ULE®, Corning Code 7972 Ultra Low Expansion glass is a titanium silicate glass with unique characteristics that has made it the material of choice in applications ranging from machine tool reference blocks to solid and lightweight mirror blanks for large astronomical telescopes and space satellite applications.

Leading industry experts in the semiconductor integrated circuits manufacturing industry have identified ULE as a "material of choice" for EUV applications.

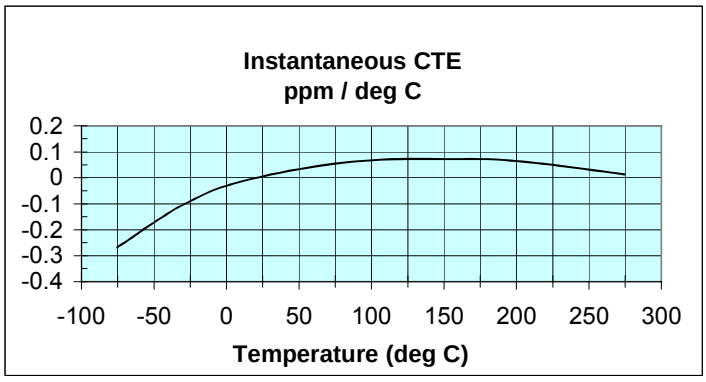
LINEAR COEFFICIENT OF THERMAL EXPANSION (CTE) - The guaranteed maximum limits for CTE and Optical Retardation are as follows:

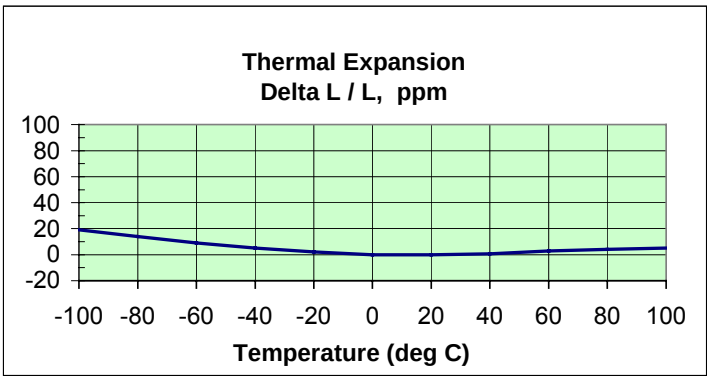
- For all grades, CTE shall be 0 ± 30 ppb/$^{\circ}$C over a temperature range of 5 to 35°C, with a 95% confidence level.
- Delta CTE = Variation of CTE measurements within a part as measured in the radial and axial direction.

INCLUSION QUALITY - The guaranteed maximum limits for seeds, bubbles, and opaque inclusions are as follows:

Quality Grade Selection Chart

	Delta CTE (ppb/°C)		Birefringence (nm/cm)	Inclusion Quality Information		
	Radial	Axial	Optical		Diameter or Diagonal:	
GRADE	Range	Range	Retardation	Inclusion Definition	< 20"	20" to 58"
Premium	**10**	**10**	**10**	Mean Diameter	**0.040"**	
				Inclusions per cubic inch	**4**	**N/A**
				Avg. no. of inclusions per cubic inch	**0.1**	
Mirror	**15**	**15**	**20**	***Critical Zone* - See Notes Below**		
				Mean Diameter	**0.040"**	**0.080"**
				Inclusions per cubic inch	**4**	**6**
				Avg. no. of inclusions per cubic inch	**0.1**	**0.2**
				***Non-Critical Zone* - See Notes Below**		
				Mean Diameter	**0.100"**	**0.250"**
				Avg. no. of inclusions per cubic inch	**0.2**	**0.6**
Standard	**15**	**15**	**20**	Mean Diameter	**0.100"**	**0.250"**
				Avg. no. of inclusions per cubic inch	**0.2**	**0.6**
Tooling	**Delta CTE not specified. Delta CTE data is not available.**			**No guaranteed maximum limits on inclusions.**		





- **No measurable hysteresis** results from thermal cycling of ULE regardless of the rate of temperature change.
- **Full characterization** of CTE is achieved through a rapid, non destructive ultrasonic method.
- **Stability:**
  - ► Excellent long term dimensional stability at room temperature.
  - ► No residual figure change when taking a mirror from 350°C to a water quench.
- **Delayed Elastic Effect -** There has been no measurable delayed elastic effect in ULE. This is an important consideration when large strain is present during fabrication or when environmental loading is present, such as during gravity release or dynamic control of active optics.

