

ULTRA-LOW EXPANSION GLASS-CERAMICS

CLEARCERAM[®]-Z

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CLEARCERAM[®]-Z

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Thermal Properties

Mechanical Properties

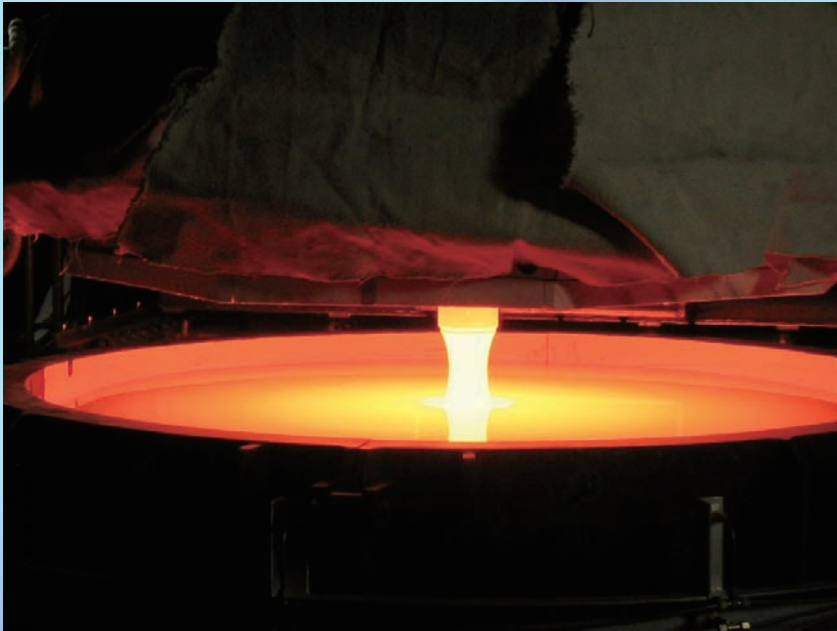
Optical Properties

Chemical Properties

Electrical Properties

Helium Permeability

Internal Quality



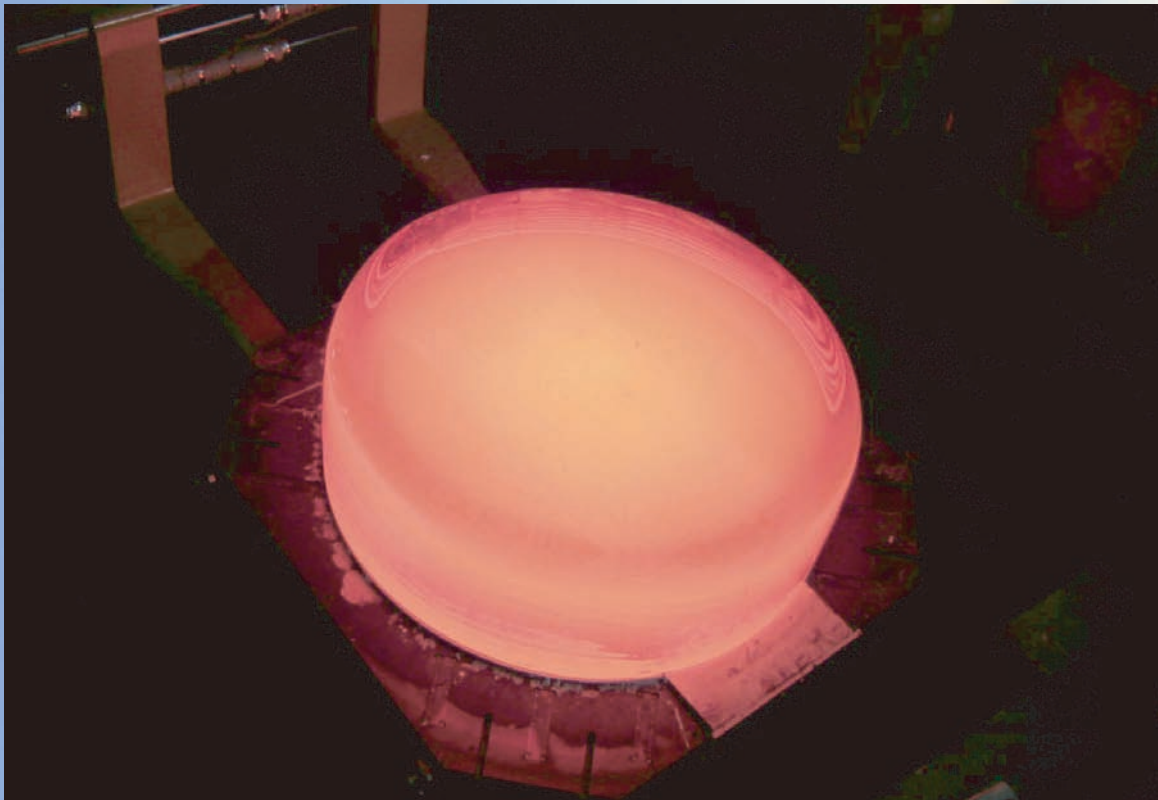
CLEARCERAM[®]-Z



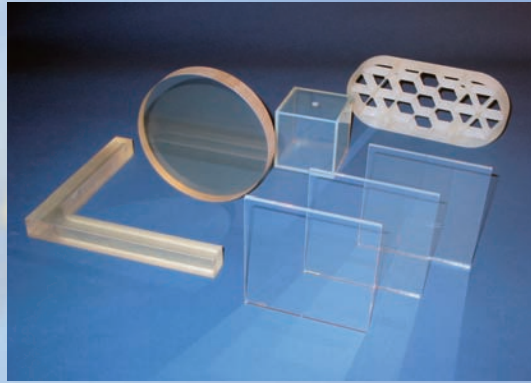
CLEARCERAM[®]-Z is a Glass-Ceramic with an Ultra-Low Thermal Expansion Coefficient which was developed by Ohara based on our knowledge of High Homogeneity Melting and Precise Crystallization.

This material is produced under tightly controlled conditions and offers outstanding thermal, mechanical and chemical properties.

There are 2 versions of CLEARCERAM[®]-Z; CCZ Regular and CCZ HS.



1.8 Meter Diameter Blank



Key Properties of CLEARCERAM[®]-Z

1 Ultra-Low Expansion

The material shows almost Zero Thermal Expansion over a wide temperature range and offers superior thermal shock resistance. CCZ Regular offers lower thermal expansion across a wide temperature range, while the CCZ HS offers lower thermal expansion near room temperature.

