$ | $1 \leq a \leq 4$ | $4 < a \leq 25$ | $25 < a \leq 102$ | $102 < a \leq 190$ | $190 < a$ |
|--------------------------|---------|-------------------|-----------------|-------------------|--------------------|-----------|
| Tolerance<br>(±)         | 0.05    | 0.1               | 0.2             | 0.25              | 0.5                | 1         |

● Machining accuracy: Tube 1.A.10.A. and standard tube thickness tolerance...  $\pm 0.25$ .

Hole diameter and standard pitch tolerance...  $\pm 0.1$

## 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



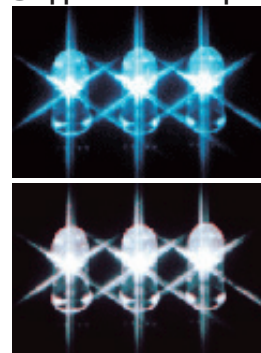
#### Standard Dimension and Tolerance

|    | Size                                      | O.F. Length |
|----|-------------------------------------------|-------------|
| 8" | $\phi 200 \pm 0.25 \times 0.725 \pm 0.05$ | 55~60       |
| 6" | $\phi 150 \pm 0.25 \times 0.625 \pm 0.05$ | 45~50       |
| 5" | $\phi 125 \pm 0.25 \times 0.625 \pm 0.05$ | 40~45       |
| 4" | $\phi 100 \pm 0.25 \times 0.53 \pm 0.05$  | 30~35       |
| 3" | $\phi 76.2 \pm 0.25 \times 0.43 \pm 0.05$ | 19~25       |
| 2" | $\phi 50.8 \pm 0.25 \times 0.33 \pm 0.05$ | 13~19       |

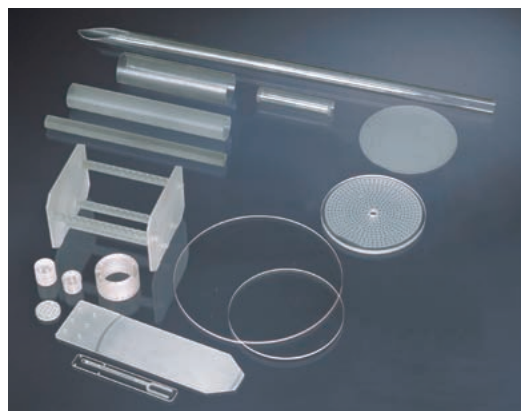
※ Specifications other than above are available.

※ 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.

#### Application Examples

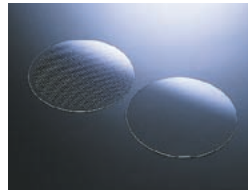


### Semiconductor Process Equipment Parts



#### Application

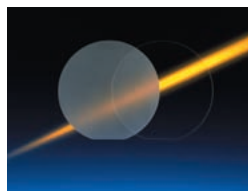
- (1) Carrier Plate
  - (2) Microwave Entrance Tube
  - (3) Dummy Water
  - (4) Handling Arm
  - (5) Vacuum Chuck
  - (6) Window
- It is used as various Semiconductor Process Equipment due to its high anti-plasma and high anti-heat characteristics.



(1)



(2)



(3)



(4)

## Optical Products for LCD Projectors



JP Patent No. 3091183, No.3443549  
U.S. Patent No. 6577375, No.6642989

### Application

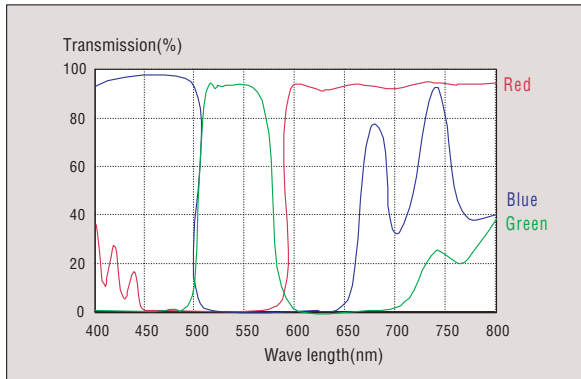
- (1) Sapphire Plate
  - Polarizing Film Attached
  - Holder Assembled
  - Dichroic Filter
- (2) LCD Projector
  - Dust Control Plate

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

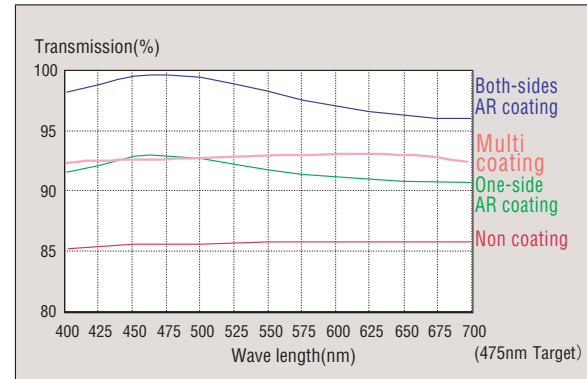
● Coating such as Dichroic Filter, to prevent reflection features is available.

● 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



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