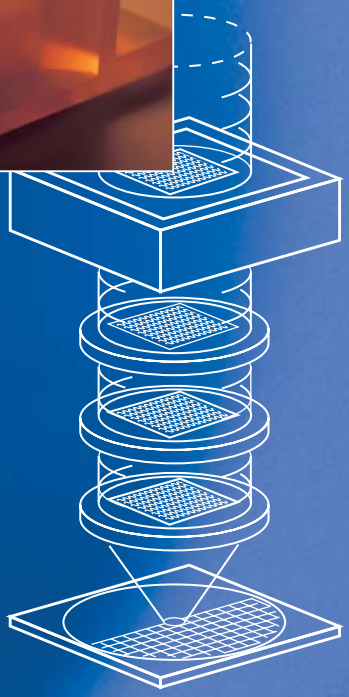
ZERODUR®

Zero thermal expansion glass ceramic



SCHOTT lithotec

Schott Lithotec ZERODUR®

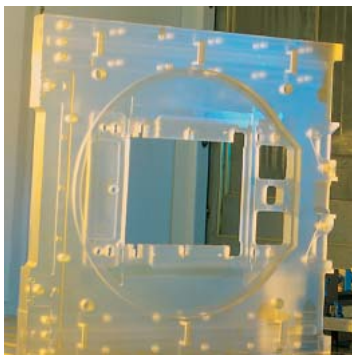
For many years ZERODUR® zero thermal expansion material has provided for reliable designs in precision optical applications. The homogeneity of the material properties of ZERODUR® enables opto-mechanical engineering solutions with long-term mechanical and thermal stability. The easy-to-achieve optical figure and improved microroughness have contributed to the success of this material.

ZERODUR® is widely used as a mirror substrate material and for precision frames in current state-of-the-art microlithography equipment.

Specific structuring of the material allows superior stability of designs in ambitious dynamic environments, such as stages in wafer steppers and scanners.

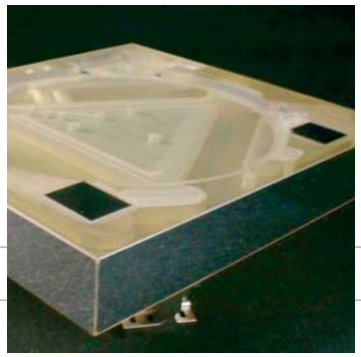
With its ability to match zero thermal expansion very closely, ZERODUR® is one of the prime material candidates for substrates in lithography applications at wavelengths around 13 nm (EUVL).

Applications support from Schott Lithotec is available for material properties and specific customers designs of structured components.



BERLINER GLAS

Reticle stage made of ZERODUR®



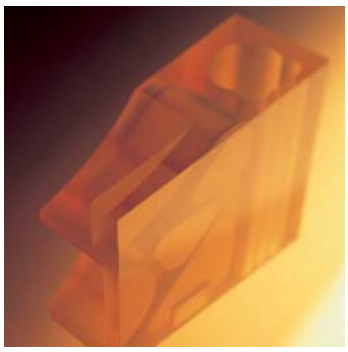
ZEISS

8 inch Wafer Stage made of ZERODUR®

Thermal properties

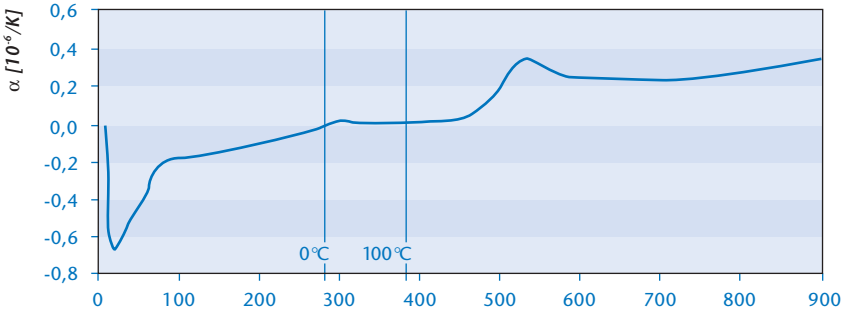
Mean coefficient of linear thermal expansion

The most important and significant properties of the optical glass ceramic ZERODUR® are the extremely small coefficient of linear thermal expansion as well as the homogeneity of this coefficient throughout the entire piece. Individual pieces of ZERODUR® (discs, plates, rods) can be supplied with a mean coefficient of linear thermal expansion α in the temperature range 0°C to 50°C in three expansion classes as follows:



