ZERODUR®

Glass-ceramic with near-zero thermal expansion

ZERODUR® is a glass-ceramic with near-zero thermal expansion over a wide temperature range. This extraordinary property means that applications requiring the highest precision can avoid geometrical shape and distance changes between parts even when exposed to temperature variances.

Mean coefficient of linear thermal expansion

ZERODUR® glass-ceramic is supplied with a mean coefficient of linear thermal expansion (CTE) in the temperature range 0 °C to 50 °C in six expansion classes as follows:

CTE (0 °C; 50 °C) specification tolerances	
Expansion Class 2	0 ± 0.100 ppm/K
Expansion Class 1	0 ± 0.050 ppm/K
Expansion Class 0	0 ± 0.020 ppm/K
Expansion Class 0 Special	0 ± 0.010 ppm/K
Expansion Class 0 Extreme	0 ± 0.007 ppm/K

CTE optimized for application temperature profiles	
ZERODUR® tailored	0 ± 0.020 ppm/K (± 0.010 ppm/K upon request)

Table 1
Coefficient of thermal expansion tolerance classes available at SCHOTT

SCHOTT
glass made of ideas

ZERODUR® TAILORED

ZERODUR® TAILORED optimizes the thermal expansion behavior of components for individual customer application temperature profiles. It is based on a physical material model that takes into account structural relaxation effects.[1]

CTE measurement accuracy

The CTE measurements are performed using a standardized, highly accurate, and reproducible measurement procedure based on dilatometry and are proprietary to SCHOTT AG.[2]

Figure 1 below shows the typical relative expansion in length Δl/l and CTE of ZERODUR® TAILORED during heating from –50 °C to +100 °C.

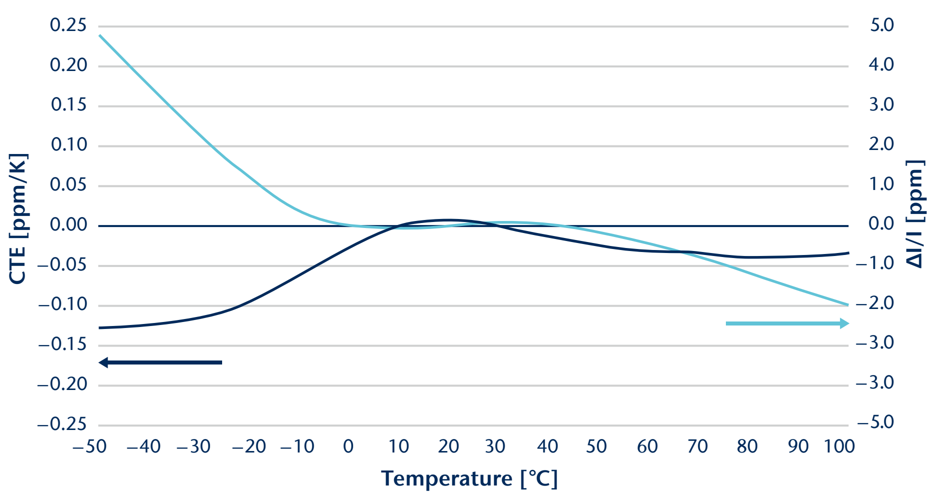

Figure 1
Coefficient of thermal expansion (left axis, light blue) and relative change of length (right axis, dark blue) as a function of temperature between –50 °C and +100 °C

Single-digit – CTE homogeneity over the entire volume

CTE (0 °C; 50 °C) homogeneity tolerances (peak to valley)	
up to 4.0 m diameter	≤ 20 ppb/K
up to 2.5 m diameter	≤ 15 ppb/K
up to 1.5 m diameter	≤ 10 ppb/K

Tighter tolerances on request.

Table 2
CTE homogeneity tolerances

[1] Ralf Jedamzik, Thoralf Johansson, and Thomas Westerhoff, Modeling of the thermal expansion behaviour of ZERODUR® at arbitrary temperature profiles, in "Proc. SPIE 7739", 2010; **https://doi.org/10.1117/12.855980**

[2] Jedamzik, Westerhoff, Homogeneity of the coefficient of linear thermal expansion of ZERODUR: a review of a decade of evaluations in "Proc. SPIE 10401", 2017, **https://doi.org/10.1117/12.2272902**

Maximum application temperature of 600 °C

The CTE specifications are effected by using ZERODUR® above 100 °C and not properly cooling it down.[1]

Extensive data on the strength of ZERODUR® glass-ceramic[2]

The bending strength of glass and glass-ceramic is not a material constant. It mainly depends on the amount of sub-surface damage after surface finishing, the loading geometry, and the environmental conditions of the specific part in its intended application.

