KYOCERA

Fine Ceramics in Space

Customized ceramic technology for satellite components, space observation and astronomy

KYOCERA – it all started with ceramics

Our first product was a U-shaped ceramic insulator used in early television picture tubes. It was made in a small suburban workshop in 1959 when 28 young colleagues started the company with big dreams. Today Kyocera is a highly diversified global enterprise with over 75,500 employees. The company is one of the world leaders in the manufacturing of ceramic components and products, with an extensive range of applications. Kyocera now provides over 200 kinds of ceramic materials including oxide, non-oxide and some special composites, with cutting edge technology and services designed to meet the individual needs. Our long-standing experience in the field of ceramics is applied in the production of very precise, high quality products used in multiple fields.

Our strength – wide variety of customized ceramic materials

ALUMINA

Alumina is the most widely used material among fine ceramics, and exists under two distinct structures: polycrystal (sintered alumina) or monocrystal (sapphire). Its applications are diverse due to its superb properties such as high insulation, high strength, high wear resistance and chemical resistance.

SILICON NITRIDE

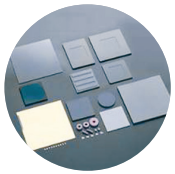
Silicon nitride is a material with excellent specific strengths and very good thermal shock resistance up to application temperatures of 1600°C. The low thermal expansion in combination with high stiffness, strength and fracture toughness qualifies the material especially for applications where abrasion is a major problem. Typical applications are parts for mining, milling, mixing and oil and gas industry.

SILICON CARBIDE

Silicon carbide retains its strength at elevated temperatures as high as 1400°C. In its sintered form (sintered SiC – SSiC) it features high corrosion resistance. As silicon-infiltrated SiC – SiSiC, high precision parts with fine detailed and complex structures can be manufactured. Applications include mechanical seals, pump parts, semiconductor equipment related frame and structural components.

ZIRCONIA

Zirconia offers high strength and toughness. Before zirconia, ceramics were considered impractical for scissors or knife applications. With its excellent properties, zirconia is also used for engineering applications such as pumps.



SPECIAL CERAMICS

Our portfolio also includes other ceramics such as aluminum nitride, aluminium titanate, single crystal sapphire, ferrites, dielectric ceramics and special materials like cordierite. Each of the materials has a customized application.

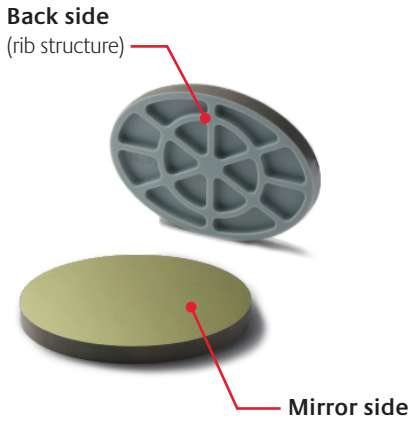
Space & Astronomy materials

Cordierite (CO720)

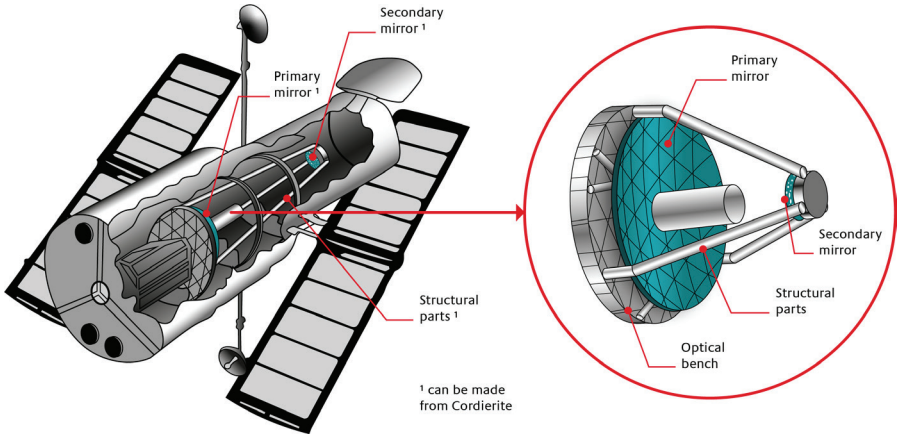
Cordierite is an extremely low thermal expansion ceramic which was developed over two decades back, and we have been constantly improving on its characteristics since.

