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Selected publications – ZERODUR® glass-ceramic

In this document you will find scientific papers related to our ZERODUR® products.

Please keep an eye out for - (open access) – added to some of the listed articles. This means that you can access these articles online free of charge.

We are committed to transparency and collaboration and hope that you will benefit from these additional resources.

Thank you for your trust in our products and services.

1. Coefficient of thermal expansion
2. Mechanical strength and behavior
3. Light-weighted mirror blanks and space applications
4. Production
5. Radiation resistance
6. ZERODUR® review

1. Coefficient of thermal expansion

No.	Year	Title	Authors	Published in
[1-15]	2020	CTE homogeneity of ZERODUR® in the ELT century	R. Jedamzik, P. Hartmann, T. Westerhoff	Proc. SPIE Vol. 11451
[1-14]	2018	Advices for the use of ZERODUR® at higher temperatures	R. Jedamzik, T. Westerhoff	Proc. SPIE Vol. 10706
[1-13]	2017	Homogeneity of the coefficient of linear thermal expansion of ZERODUR: a review of a decade of evaluations	R. Jedamzik, T. Westerhoff	Proc. SPIE Vol. 10401
[1-12]	2016	Effects of thermal inhomogeneity on 4m class mirror substrates	R. Jedamzik, C. Kunisch, T. Westerhoff	Proc. SPIE Vol. 9912
[1-11]	2016	Progress on glass ceramic ZERODUR® enabling nanometer precision	R. Jedamzik, C. Kunisch, J. Nieder, P. Weber, T. Westerhoff	Proc. SPIE Vol. 9780
[1-10]	2016	ZERODUR® thermo-mechanical modelling and advanced dilatometry for the ELT generation	R. Jedamzik, C. Kunisch, T. Westerhoff	Proc. SPIE Vol. 9912
[1-9]	2015	Next generation dilatometer for highest accuracy thermal expansion measurement of ZERODUR®	R. Jedamzik, A. Engel, C. Kunisch, G. Westenberger, P. Fischer, T. Westerhoff	Proc. SPIE Vol. 9574
[1-8]	2014	ZERODUR® TAILORED for cryogenic application	R. Jedamzik, T. Westerhoff	Proc. SPIE. Vol. 9151
[1-7]	2013	ZERODUR®: progress in CTE characterization	R. Jedamzik, C. Kunisch, T. Westerhoff	Proc. SPIE Vol. 8860
[1-6]	2013	Zero expansion glass ceramic ZERODUR® roadmap for advanced lithography	T. Westerhoff, R. Jedamzik, P. Hartmann	Proc. SPIE Vol. 8683
[1-5]	2010	Modelling of the thermal expansion behavior of ZERODUR® at arbitrary temperature profiles	R. Jedamzik, T. Johansson, T. Westerhoff	Proc. SPIE Vol. 7739
[1-4]	2009	CTE characterization of ZERODUR® for the ELT century	R. Jedamzik, T. Doehring, T. Johansson, P. Hartmann, T. Westerhoff	Proc. SPIE Vol. 7425
[1-3]	2006	Homogeneity of the linear thermal expansion coefficient of ZERODUR® measured with improved accuracy	R. Jedamzik, R. Müller, P. Hartmann	Proc. SPIE Vol. 6273
[1-2]	2006	Influence of striae on the homogeneity of the linear thermal expansion coefficient of ZERODUR®	R. Jedamzik, P. Hartmann	Proc. SPIE Vol. 6288
[1-1]	2005	Homogeneity of the coefficient of linear thermal expansion of ZERODUR®	R. Jedamzik, T. Doehring, R. Mueller, P. Hartmann	Proc. SPIE Vol. 5868

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2. Mechanical strength and behavior