The maximum sub-surface damage depth determines the load that a specific part can endure in regions of tensile stress. This is reflected in the probabilistic approach of the Weibull distribution determining a breakage stress threshold.

The breakage stress results for the investigated ZERODUR® samples follow the statistical three-parameter Weibull distribution.

For a D151-ground surface, the breakage stress threshold is 47.3 MPa according to the three-parameter Weibull fit. Finer grinding and etching an appropriate thickness of surface layer increases the threshold significantly.

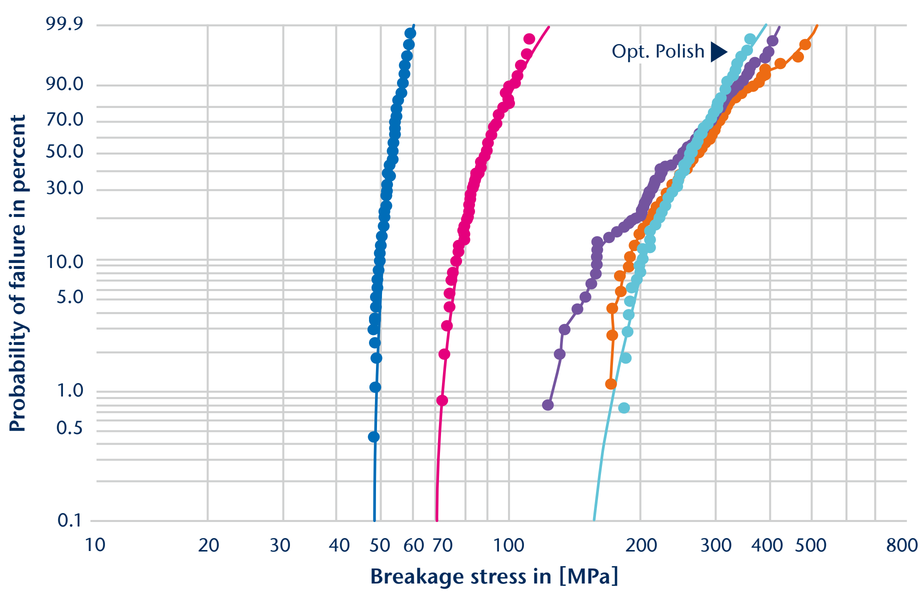

Figure 2
D64 and D151 are diamond grain size distributions; the E-value delineates the µm etched off

Sample	N	Min.	Max.
D151	157	49.1	59.2
D25	86	70.7	112.0
D151 E83	91	124.7	405.8
D64 E73	65	172.9	486.5
Opt. polish	93	185.5	364.4

[1] Jedamzik, Westerhoff, Advice for the use of ZERODUR® at higher temperatures, in “Proc. SPIE 10706”, 2018, **https://doi.org/10.1117/12.2311648**

[2] Hartmann, Minimum lifetime of ZERODUR® structures based on the breakage stress threshold model: a review, in “Optical Engineering Vol. 58 Issue 2”, 2019, **https://doi.org/10.1117/1.OE.58.2.020902**

Mechanical, optical, and chemical properties

Table 3
Mechanical, optical, and chemical properties of ZERODUR®

	ZERODUR®
Thermal conductivity λ at 20 °C [W/(m · K)]	1.46
Thermal diffusivity index a at 20 °C [10^{-6} m^2/s]	0.72
Heat capacity cp at 20 °C [J/(g · K)]	0.80
Young's modulus E at 20 °C [GPa]-mean value	90.3
Poisson's ratio	0.24
Density [g/cm^3]	2.53
Knoop Hardness HK 0,1/20 (ISO9385)	620
Refractive index n_d	1.5424
Abbe number ν_d	56.1
Internal transmittance at 580 nm	
5 mm thickness	0.95
10 mm thickness	0.90
Stress optical coefficient K at λ = 589.3 nm [10^{-6} MPa^{-1}]	3.0
Hydrolytic resistance class (ISO 719)	HGB 1
Acid resistance class (ISO 8424)	1.0
Alkali resistance class (ISO 10629)	1.0
Climate resistance	Class 1
Stain resistance	Class 0
Electrical resistivity ρ at 20 °C [Ω · cm]	$2.6 \cdot 10^{13}$
T_{k100} [°C], Temperature for ρ = 108 [Ω · cm]	178
Helium permeability [atoms/(cm · s · bar)]	
at 20 °C	$1.6 \cdot 10^{6}$
at 100 °C	$5.0 \cdot 10^{7}$
at 200 °C	$7.2 \cdot 10^{8}$

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