2 Superior Mechanical Properties

The material is comprised of approximately 70% ceramic, which makes the mechanical characteristics superior to regular amorphous glass when comparing properties such as Young's Modulus, Rigidity, Bending Strength, and Hardness.

3 Superior Machinability

The crystal grain structure of the material prevents the propagation of micro cracks caused in machining processes. This property allows the material to be processed into various shapes with high accuracy, with ease of machinability and elevated yield rates.

4 Excellent Chemical Properties

The material has very high chemical durability and is very stable in various cleaning and thin-film coating processes. CLEARCERAM[®]-Z does not contain Na, K, B, F, and Pb in its composition which is a main reason for the excellent chemical resistance the material displays.

1 Thermal Properties

1-1 Thermal Expansion Properties

The key characteristic of CLEARCERAM[®]-Z is its thermal expansion property. The CCZ Regular maintains an extremely low thermal expansion over a wide temperature range. The HS Grade shows almost zero expansion near room temperature.

The typical Coefficient of Thermal Expansion of CLEARCERAM-Z for the temperature range -60 to +160 °C is:

CCZ Regular $+0.2 \times 10^{-7}/^{\circ}\text{C}$

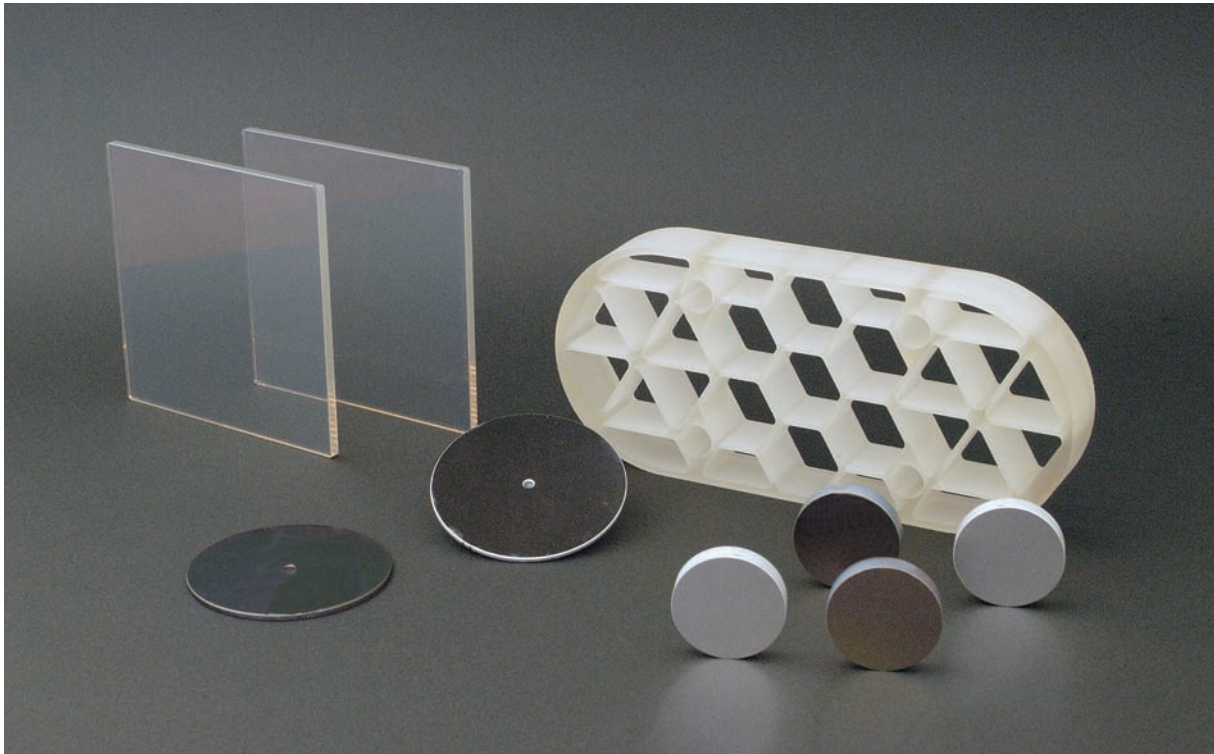
CCZ HS $-0.8 \times 10^{-7}/^{\circ}\text{C}$

The guaranteed Coefficient of Thermal Expansion of CLEARCERAM[®]-Z for the temperature range 0 to +50°C is:

CCZ Regular $0.0 \pm 1.0 \times 10^{-7}/^{\circ}\text{C}$

CCZ HS $0.0 \pm 0.2 \times 10^{-7}/^{\circ}\text{C}$

Chart No.1 & 2 show the curves of the thermal expansion.