No.	Year	Title	Authors	Published in
[2-13]	2019	Minimum lifetime of ZERODUR® structures based on the breakage stress threshold model: a review	P. Hartmann	Optical Engineering Vol. 58, Issue 2 (open access)
[2-12]	2018	The relation of surface treatment and sub-surface damage on ZERODUR®	R. Jedamzik, P. Hartmann, I. Burger, T. Westerhoff	Proc. SPIE Vol. 10706
[2-11]	2017	ZERODUR®-bending strength: review of achievements	P. Hartmann	Proc. SPIE Vol. 10371
[2-10]	2016	ZERODUR® strength modeling with Weibull statistical distributions	P. Hartmann	Proc. SPIE Vol. 9912 (open access)
[2-9]	2015	ZERODUR®: new stress corrosion data improve strength fatigue prediction	P. Hartmann, G. Kleer	Proc. SPIE Vol. 9573
[2-8]	2014	ZERODUR®: bending strength data for etched surfaces	P. Hartmann, A. Leys, A. Carré, F. Kerz, T. Westerhoff	Proc. SPIE. Vol. 9151
[2-7]	2012	ZERODUR®, Deterministic approach for strength design	P. Hartmann	Optical Engineering 51(12)
[2-6]	2012	ZERODUR® for stressed mirror polishing II: improved modeling of the material behavior	R. Jedamzik, C. Kunisch, T. Westerhoff, U. Müller, J. Daniel	Proc. SPIE Vol. 8450
[2-5]	2011	ZERODUR®: new results on bending strength and stress corrosion	P. Hartmann	Proc. SPIE Vol. 8146
[2-4]	2011	ZERODUR® for stress mirror polishing	R. Jedamzik, C. Kunisch, T. Westerhoff	Proc. SPIE Vol. 8126
[2-3]	2009	ZERODUR® glass ceramics for high stress applications	P. Hartmann, K. Nattermann, T. Doehring, R. Jedamzik, M. Kuhr, P. Thomas, G. Kling, S. Lucarelli,	Proc. SPIE Vol. 7425
[2-2]	2007	Strength aspects for the design of ZERODUR® glass ceramics structures	P. Hartmann, K. Nattermann, T. Doehring, M. Kuhr, P. Thomas, G. Kling, P. Gath, S. Lucarelli,	Proc. SPIE Vol. 6666
[2-1]	2008	ZERODUR® glass ceramics: design of structures with high mechanical stresses	K. Nattermann, P. Hartmann, G. Kling, P. Gath, S. Lucarelli, B. Messerschmidt	Proc. SPIE Vol. 7018

3. Light-weighted mirror blanks and space applications

No.	Year	Title	Authors	Published in
[3-32]	2023	Dos and don'ts in mounting ZERODUR® (a review)	R. Jedamzik, H. Esemann, C. Kunisch, J. Krieg	Proc. Vol. SPIE 12677
[3-31]	2023	Habitable Worlds Observatory (HWO): realizable ZERODUR® mirror thermal characteristics for stability	T. Hull, J. Krieg, C. Kunisch, R. Jedamzik, T. Westerhoff	Proc. Vol. SPIE 12677
[3-30]	2023	ZERODUR® characteristics that enable ultrastability for landmark future European and US space missions	T. Hull, R. Jedamzik, J. Krieg, T. Westerhoff	Proc. SPIE Vol. 12777 (open access)
[3-29]	2022	The past decade of ZERODUR® glass-ceramics in space applications	J. Krieg, A. Carre, T. Döhring, P. Hartmann, T. Hull, R. Jedamzik, T. Westerhoff	Proc. SPIE Vol. 12180
[3-28]	2022	Factors that favor ZERODUR® mirror substrates for Astro2020's IR/O/UV future Flagship	T. Hull, J. Krieg, R. Jedamzik, P. Hartmann, A. Carre, T. Westerhoff	Proc. SPIE Vol. 12180
[3-27]	2021	Telescope mirror substrate trades: is the landscape between low- and high-thermal expansion substrates changed by the entry of Kyocera Cordierite CO720?	T. Hull, A. Carre, G. Weidmann, J. Krieg, T. Westerhoff	Proc. SPIE. Vol. 11820
[3-26]	2021	Material attributes that define performance and efficiency of spaceborne mirrors	T. Hull, J. Krieg, R. Jedamzik, T. Westerhoff	Proc. SPIE. Vol. 11852
[3-25]	2021	Correlation of subsurface damage and surface roughness on ZERODUR ground surfaces by using rotation table peripheral grinding process	A. Leys, T. Hull, A. Carré, T. Westerhoff	Proc. SPIE. Vol. 11852
[3-24]	2021	Better, Faster, Cheaper: Recent SCHOTT ZERODUR® facilities are game-changing for high performance Lightweight Mirrors	T. Hull, J. Krieg, T. Westerhoff	Proc. SPIE. 11852
[3-23]	2020	Parameters for mirror selection: trades between glass ceramics, glass, metals, ceramics and cordierites	T. Hull, J. Krieg, T. Westerhoff, R. Jedamzik	Proc. SPIE. 11443
[3-22]	2020	Enablement and optimization of next generation ground and spaceborne telescope mirrors and structures through engineering and manufacturing advances at SCHOTT AG	J. Krieg, T. Westerhoff, T. Hull	Proc. SPIE. 11487
[3-21]	2020	Selection considerations for astronomical mirror materials: Trade criteria	T. Hull, T. Westerhoff, J. Krieg	Proc. SPIE. 11487
[3-20]	2019	ZERODUR® as a dimensionally stable mirror substrate material for spaceborne telescopes	T. Hull, A. Carre, R. Jedamzik	Proc. SPIE Vol. 11180 (open access)
[3-19]	2018	Advances in ZERODUR® manufacturing for space and ground-based telescopes	T. Westerhoff, T. Werner	Proc. SPIE Vol. 10706