Characteristics

- **Minimal temperature deformation** due to unique material composition with an extremely low thermal expansion rate
- **Approx. 70% weight reduction** when compared to low CTE glass* with a slim ribbed structure design featuring high rigidity
- **Rapid process time** even for complex designs due to good machinability

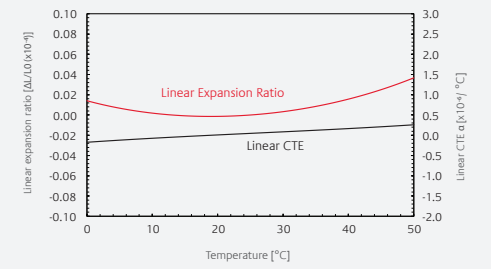


Structural parts made of ceramics in a satellite



*based on Kyocera's research

Temperature dependency graph <Cordierite CO720>



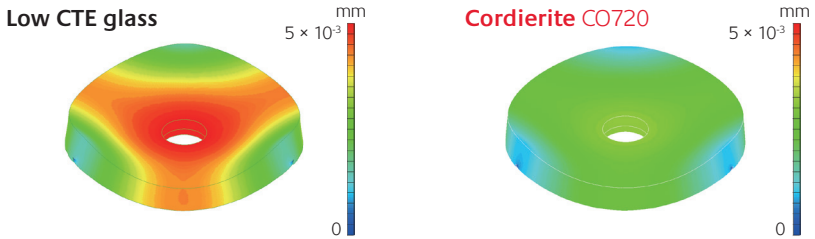
Material characteristics comparison with Low CTE glass

	Low CTE glass	Cordierite CO720
Density [g/cm³]	2.53	2.55
CTE** [ppm/K]	0.02	0.02
Elasticity modulus [GPa]	90	145
Specific rigidity	36	57

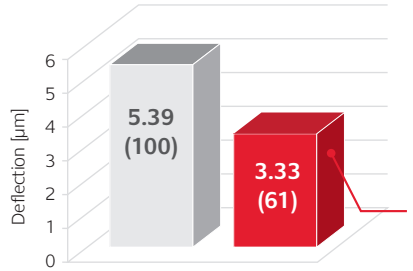
The values are typical material properties and may vary according to product configuration and manufacturing process.

**temperature dependency graph

Displacement map***



3-point supported deflection***



Low CTE glass vs. **Cordierite** CO720

Comparison conditions:

- Product size: ø1020 x 120mm (rib structure)
- Supported points: outside 3 points
- Load: self-weight

approx. 40% improvement

***based on Kyocera's research

Silicon-infiltrated Silicon Carbide (SiSiC)

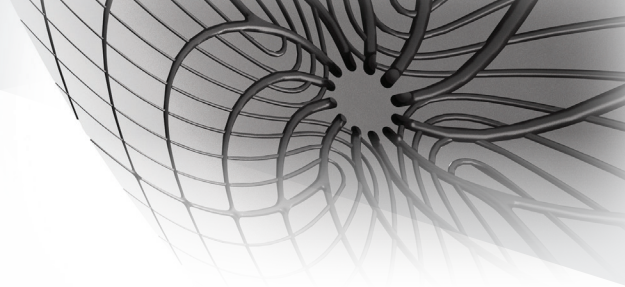
Proprietary joining and manufacturing technology combined with our excellent StarCeram® materials enables high precision components with unique design features.

- Hidden internal cavities possible (e.g. cooling channels)
- Complex and fine detailed structures below 1mm achievable
- Large-scale parts monolithically up to 950mm x 950mm x 650mm and larger via proprietary joining technologies
- High strength, extreme stiffness and reliability components at lowest weight
- Joining areas with identical material properties, such as E Modulus and strength

Characteristics

- **Closed porosity** for water and gas tightness requirements
- **Superior impurity levels** by utilization of semiconductor grade constituents
- **Extremely homogeneous material** through large-scaled part