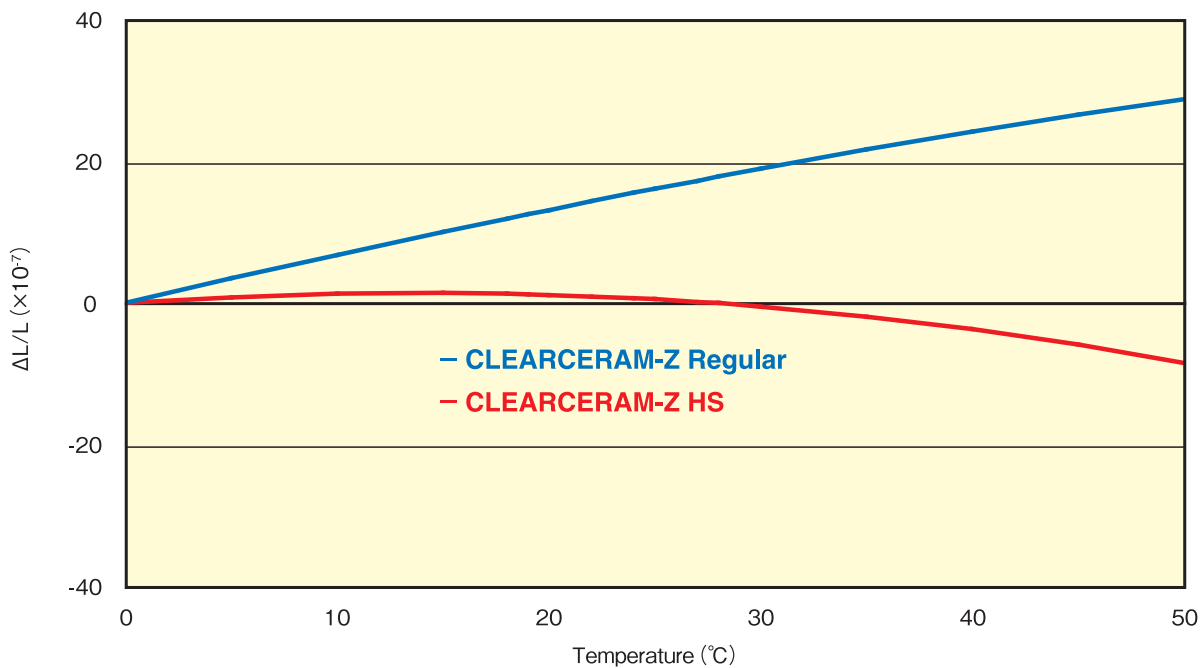


Chart No.1 Thermal expansion curves for CLEARCERAM®-Z (Temp. Range: 0-+50°C)

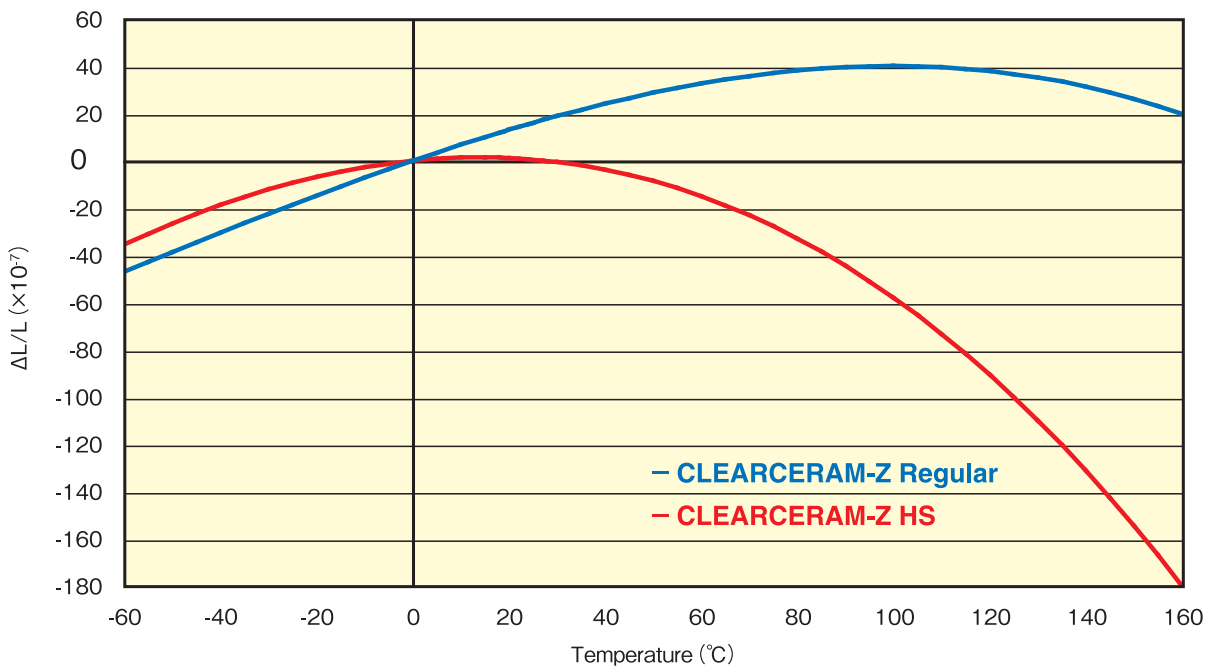


Chart No.2 Thermal expansion curves for CLEARCERAM®-Z (Temp. Range: -60-+160°C)

Ohara's ability to measure Precision Expansion Coefficient:	Temp. Range = 0-50°C, Repeatability $\sigma = 0.05 \times 10^{-7} / ^\circ\text{C}$
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1-2 Thermal Expansion Properties at Extremely Low Temperatures

Chart No.3 shows the curves of thermal expansion for CCZ Regular and CCZ HS at extremely low temperatures.

This data was obtained by the National Institute of Advanced Industrial Science and Technology.

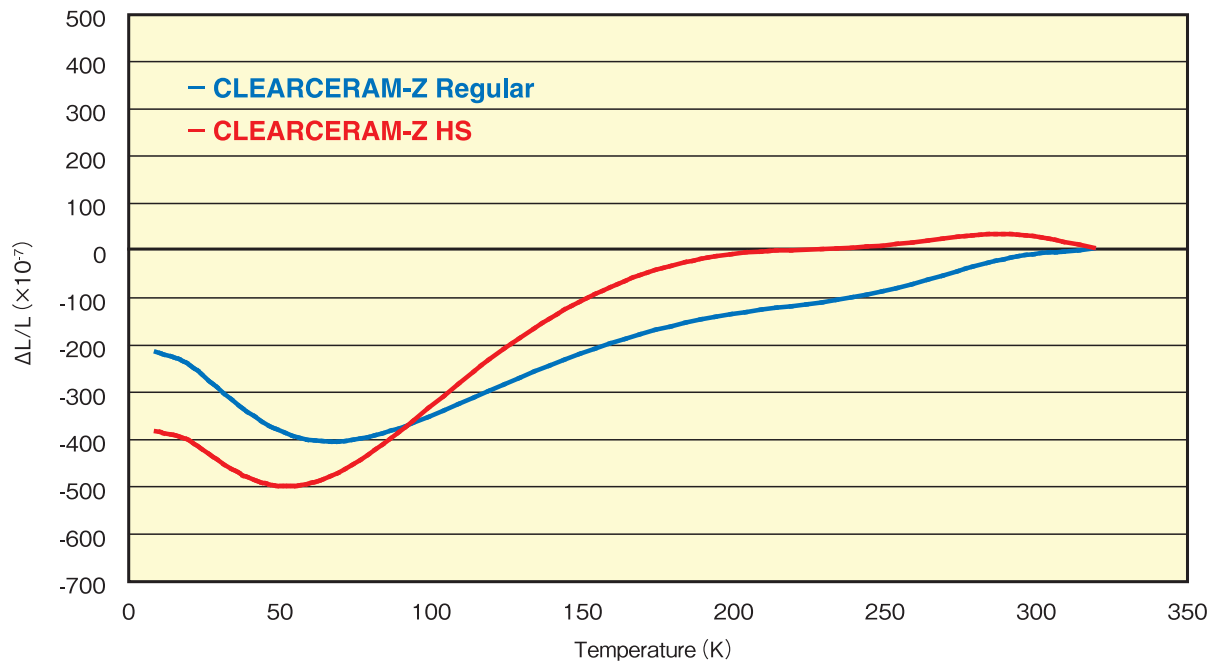


Chart No.3 Thermal expansion curves for CLEARCERAM[®]-Z (Temp. Range: 10~320K)