Properties: Unless otherwise stated, all values @ 25°C

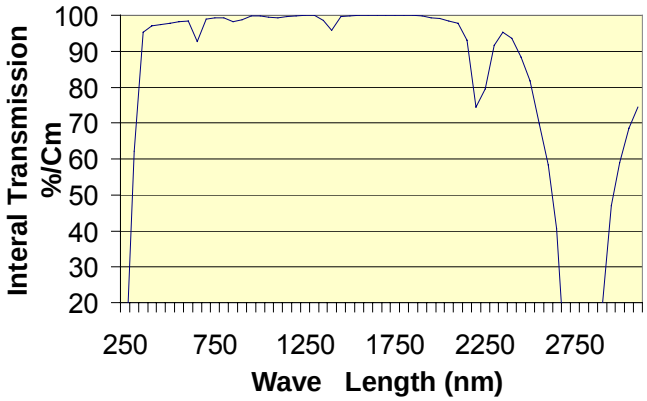
Thermal Properties:			
Mean Coefficient of Thermal expansion (α)	0×10^{-9}/K [0 ppb/°C]	Mean Specific Heat (C_p)	767 J/ (kg • °C) [0.183 cal/ (g • °C)]
CTE Maximum Variation 5-35 °C ($\Delta\alpha$)	$\pm 30 \times 10^{-9}$/K [± 30 ppb/°C]	Thermal Conductivity (K)	1.31 w/(m • °C) [1.13 kcal/(m • hr •°C)]
Thermal Diffusity (D)	0.0079 cm^2/s	Strain Point	890 °C [1634 °F]
D.C. Volume Resistivity, 200 °C, 100Hz (R)	$10^{11.6}$ ohm • cm	Annealing Point	1000 °C [1832 °F]
		Softening Point (Estimated)	1490 °C [2714 °F]
Mechanical Properties:			
Poisson's Ratio (ν)	0.17	Specific Stiffness (E/ρ)	3.12×10^6 m [1.23×10^8 in]
Ultimate Tensile Stress (MOR)	49.8 MPa [7220 psi]	Shear modulus (G)	29.0 GPa [4.20×10^6 psi]
Knoop Hardness, 200 g load	460 kg/mm^2	Bulk Modulus (K)	34.1 GPa [4.95×10^6 psi]
Density (ρ)	2.21 g /cm^3 [0.07966 lb/in^3]	Elastic Modulus (E)	67.6 GPa [9.80×10^6 psi]
Optical Properties:			
Stress Optical Coefficient	4.15 (nm/cm)/(kg/cm^2) [0.292 (nm/cm) psi]	Abbe' Number (ν_d)	53.1
Refractive Index (nominal CTE material)		dn/dt 20-40°C	10.68×10^{-6}/°C
n_F(486 nm)	1.4892	40-60°C	11.24×10^{-6}/°C
n_D(589 nm)	1.4828		
n_C(656 nm)	1.4801		

Chemical Durability:

- Excellent resistance to weathering.
- Exhibits virtually no surface clouding or electrical surface leakage when subject to attack by water, sulfer dioxide, and atmospheric gases.
- High resistance to attack by nearly all chemical agents.

Solution @ 95°C	Test Duration	Wgt Loss
5% HCl	24 hrs	<0.01 mg/cm^2
5% NaOH	6 hrs	0.9 mg/cm^2
.02N Na_2CO_3	6 hrs	0.02 mg/cm^2
5% H_2SO_4	24 hrs	<0.01 mg/cm^2
H_2O	24 hrs	<0.01 mg/cm^2

ULE Internal Transmission



NOTES:

- ***Critical Zone*** **-** a quality layer typically extending to a depth of 0.200" below the surface specified by the customer for finishing:
- ***Non-Critical Zone*** **-** all glass outside the Critical Zone:
- Inclusions with 0.005" or smaller mean diameter are disregarded.
- Premium Grade available in sizes up to 20" diameter or diagonal by 3" thick.
- Mirror and Standard Grades available in sizes up to 58" diameter or diagonal by 5" thick. Corning would be pleased to quote larger sizes to customer specs.
- Tooling Grade available. Please contact Corning for availability.

For additional information or quotes, please contact us:

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Product Engineering **Tel: (315) 379 - 3381** **Fax: (315) 379 - 3317**

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