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[3-18]	2017	ZERODUR® expanding capabilities and capacity for future spaceborne and ground-based telescopes	T. Westerhoff, T. Werner	Proc. SPIE Vol. 10401
[3-17]	2016	Production of ELZM mirrors: performance coupled with attractive schedule, cost, and risk factors	A. Leys, T. Hull, T. Westerhoff	Proc. SPIE Vol. 9911
[3-16]	2016	Use of updated material properties in parametric optimization of spaceborne mirrors	T. Hull, T. Westerhoff, G. Weidmann, R. Kirchhoff	Proc. SPIE Vol. 9904
[3-15]	2015	Cost-optimized methods extending the solution space of lightweight spaceborne monolithic ZERODUR® mirrors to larger sizes	A. Leys, T. B. Hull, T. Westerhoff	Proc. SPIE Vol. 9573
[3-14]	2015	Selection considerations between ZERODUR® and silicon carbide for dimensionally stable spaceborne optical telescopes in low-earth-orbit	T. Hull, A. Leys, T. Westerhoff	Proc. SPIE Vol. 9573
[3-13]	2014	Lightweight ZERODUR® mirror blanks: recent advances supporting faster, cheaper, and better spaceborne optical telescope assemblies	T. Hull, T. Westerhoff	Proc. SPIE. Vol. 9241
[3-12]	2014	Extreme lightweight ZERODUR® mirrors (ELZM): supporting characteristics for spaceborne applications	T. Hull, T. Westerhoff	Proc. SPIE. Vol. 9143
[3-11]	2014	ZERODUR® iso-grid design of a 3m class light weighted mirror blank for the E-ELT M5	R. Jedamzik, A. Leys, V. Seibert, T. Westerhoff	Proc. SPIE. Vol. 9151
[3-10]	2014	Lightweighted ZERODUR® for telescopes	T. Westerhoff, M. Davis, P. Hartmann, T. Hull, R. Jedamzik	Proc. SPIE. Vol. 9151
[3-9]	2014	Lightweight ZERODUR®: a cost-effective thermally stable approach to both large and small spaceborne telescopes	T. Hull, T. Westerhoff	Proc. SPIE. Vol. 9070
[3-8]	2013	Practical aspects of specification of extreme lightweight ZERODUR® mirrors for spaceborne missions	T. Hull, T. Westerhoff, A. Lays, J. Pepi	Proc. SPIE Vol. 8836
[3-7]	2012	Game-changing approaches to affordable advanced lightweight mirrors II: new cases analyzed for extreme ZERODUR® lightweighting and relief from the classical polishing parameter constraint	T. Hull, T. Westerhoff, J. W. Pepi, R. Jedamzik, G. J. Gardopee, F. Piché, A. R. Clarkson, A. Leys, M. Schaefer, V. Seibert	Proc. SPIE Vol. 8450
[3-6]	2011	Game-changing approaches to affordable advanced lightweight mirrors: Extreme ZERODUR® lightweighting and relief from the classical polishing parameter constraint	T. Hull, T. Westerhoff et al.	Proc. SPIE Vol. 8125
[3-5]	2011	Design and fabrication of a 3m class light weighted mirror blank for the E-ELT M5	R. Jedamzik, V. Seibert, A. Thomas, T. Westerhoff, M. Müller, M. Cayrel	Proc. SPIE Vol. 8126