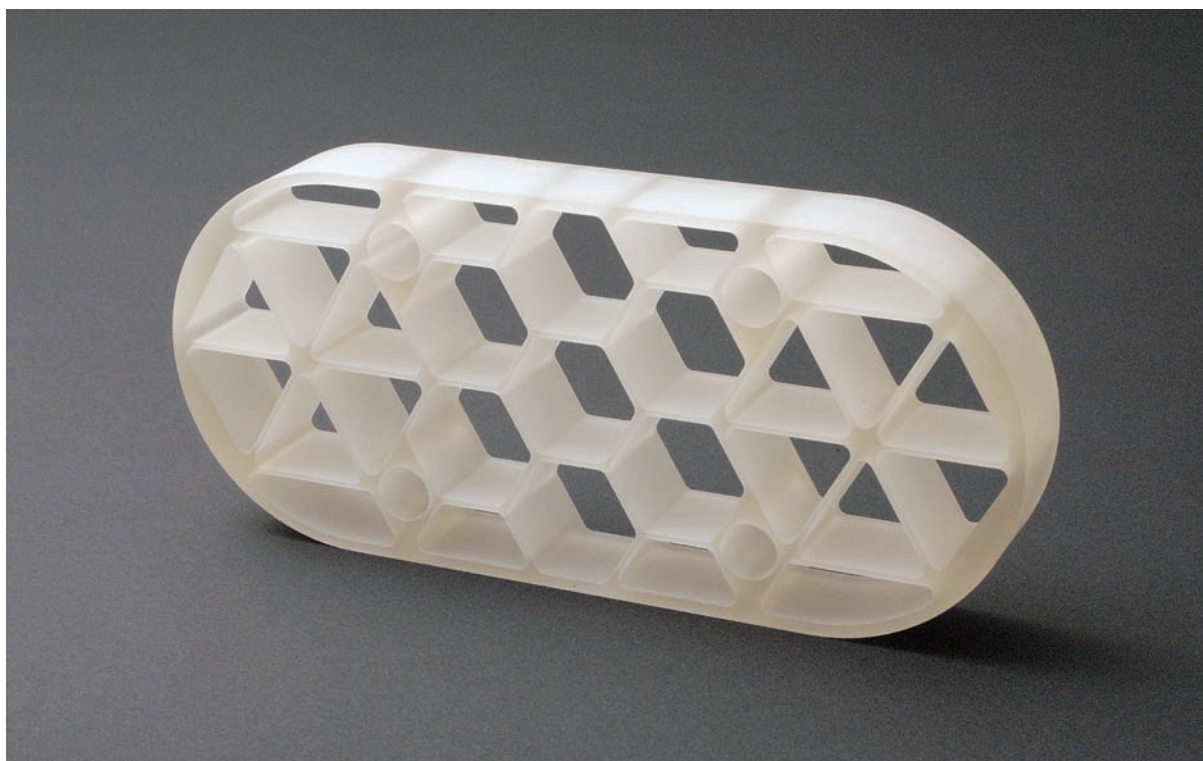
Light Weight Processing Product (Water Jet / Diffusion Bonding Method)

1-3 Thermal Conductivity

	CCZ Regular	CCZ HS
Thermal Conductivity (W/(m•K))	1.51	1.52
Thermal Diffusion ($\times 10^{-4} \text{m}^2/\text{s}$)	0.00762	0.00775
Specific Heat (kJ/(kg•K))	0.777	0.773

1-4 Thermal Resistance

The operational temperature of CLEARCERAM[®]-Z is 650°C. Even after storing in an environment of 650°C \times 100 hours, there is little variation in the thermal expansion coefficient and the refractive indices.



CLEARCERAM[®]-Z Processed by Water-Jet

2 Mechanical Properties

2-1 Young's Modulus and Rigidity

Chart No.4 shows the relationship between Young's Modulus and Rigidity Modulus versus Temperature for CLEARCERAM[®]-Z. The Young's Modulus and Rigidity Modulus remain very stable, even when the material is heated up to 300°C.

