

# ZERODUR® – Extremely low Expansion Glass Ceramic

## Applications

ZERODUR® has become a performance- and quality-benchmark in many spectacular applications within modern technology:

- Stages and mirrors for lithography equipment
- Mirror substrates for segmented and monolithic large astronomical telescopes
- Ultra light weighted mirror blanks
- Standards for precision measurement technology
- High precision mechanical parts, e. g. ring laser gyroscope bodies
- Reference standards for precision measurement technology and comet probes

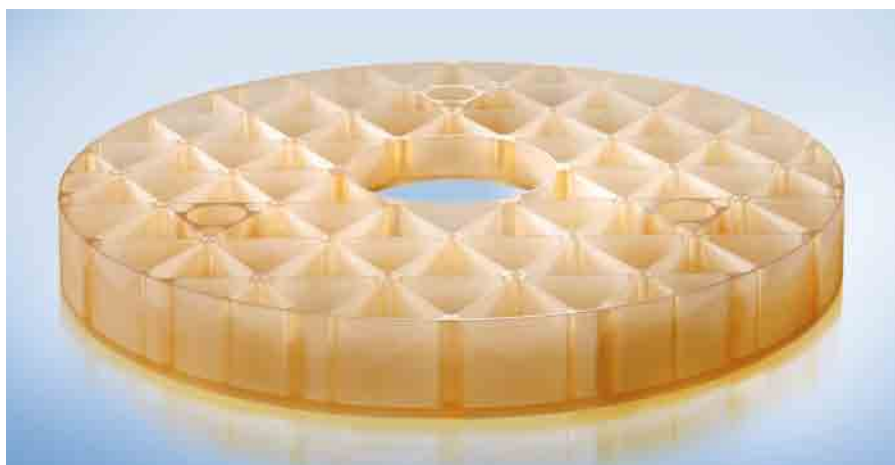
## Properties

ZERODUR® is a glass ceramic with an extremely low thermal expansion for demanding applications in which geometrical shape and distance changes must be kept smallest possible under temperature variations.

The key properties of ZERODUR® are:

- Extremely low coefficient of thermal expansion (CTE) for a wide temperature range
- Excellent CTE homogeneity throughout the total volume
- Very low content of imperfections
- Wide range of precise geometrical shapes
- Extremely smooth surface with residual roughness below 1 nm
- Excellent chemical stability

All these properties are realized for small components as well as for astronomy telescope mirror blanks weighting several tons with extraordinary reproducibility.



## Extremely low thermal expansion

ZERODUR® is an inorganic glass ceramic with 70 to 78% of high-quartz micro-crystallites 50 to 80 nm in size, embedded in a remaining glassy phase. The micro-crystals contract when they are subjected to heating, whereas the glass itself expands. Size and number of the micro-crystallites are carefully adjusted to achieve an extremely low thermal

expansion. At ambient temperature the net thermal expansion is nearly zero, achieved with an accuracy of down to  $0 \pm 7$  ppb/K. Thanks to the careful temperature processing the thermal expansion of ZERODUR® is extremely homogeneous. About 5 ppb/K CTE homogeneity values have been achieved for 1.5 m class and 4 m class ZERODUR® blanks as well.

Properties	ZERODUR®
Density [g/cm <sup>3</sup> ]	2.53
Young's Modulus E [GPa]	90.3
Poisson's Ratio $\mu$	0.24
Knoop Hardness [HK 0.1/20]	620
Coefficient of thermal expansion $\alpha$ CTE (0 °C; 50 °C) [ $10^{-6}/K$ ]	$0 \pm 0.100$ (class 2) $0 \pm 0.050$ (class 1) $0 \pm 0.020$ (class 0) $0 \pm 0.010$ (SPECIAL) $0 \pm 0.007$ (EXTREME)
ZERODUR® TAILORED	TAILORED $\pm 0.020$ ppm/K Optimized for application temperature profile
CTE (0 °C; 50 °C) Homogeneity	$< 0.01 - 0.03 \cdot 10^{-6}/K$
Heat Capacity $c_p$ (20 °C) [J/(gK)]	0.80
Thermal Conductivity $\lambda_{90^\circ C}$ [W/(mK)]	1.46
Max. Application Temperature [°C]	600



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