Expansion class 0	$0 \pm 0.02 \cdot 10^{-6}$/K
Expansion class 1	$0 \pm 0.05 \cdot 10^{-6}$/K
Expansion class 2	$0 \pm 0.10 \cdot 10^{-6}$/K

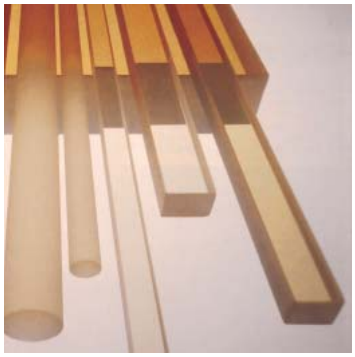
Material up to Expansion class 2 will be supplied as a standard. Closer tolerances will be supplied upon request.
The graph below illustrates the typical coefficient of linear thermal expansion α. ZERODUR® exhibits a very slight linear expansion over the entire temperature range. It is especially low in the room temperature range.

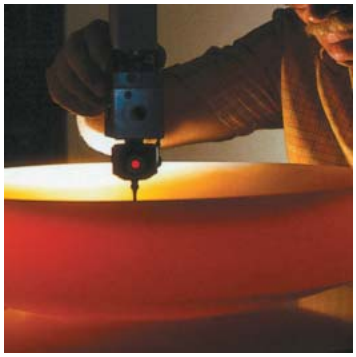


ZERODUR® M

If even higher thermal expansion quality is required and cooling rates other than 0.1K/min (or the initial cooling rate) can not be avoided in the critical temperature region during processing or use of ZERODUR®, we recommend considering the use of ZERODUR® M as a material variation of ZERODUR®.

Shapes and dimensional tolerances



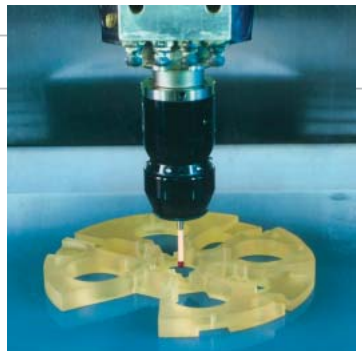


The table shows the typical and improved tolerances for disks, rectangular blocks, rods and complex shapes. Improved tolerances can be provided for an additional charge.

Even tighter tolerances can be provided upon special request.

Shape	Criterion	Dimensions	Typical tolerance	Improved tolerance
Disks	Diameter	< 500 mm	± 0.3 mm	± 0.1 mm
	Diameter	< 1000 mm	± 0.4 mm	± 0.2 mm
	Diameter	< 4200 mm	± 0.5 mm	± 0.3 mm
	Thickness	–	± 0.3 mm	± 0.05 mm
	Profile tolerance zone of radius	< ø 2000 mm	≤ 0.2 mm	≤ 0.1 mm
	Profile tolerance zone of radius	> ø 2000 mm	≤ 0.3 mm	≤ 0.2 mm
Rods	Diameter	L ≤ 500 mm and/ or ø ≤ 80 mm	± 0.3 mm	± 0.01 mm
	Diameter	L > 500 mm and/ or ø > 80 mm	± 0.3 mm	–
	Length	ø ≤ 80 mm	± 0.3 mm	± 0.2 mm
	Length	ø > 80 mm	± 0.4 mm	± 0.3 mm
Plates	Length/thickness	–	± 0.3 mm	± 0.05 mm
	Flatness	< 500 mm	≤ 0.4 mm	≤ 0.05 mm
	Flatness	≥ 500 mm	≤ 0.4 mm	≤ 0.2 mm
Polishing/ Lightweighting	Detailed specification required			

Mechanical Properties



Criterion	
Young's modulus (at 20 °C, GPa) – mean value	90,3
Poisson's ratio μ	0,243
Knoop hardness HK 0,1/20 acc. to ISO 9385	620
Density ρ (g/cm^3)	2,53

Internal quality

The internal quality of ZERODUR® is essentially determined through

- Inclusions
- Striae
- Bulk stress

Inclusions

As a rule inclusions are mainly bubbles and to some extent individual particles. Inclusions have no effect on the function of ZERODUR® as a substrate material for surfaces of the highest quality in so far as they lie completely within the volume.

Inclusions in ZERODUR® are distinguished by the designations "Standard" and "Special" and also draw on the Inclusion Classes 3 to 0 which apply to optical glass.