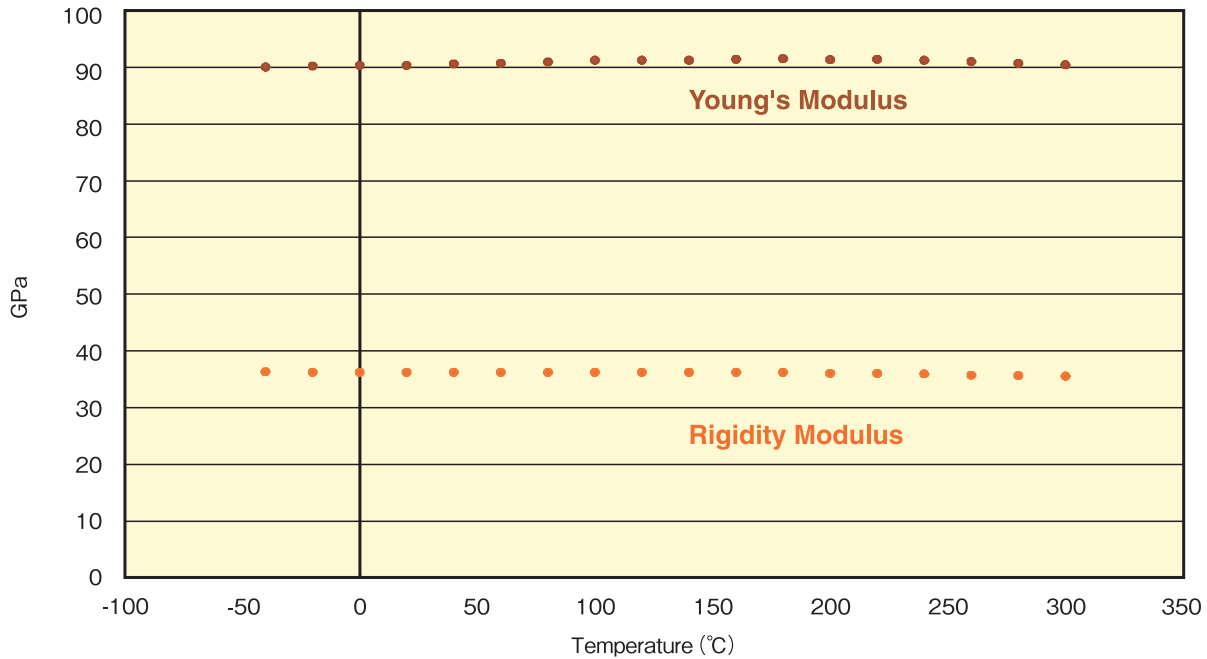


Chart No.4 Young's Modulus & Rigidity of CLEARCERAM[®]-Z

	CCZ Regular	CCZ HS
Young's Modulus GPa	90	90
Rigidity GPa	36	36
Poisson's Ratio	0.25	0.25

2-2 Bending Strength

Values by Four-Point Measuring Method per JIS R1601 procedure.

CCZ Regular 116MPa

CCZ HS 111MPa

2-3 Hardness

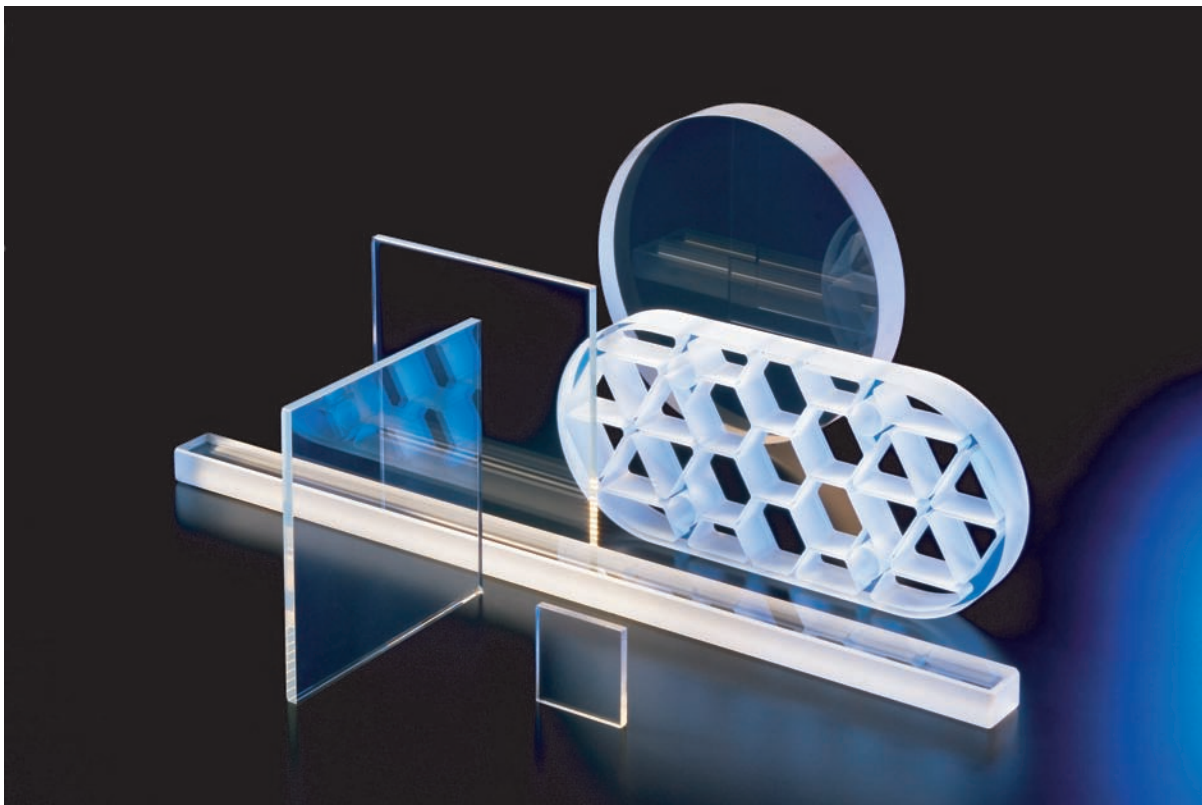
	CCZ Regular	CCZ HS
Knoop Hardness Hk	600	640
Vickers Hardness Hv	680	700

2-4 Specific Gravity & Abrasion

	CCZ Regular	CCZ HS
Specific Gravity	2.55	2.55
Abrasion Aa	62	64

2-5 Change in Surface by Coating

Precisely polished surfaces of CLEARCERAM[®]-Z do not change after coating with metals (such as Cr), and the coatings remain stable over time (no aging).



Various components made with CLEARCERAM[®]-Z

3 Optical Properties

3-1 Refractive indices at various wavelengths

Spectral Lines	n_{1813}	n_{1529}	n_{1129}	n_t	n_c
Wave length (nm)	1813.07	1529.58	1128.64	1013.98	643.85
Regular Grade	1.52441	1.52819	1.53334	1.53499	1.54357
HS Grade	1.52484	1.52863	1.53379	1.53545	1.54409

Spectral Lines	n_d	n_e	n_f	n_g	n_h
Wave length (nm)	587.56	546.07	479.99	435.83	404.65
Regular Grade	1.54607	1.54841	1.55350	1.55838	1.56300
HS Grade	1.54662	1.54899	1.55415	1.55913	1.56387