	StarCeram® Si SiSiC
SiC	> 85 wt%
Si	balance
Cu	< 3 ppm



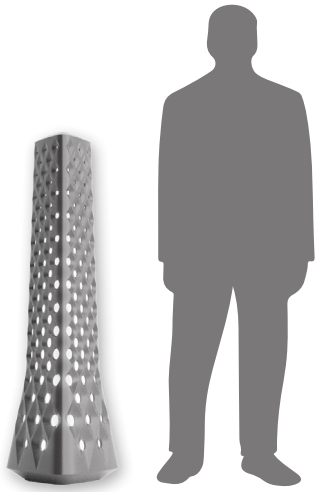
Silicon Carbide (SiC)

- **Excellent chemical resistance** from basic to acidic materials allowing applications in harsh environments
- **Large-scaled parts** with outstanding high-temperature performance answering the demanding needs of the aerospace industry

Chemical resistance

Material characteristics

	StarCeram® S SSiC	StarCeram® Si SiSiC
Density [g/cm³]	3.13	3.05
Fracture strength RT [MPa]	375	300
Young's modulus RT [GPa]	395	380
Thermal conductivity RT [W/mK]	125	200
CTE (RT -1000C°) [$x10^{-6}K^{-1}$]	4.5	4.0
Resistivity RT [Ωm]	10^{4}	10^{-2}
Thermal shock coefficient R1 [K]	180	190
Max. working temperature [°C]	1600	1350



Alumina (Al_2O_3) and Zirconia (ZrO_2)

Kyocera's oxide ceramics display operational safety, reliability and long lifetime based on the following physical characteristics:

- Mechanical strength
- High chemical resistance
- Good thermal shock resistance at high and low temperatures
- Good thermal conductivity
- Excellent electrical resistance
- Low dielectric loss at high frequency

Brazed oxide ceramic-to-metal assemblies outreach the excellent properties of ceramics and metal. Ceramics show electrical insulation; metal components feature weldability. This advantageous combination enables a wide range of vacuum, high-voltage and high-pressure applications.

	Alumina F99.7 α-Al_2O_3	Zirconia FZM ZrO_2 MgO
Purity [wt-%]	> 99.7	> 99.7
Apparent density [g/cm³]	≥ 3.90	≥ 5.70
Bending strength [N/mm² (MPa)]	350	500
Maximum operating temperature [°C]	1950	900

Space & Astronomy applications

Camera lens spacer

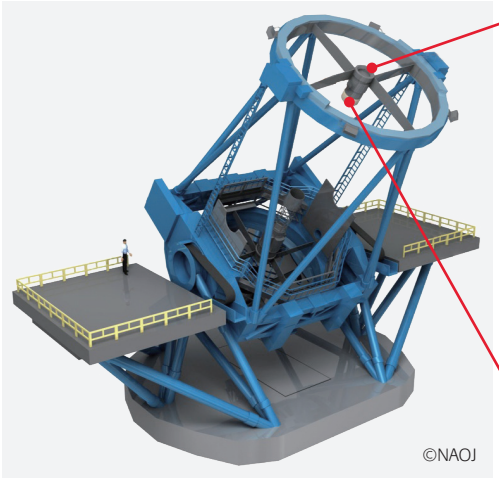
Subaru Telescope is an 8.2-meter (320 in) optical-infrared flagship telescope operated by the National Astronomical Observatory of Japan (NAOJ), located at the Mauna Kea Observatory on Hawaii.

In 2012, when NAOJ installed a new super wide angle camera "Hyper Suprime-Cam (HSC)" into the SUBARU Telescope, there were two design requirements for adaptive optics. One was to make a larger lens aperture and the other was to make the lens lighter.

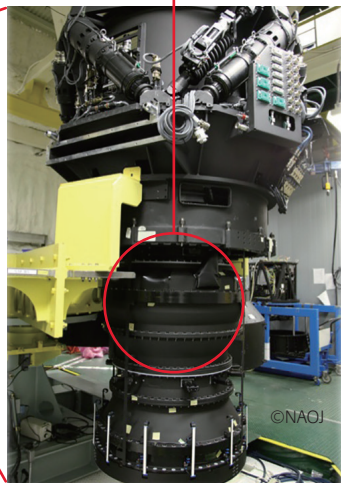
Kyocera's cordierite was chosen as the best material to achieve the two design requirements for the lens support. Cordierite's superior characteristics enabled a slim design with enough material strength and rigidity to support the lens structure as well as minimal deformation due to temperature fluctuations.