	Standard	Special	Class 3	Class 2	Class 1	Class 0
Maximum diameter of individual inclusions in mm for different diameters or diagonals of the ZERODUR® part						
In the critical volume						
< 500 mm	1.4	1.2	1.0	0.8	0.6	0.4
In the uncritical volume						
< 500 mm	3.0	2.0	1.5	1.0	0.8	0.6

Striae

Striae are locally very limited transparent regions with composition differing only slightly from the basic material.

The striae values listed below are maximum values for five quality levels up to a given diameter or diagonal of ZERODUR® parts.

Stress birefringence caused by striae [nm/stria] for parts with diameters or diagonals	Standard	Special	Class 3	Class 2	Class 1
< 500 mm	60	45	30	5	–

Bulk stress

All ZERODUR® parts are subjected to precision optical annealing in order to achieve permanent bulk stress, which is low and symmetrically distributed.

Bulk stress causes optical birefringence. The stress birefringence is measured as a path difference.

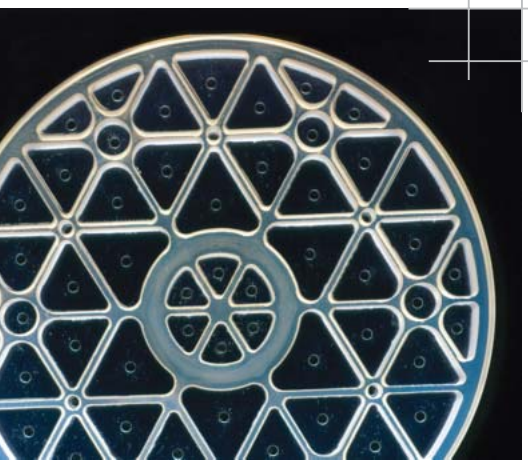
Bulk stress birefringence [nm/cm] for parts with diameters or diagonals	Standard	Special
< 500 mm	6	4

ZERODUR® Bonded Components

General Low Temperature Bonding (LTB) information

Narrative adapted from telecom write-up previously prepared for OFC.

Bonded ZERODUR® components are mechanically robust and can be machined, chemically durable in traditional grinding and polishing environments, and are thermally stable in environments ranging from room temperature to at least 600 °C.



Shapes and Dimensional Information

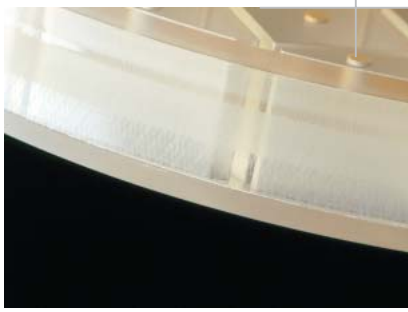
LTB can be applied to solid parts as well as light-weighted (ribbed) structures.

Solid ZERODUR® components have been fabricated up to 2 inches in diameter with high strength suitable to subsequent post-processing (core drilling, blocking, grinding and polishing).

Lightweighted structures have been fabricated from ZERODUR® up to sizes of 265 mm diameter with rib structures as thin as 2 mm. An example of a light-weighted ZERODUR® sample is shown at the left.