3-2 Optical Transmission

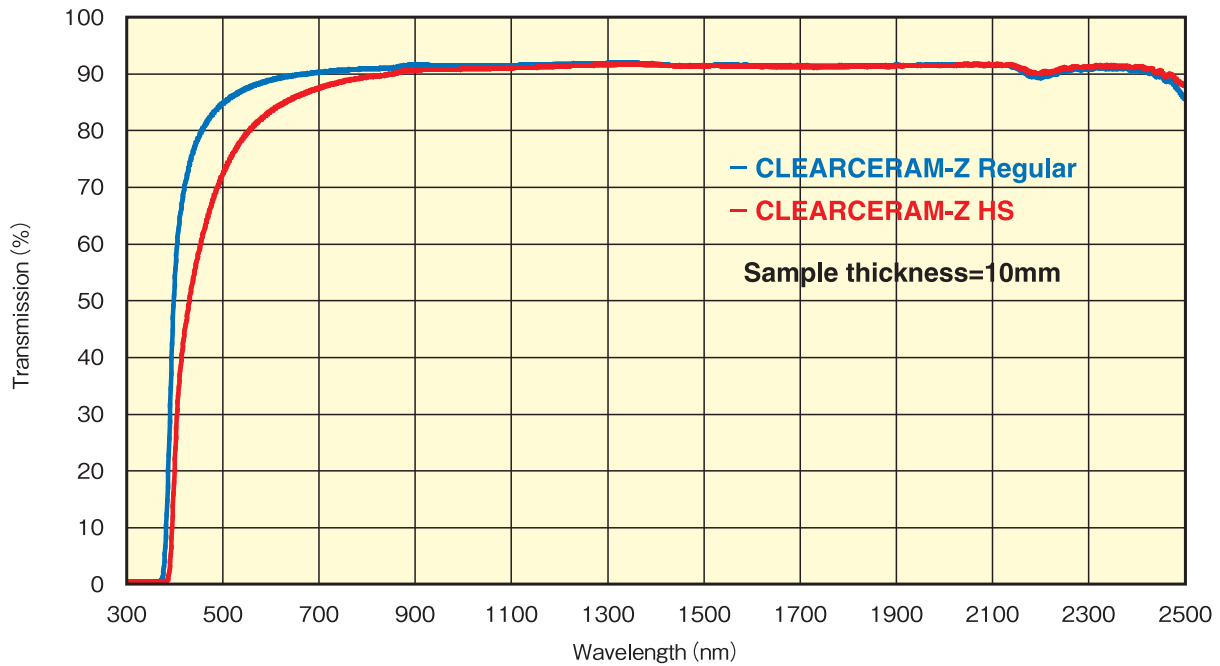


Chart No.5 Transmission Curves for CLEARCERAM[®]-Z

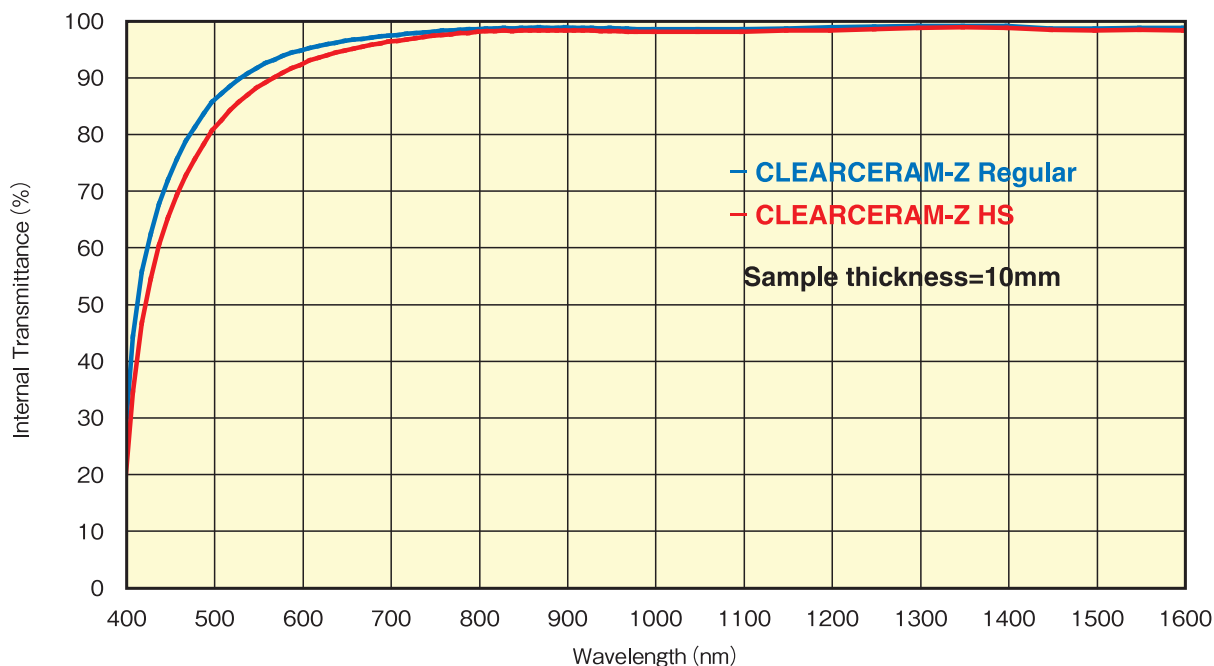


Chart No.6 Internal Transmittance Curves for CLEARCERAM®-Z

3-3 Effect of Temperature on Refractive Indices

CLEARCERAM®-Z Regular

Temp. Range (°C)	dn/dt relative (10 ⁻⁶ /°C)							
	1523	t _(1013.98)	C _(643.85)	He-Ne	D _(589.29)	e _(546.07)	F _(479.99)	g _(435.84)
-40 ~ -20	12.6	12.7	13.2	13.2	13.4	13.6	14.0	14.4
-20 ~ 0	13.0	13.1	13.6	13.6	13.8	14.0	14.4	14.8
0 ~ 20	13.3	13.5	14.0	14.0	14.2	14.4	14.8	15.2
20 ~ 40	13.7	13.8	14.4	14.4	14.6	14.8	15.2	15.7
40 ~ 60	14.0	14.2	14.8	14.8	15.0	15.2	15.7	16.2
60 ~ 80	14.4	14.6	15.2	15.2	15.4	15.6	16.1	16.6

CLEARCERAM®-Z HS

Temp. Range (°C)	dn/dt relative (10 ⁻⁶ /°C)							
	1523	t _(1013.98)	C _(643.85)	He-Ne	D _(589.29)	e _(546.07)	F _(479.99)	g _(435.84)
-40 ~ -20	12.3	12.7	12.8	12.9	13.0	13.2	13.5	13.9
-20 ~ 0	12.7	13.1	13.3	13.4	13.5	13.7	14.1	14.5
0 ~ 20	13.2	13.5	13.8	13.9	14.0	14.2	14.6	15.0
20 ~ 40	13.7	13.8	14.3	14.4	14.5	14.7	15.1	15.6
40 ~ 60	14.1	14.2	14.8	14.9	15.0	15.2	15.7	16.2
60 ~ 80	14.6	14.6	15.3	15.4	15.5	15.7	16.2	16.7