Lens support made by Kyocera's Low CTE ceramic
Cordierite CO720

SUBARU Telescope support structure



HSC module



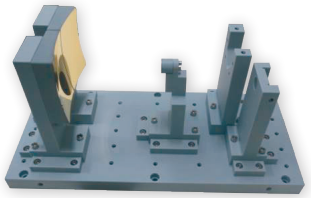
Optical systems including mirrors

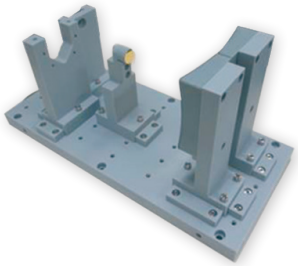
We have developed diffraction-limited off-axis reflective optical systems (mirrors, mirror holders, and optical benches) made entirely of cordierite materials, with Kyocera's high accuracy assembling technology.

Cordierite was used as it has a great "athermal property" whereby the optical performance does not degrade under varying temperature conditions owing to its monoclinic nature. We were able to process this extremely low thermal expansion ceramic to include cordierite mirrors coated with metal (Au), as seen in the pictures. Alternatively, larger cordierite mirrors of over 1 meter diameter, can be produced with a light weight design and the required surface roughness.

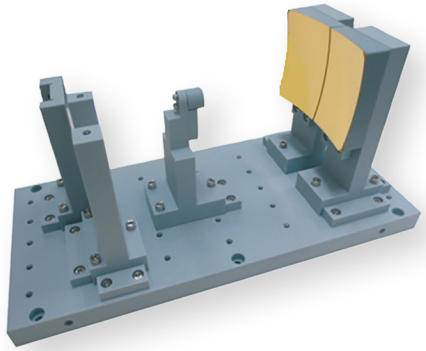
Such structures are expected to be installed in large telescopes (30 meters) and space telescopes in the coming years.

Optical bench from different perspectives





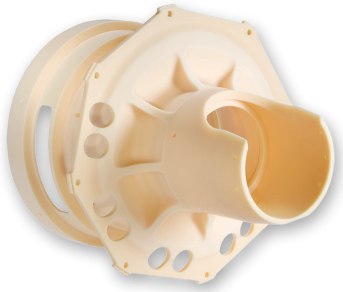
KYOTO SANGYO UNIVERSITY

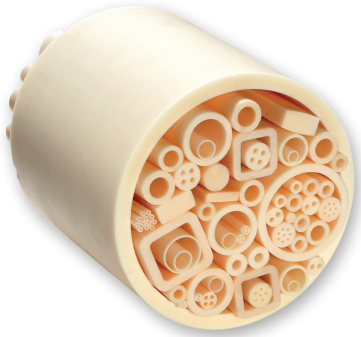


Camera housing made of F99.7

for aerospace industry

In-house 5-axis CNC machining supported by ultrasonic processing allows the manufacture of complex components such as camera housing. The permeability of ceramics for electromagnetic radiation takes effect in this type of application: the electromagnetic waves of the sensors inside the housing can pass through to the outside, while radar beams from outside are hardly reflected thus impeding detection of aircraft.



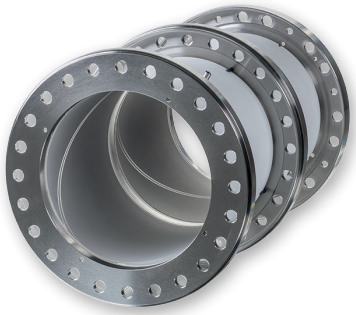


Insulators for ion thrusters

High electrical insulation and thermal strength of our F99.7 alumina material allow its use in components of ion thrusters. Excellent performance in ultra-high vacuum is guaranteed by minimal desorption and leakage rate. When required, we combine ceramics with metals.

Customized parts

Low weight and high corrosion resistance combined with high mechanical strength make our ceramic materials perfectly suitable for space applications. We excel in specific solutions. Our years of experience as a manufacturer of customized and standard components guarantee superior solutions to accomplish a variety of tasks.



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