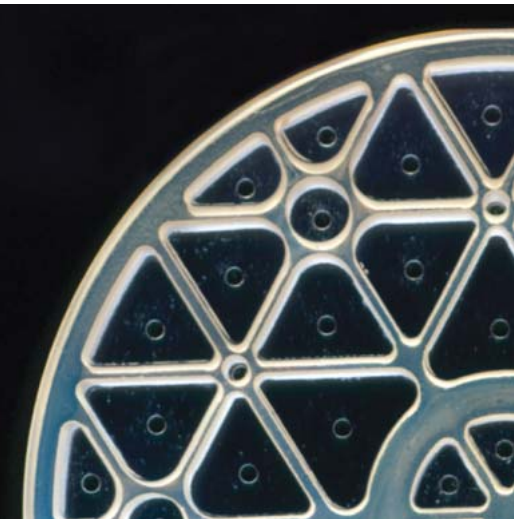
Visual Appearance and Bond Thickness

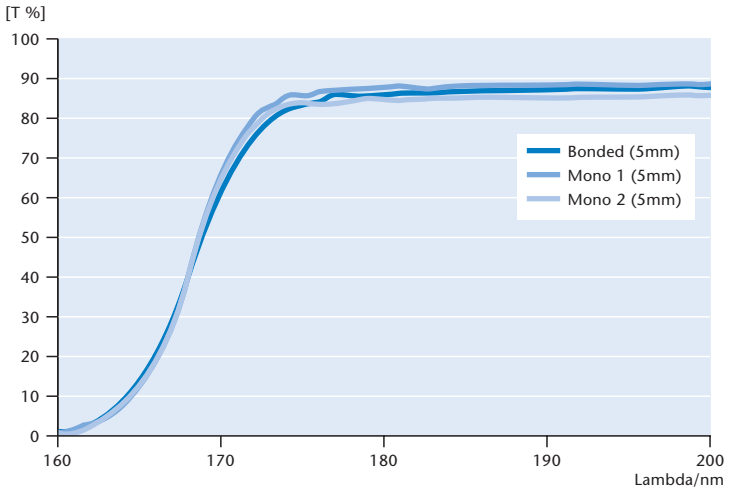
Bonds formed between ZERODUR® material are optically transparent and can be tailored to fill gaps of defined thickness. Bond thicknesses can be varied by modifying processing conditions and part attributes. Typical FIB/SEM results are shown at the right for thick bonds as well as thin bonds.

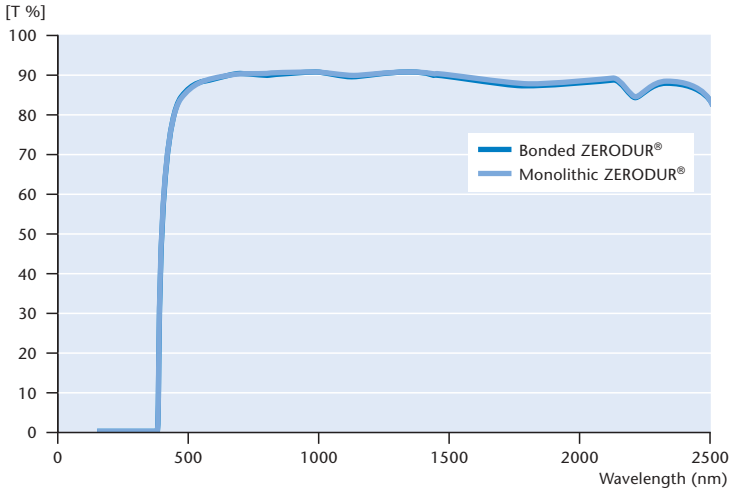


Transmission

Bonds are transparent from 160 nm to 2 µm (see figures) and have a nominal refractive index (25 °C) of 1.47.



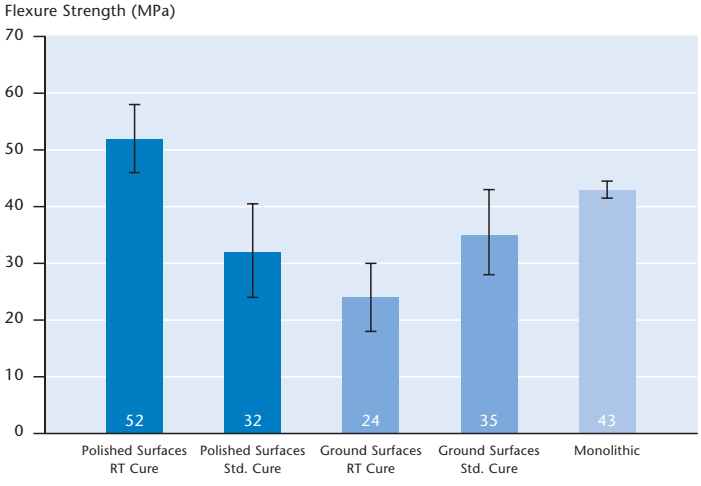




Bonded components contain minimal residual stress (3nm/cm).

Mechanical Strength

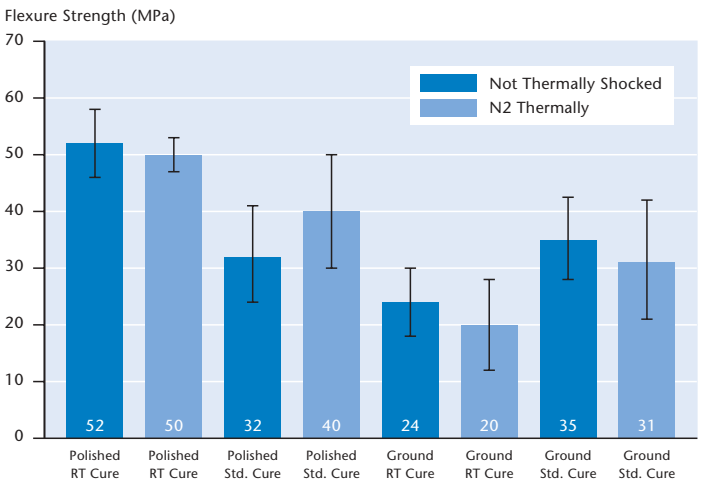
Bonded ZERODUR® components are mechanically robust, showing MOR's comparable to that of monolithic ZERODUR® as determined from 4 pt bend flexure testing.