4 Chemical Properties

4-1 Powder Method

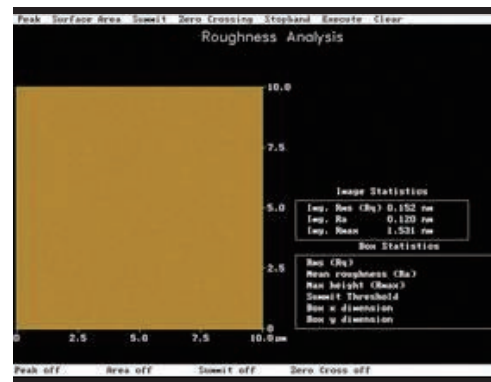
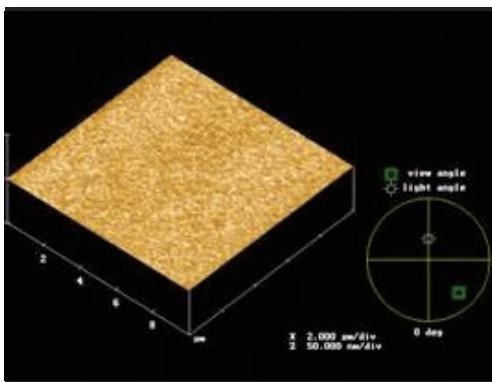
The Chemical Resistance of CLEARCERAM[®]-Z is determined using a testing method written in Japan Optical Glass Industrial Standards (JOGIS). The alkali resistance is determined by Ohara's own method.

For testing, CLEARCERAM[®]-Z is milled to a grain size of 425~600 μ m. Then it is kept in boiling water for 60 minutes in a quartz flask which is situated in a platinum basket. The reduction in weight (wt%) is determined after this process is complete and the material is allowed to dry. We use Pure Water (pH6.5~7.5), for the Water Resistance Test, 0.01N Nitric Acid solution for the Acid Resistance Test, and 0.1N NaOH solution for the Alkali Resistance Test.

	CCZ Regular	CCZ HS	Std.
Water Resistance Rw	Class 2	Class 1	JOGIS
Acid Resistance RA	Class 1	Class 1	JOGIS
Alkali Resistance Ralk	0.25%	0.21%	OHARA

CLEARCERAM[®]-Z has excellent chemical properties and offers better chemical resistance than amorphous glasses.

Polished Surface of CLEARCERAM[®]-Z (AFM)



Rms : 0.15nm Ra : 0.12nm

CLEARCERAM[®]-Z can be precisely polished to extremely low surface roughness values.

5 Electrical Properties

5-1 Volume Resistivity

Volume Resistivity at various temperatures.

Temp. (°C)	CLEARCERAM [®] -Z Regular (Ω•cm)	CLEARCERAM [®] -Z HS (Ω•cm)
25	1.5×10^{12}	6.4×10^{12}
100	1.8×10^{10}	2.9×10^{10}
200	8.6×10^8	1.9×10^9
300	1.0×10^8	6.4×10^7
400	1.2×10^7	6.1×10^6
500	1.5×10^6	1.5×10^6
600	3.4×10^5	3.8×10^5
700	9.8×10^4	1.0×10^5

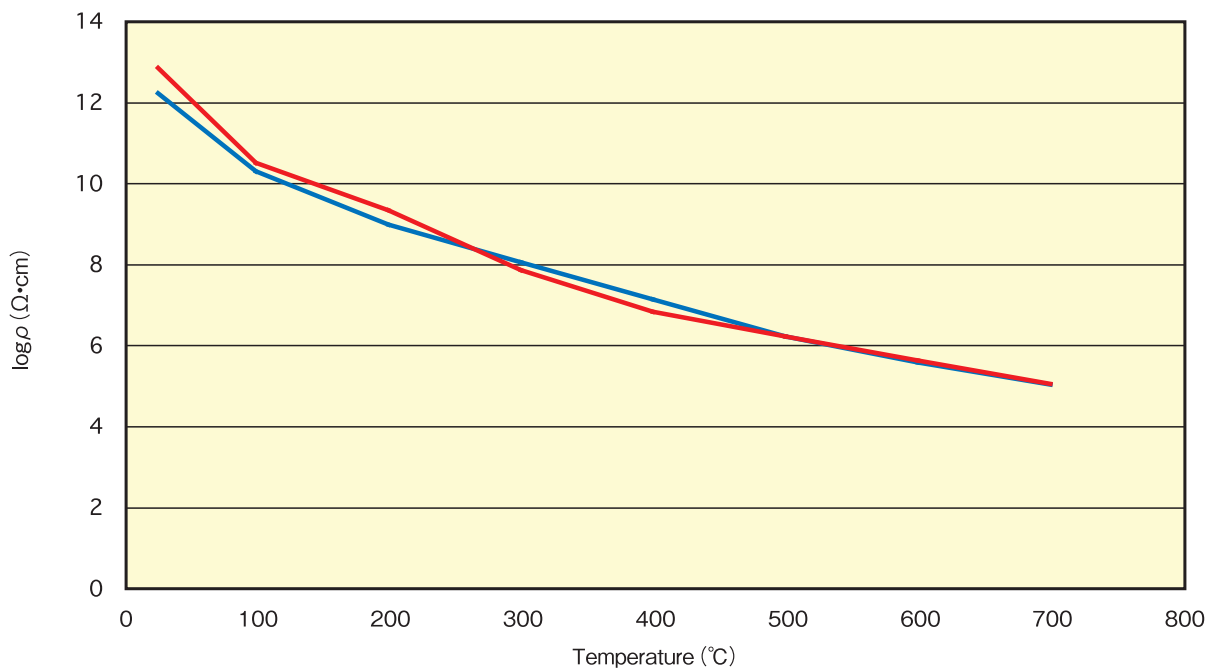


Chart No.7 Volume resistivity of CLEARCERAM[®]-Z at various temperatures.

6 Helium Permeability and Outgassing

6-1 Helium Permeability

Helium Permeability: Unit $\times 10^{-11}$ Pa·m³/sec.