[3-4]	2010	Lightweight high-performance 1-4 meter class spaceborne mirrors: emerging technology for demanding spaceborne requirements	T. Hull, P. Hartmann, A. R. Clarkson, J. M. Barentine, R. Jedamzik, T. Westerhoff	Proc. SPIE Vol. 7739
[3-3]	2010	Manufacturing of the ZERODUR® 1.5 m primary mirror for the solar telescope GREGOR as preparation of light weighting of blanks up to 4m diameter	T. Westerhoff, M. Schäfer, A. Thomas, M. Weisenburger, T. Werner, A. Werz	Proc. SPIE Vol. 7739
[3-2]	2009	Heritage of ZERODUR® glass ceramic for space applications	T. Doehring, P. Hartmann, F.-T. Lentes, R. Jedamzik, M. J. Davis	Proc. SPIE Vol. 7425
[3-1]	2007	Manufacturing of light weighted ZERODUR® components at SCHOTT	T. Doehring, A. Thomas, R. Jedamzik, H. Kohlmann, P. Hartmann	Proc. SPIE Vol. 6666

4. Production

No.	Year	Title	Authors	Published in
[4-23]	2022	Let's rethink OWL, ZERODUR® as mirror substrate material is available	T. Westerhoff, R. Jedamzik, J. Krieg, T. Werner, T. Hull	Proc. SPIE Vol. 12182
[4-22]	2022	Half time on the production of 949 ZERODUR® ELT M1 segment blanks	R. Jedamzik, T. Werner, T. Westerhoff	Proc. SPIE Vol. 12188
[4-21]	2021	ZERODUR precision processing with optimized front figure tolerances at SCHOTT AG	J. Krieg, R. Jedamzik, T. Hull, T. Westerhoff	Proc. SPIE Vol. 11889
[4-20]	2021	Status of the serial production of 949 ZERODUR® ELT M1 segment blanks	T. Werner, R. Jedamzik, T. Westerhoff	Proc. SPIE. Vol. 11820
[4-19]	2020	Production of the world's largest convex ZERODUR mirror blank for the ELT	R. Jedamzik, T. Werner, T. Westerhoff	Proc. SPIE Vol. 11445
[4-18]	2020	ZERODUR® manufacturing capacity: ELT and more	T. Westerhoff, T. Hull, R. Jedamzik	Proc. SPIE Vol. 11116
[4-17]	2020	Establishing a substrate manufacturing center for ZERODUR 4-meter diameter lightweight mirrors	T. Westerhoff, T. Hull, R. Jedamzik	Proc. SPIE Vol. 11117
[4-16]	2020	Optimizing ZERODUR® mirror substrate fabrication processes for efficient optical fabrication	T. Westerhoff, T. Hull, R. Jedamzik	Proc. SPIE Vol. 11116
[4-15]	2017	ZERODUR® 4-m blank surviving up to 20 g acceleration	T. Westerhoff, T. Werner, T. Gehindy	Proc. SPIE Vol. 10401
[4-14]	2012	Performance of industrial scale production of ZERODUR® mirrors with diameter of 1.5 m proves readiness for the ELT M1 segments	T. Westerhoff, P. Hartmann, R. Jedamzik, A. Werz	Proc. SPIE Vol. 8444
[4-13]	2012	Zero-expansion glass ceramic ZERODUR®: recent developments reveal high potential	P. Hartmann, R. Jedamzik, T. Westerhoff	Proc. SPIE Vol. 8450
[4-12]	2011	Progress on 4 m class ZERODUR® mirror production	T. Westerhoff, S. Gruen, R. Jedamzik, C. Klein, T. Werner, A. Werz	Proc. SPIE Vol. 8126
[4-11]	2010	ZERODUR® 8m mirror for space telescope	P. Hartmann, T. Westerhoff, R. Reiter, R. Jedamzik, V. Wittmer, H. Kohlmann	Proc. SPIE Vol. 7731
[4-10]	2009	Four decades of ZERODUR® mirror substrates for astronomy	T. Doehring, R. Jedamzik, T. Westerhoff, P. Hartmann	Proc. SPIE Vol. 7281
[4-9]	2007	Mirrors for solar telescopes made from ZERODUR® glass ceramic	T. Doehring, R. Jedamzik, P. Hartmann	Proc. SPIE Vol. 6689