Measured on core drilled, fine ground specimens

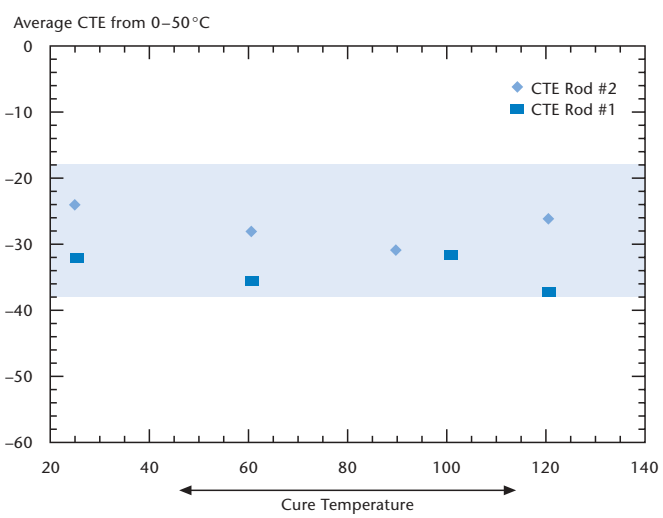
Thermal Shock Resistance

Bonded samples were submerged in liquid nitrogen for nearly 3 minutes. In all cases, there was no significant change in measured bond strength after thermal schock.



Low Thermal Expansion

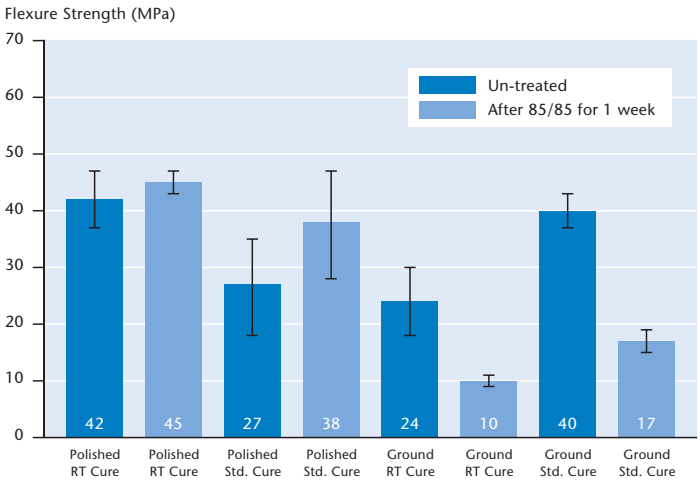
Bonded ZERODUR® components exhibit CTE performance (RT-300 °C) commensurate to monolithic ZERODUR® for bonding perpendicular to bonding axis.



Environmental Stability

All samples made with polished ZERODUR® surfaces, regardless of curing temperature, show no strength degradation after a 1-week treatment under 85/85 conditions.

Samples made using fine ground surfaces, regardless of curing temperature, show a significant strength degradation after the same 85/85 treatment.

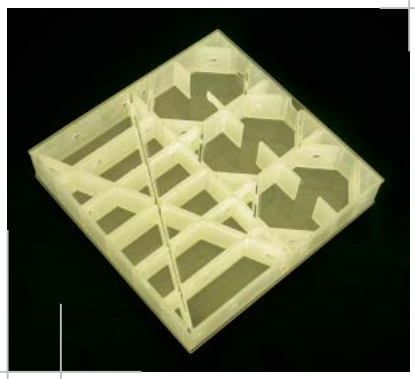


Vacuum Compatibility

Vacuum levels attained:

10^{-12} mbar/liter/sec, meaning 1 liter of He leaking per second at 10^{-12} mbar pressure, equivalent to ~3 x 10^{7} atoms/sec (ultra-high vacuum range)

- Leak rate below current detection limit; lower than that typically specified by manufacturers of UHV valves
- Same results on both heat-treated and non-heat treated samples; no signs of degassing in either sample, though samples had been bonded ~1 month prior to test
- 10^{-9} torr also demonstrated at Honeywell on non-λ/3 parts: both cured and non-cured



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