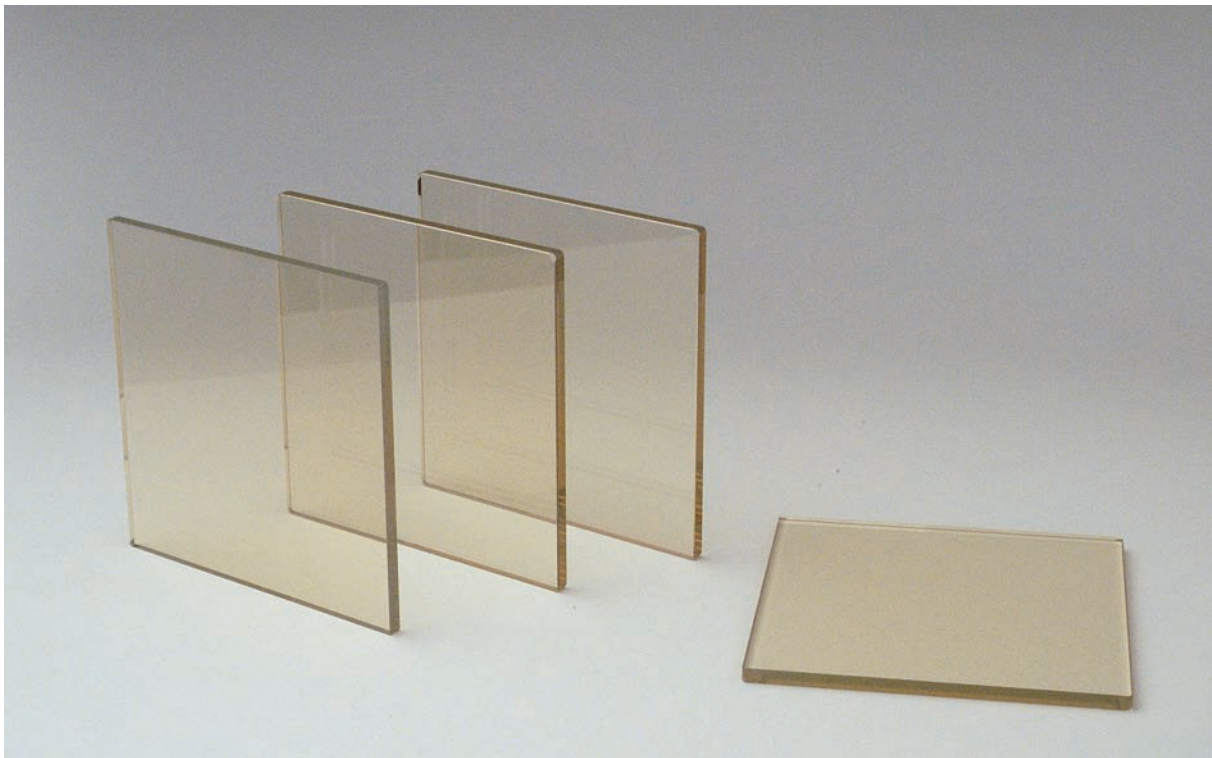
25°C	100°C	200°C	300°C	350°C
< 0.1	< 0.1	2.6	5.4	8.6

- Sensitivity limit of helium permeability test: 0.1×10^{-11} Pa·m³/sec.

6-2 Outgassing

CLEARCERAM[®]-Z is composed of various elements, but the level and the type of outgassing is comparable to quartz glass. There is little emission of metal based gas and CLEARCERAM[®]-Z will not contaminate high level vacuum chambers.

- CLEARCERAM[®]-Z was heated from room temperature to 1,000°C for the outgassing test.



EUVL Mask Substrates made of CLEARCERAM[®]-Z

7 Internal Quality

The internal quality of CLEARCERAM[®]-Z is controlled with the sizes of the products shown below:

7-1 Product Size

W (mm)	L (mm)	t (mm)
~ 200	~ 3,200	~ 80
200 ~ 500	~ 700	~ 80

7-2 Bubbles and Inclusions

The chart shows the classification of bubbles and inclusions of CLEARCERAM[®]-Z
This classification includes all bubbles and inclusions measuring ≥ 0.1 mm.

Class	C1	C2	C3	C4 (Standard)
The total cross-section of bubbles in 100cc (mm ²)	< 0.03	≥ 0.03 < 0.1	≥ 0.1 < 0.25	≥ 0.25 < 2.0

- Class C4 standard material will be used a tighter Class is designated.

7-3 Striae

Striae in CLEARCERAM[®]-Z is inspected in one direction with high intensity light by qualified inspectors.

Striae Class of CLEARCERAM[®]-Z are classified as below:

Class	Class Definition
C1	No visible striae
C2	Striae is light and scattered
C3	Only slight parallel striae is detected
C4 (Standard)	Any case which does not apply to Class C3

- Class C4 standard material will be used a tighter Class is designated.

Chart of Properties

CLEARCERAM®-Z		Regular	HS	
Thermal Properties	CTE ($\times 10^{-7}/^{\circ}\text{C}$) 0-50°C	0.0±1.0	0.0±0.2	
	Thermal Conductivity (W/m·K)	1.51	1.54	
Mechanical Properties	Young's Modulus (GPa)	90	92	
	Rigidity (GPa)	36	37	
	Poisson's Ratio	0.25	0.25	
	Knoop Hardness Hk*	600 (6)	590 (6)	
	Vickers Hardness Hv	680	700	
	Abrasion Aa*	62	62	
	Bending Strength (MPa)	116	122	
	Specific Gravity	2.55	2.55	
Optical Properties	Refractive Index n_d	1.546	1.546	
	Refractive Index (1550nm)	1.528	1.528	
	Abbe Number V_d	55.5	54.9	
	Internal Transmittance (%) (10mmt)	500nm	> 0.85	> 0.82
		980nm	> 0.98	> 0.98
1550nm		> 0.98	> 0.98	
Chemical Properties	Water Resistance (Powder) RW*	Class 2	Class 1	
	Acid Resistance (Powder) RA*	Class 1	Class 1	
	Alkali Resistance (Powder) Ralk**	0.25%	0.19%	
Electrical Properties	Volume Resistivity (Ω/cm) 25°C	1.5×10^{12}	6.4×10^{12}	

•Values in the chart may change due to ongoing development activity.

*JOGIS **OHARA

•Product Size: In case of a material requirement for product sizes which are outside of the range shown in Category No. 7 of this Catalog, please consult us. The maximum product weight we can achieve is approximately 3 tons.



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