[4-8]	2006	Properties of ZERODUR® mirror blanks for extremely large telescopes	T. Doehring, P. Hartmann, R. Jedamzik, A. Thomas, F.-T. Lentes	Proc. SPIE Vol. 6148
[4-7]	2005	Status of ZERODUR® mirror blank production at SCHOTT	T. Doehring, P. Hartmann, R. Jedamzik, A. Thomas	Proc. SPIE Vol. 5869
[4-6]	2004	ZERODUR® mirror blanks for ELTs: technology and production capacity at SCHOTT	T. Doehring, P. Hartmann, R. Jedamzik, A. Thomas	Proc. SPIE Vol. 5382
[4-5]	2004	Production of the 4.1-m ZERODUR® mirror blank for the VISTA Telescope	T. Doehring, R. Jedamzik, V. Wittmer, A. Thomas	Proc. SPIE Vol. 5494
[4-4]	2004	Forming mandrels for x-ray telescopes made of modified ZERODUR®	T. Doehring, R. Jedamzik, P. Hartmann, H. Esemann, C. Kunisch	Proc. SPIE Vol. 5168
[4-3]	2004	100 years of mirror blanks from SCHOTT	P. Hartmann, H. F. Morian	Proc. SPIE Vol. 5382
[4-2]	2003	ZERODUR® mandrels for the next generation of x-ray telescopes	T. Doehring, R. Jedamzik, A. Thomas, H. F. Morian	Proc. SPIE Vol. 4851
[4-1]	2003	ZERODUR® for large segmented telescopes	H. F. Morian, P. Hartmann, R. Jedamzik, H. W. Hoeness	Proc. SPIE Vol. 4837

5. Radiation resistance

No.	Year	Title	Authors	Published in
[5-5]	2022	Resilience of ZERODUR® glass ceramic under ionizing radiations	A. Carre, R. Kirchhoff, J. Krieg, T. Hull	Proc. SPIE Vol. 12188
[5-4]	2021	An empirical approach for space-based mirrors to evaluate the extent of radiation compaction under expected environmental doses	A. Carré, M. Valente, T. Hull, J. Krieg, T. Westerhoff	Proc. SPIE. Vol. 11852
[5-3]	2021	ZERODUR® stability in space environments	A. Carré, T. Hull, J. Krieg	Proc. SPIE. Vol. 11852
[5-2]	2018	Impact of ionizing radiations on ZERODUR®	A. Carré, T. Westerhoff, T. Hull	Proc. SPIE Vol. 10698
[5-1]	2017	Review of space radiation interaction with ZERODUR®	A. Carré, T. Westerhoff, T. Hull, D. Doyle	Proc. SPIE Vol. 10401

6. ZERODUR® review

No.	Year	Title	Authors	Published in
[6-3]	2023	Comprehensive review of the effects of ionizing radiations on the ZERODUR® glass ceramic	A. Carré, R. Kirchhoff, T. Hull, J. Krieg, D. Eppers, M. Valente, T. Westerhoff	Journal Article Vol. 9, Issue 2 (open access)
[6-2]	2021	Glass ceramic ZERODUR®: Even closer to zero thermal expansion: a review, part 2	P. Hartmann, R. Jedamzik, A. Carré, J. Krieg, T. Westerhoff	Journal Article Vol. 7, Issue 2 (open access)
[6-1]	2021	Glass ceramic ZERODUR®: Even closer to zero thermal expansion: a review, part 1	P. Hartmann, R. Jedamzik, A. Carré, J. Krieg, T. Westerhoff	Journal Article Vol. 7, Issue 2 (open access)