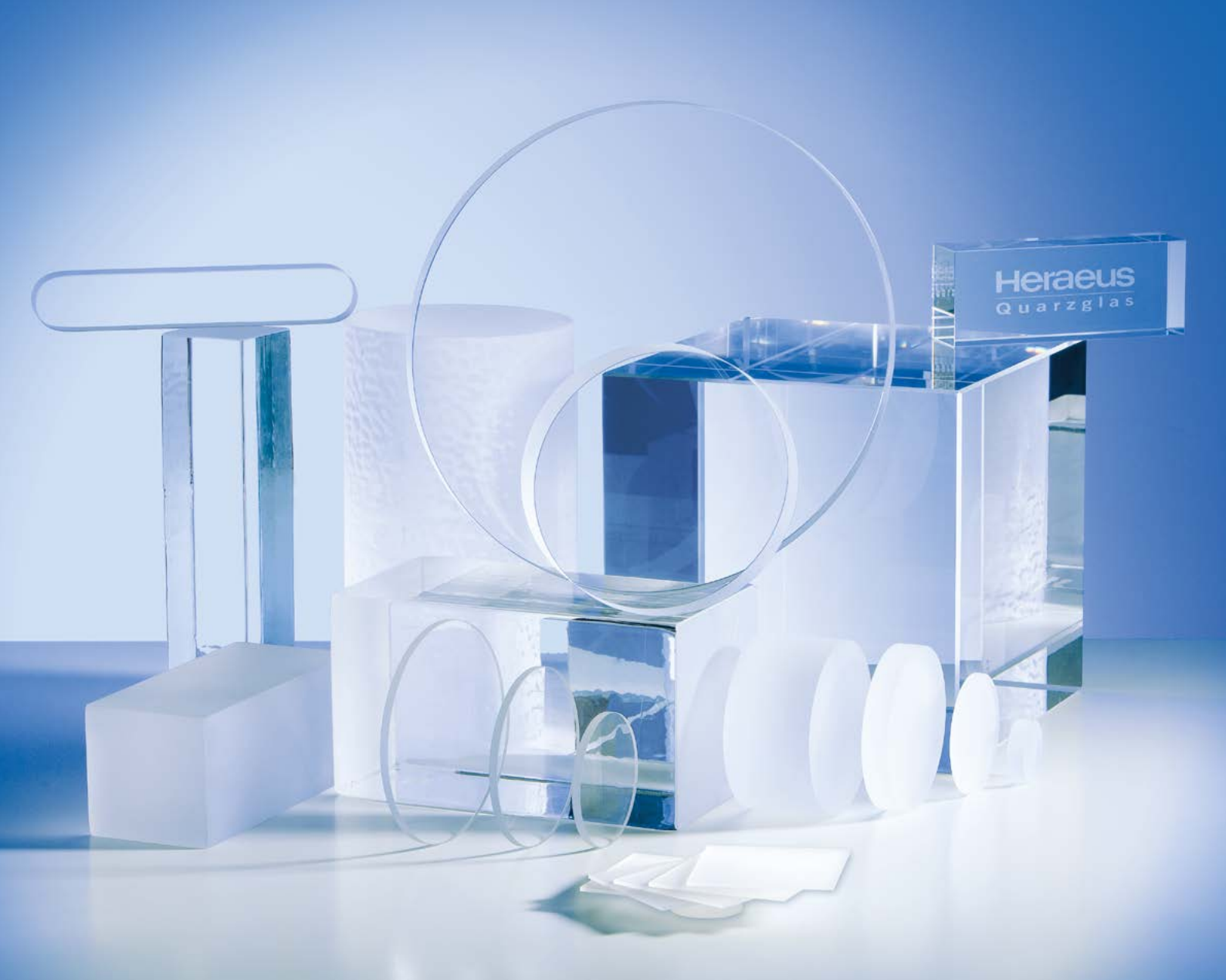


Heraeus



Quartz Glass for Optics Data and Properties

Quartz Glass for Optics Data and Properties



= 3D material, optically isotropic.

In quartz glass, the homogeneity is typically specified in one direction only. Heraeus manufactures quartz glass grades, which are controlled and specified in all 3 directions regarding striae, homogeneity and stress induced birefringence, for the most demanding applications. These materials are identified by the 3D symbol.

- For raw formed ingots the bubble specification is valid for the area defined by the minimum diameter tolerance. For machined parts it is defined as 100% of the material.

- Bubbles or inclusions ≤ 0.08 mm diameter are not counted. Tighter specification for bubbles and inclusions down to $\leq 10\mu\text{m}$ is possible on request.
- For non-spherical bubbles the maximum dimension is used.
- The Δn value is the maximum permissible lateral variation in refractive index (measured by interferometer at 632.8 nm after subtraction of tilt and offset) over 90% of the diameter or edge length of a fine ground piece, or 80% of a raw formed ingot.

Grade	Bubbles and Inclusions ^{1 2}			Homogeneity ⁵	
	The bubble grade is given for every 100 cm ³ . Quartzglass from Heraeus is free of inclusions.			Δn -value ⁴	
	DIN 58927	DIN ISO 10110 ³	Total cross-sections (in mm ²) of all bubbles (TBCS value)	Striae class as ⁴ per DIN ISO 10110 (per 30 mm thickness)	PV value ⁶ (Peak-to-Valley)
Suprasil® 311	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 3 \cdot 10^{-6}$
Suprasil® 312	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 4 \cdot 10^{-6}$
Suprasil® 313	0	1/1*0.08	≤ 0.015	2 / -,5	n. sp. ⁷
Suprasil® 3001	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 4 \cdot 10^{-6}$
Suprasil® 3002	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 10 \cdot 10^{-6}$
Suprasil® 300	0	1/1*0.08	≤ 0.015	acc. MIL	n. sp.
Suprasil® 3301	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 2 \cdot 10^{-6}$
Suprasil® 3302	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 3 \cdot 10^{-6}$
Suprasil® 1	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade A	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 Grade B	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 10 \cdot 10^{-6}$
Suprasil® CG	0	1/1*0.08	≤ 0.015	acc. MIL	$\leq 30 \cdot 10^{-6}$
Suprasil® 1 ArF / KrF	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Suprasil® 2 ArF / KrF	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 5 \cdot 10^{-6}$
Spectrosil® 2000	0	1/1*0.08	≤ 0.015	2 / -,5	$\leq 10 \cdot 10^{-6}$
Infrasil® 301	0	1/1*0.16	≤ 0.03	2 / -,5	$\leq 5 \cdot 10^{-6}$
Infrasil® 302	0..1	1/1*0.35	≤ 0.1	2 / -,5	$\leq 6 \cdot 10^{-6}$
HOQ® 310	2...3	1/1*0.63 ≤ 6 kg 1/2*1.0 > 6 kg	0.5	n. sp.	n. sp.

Synthetic Fused Silica

Natural Quartz⁸

n. sp. = not specified

= 3D material, optically isotropic

The maximum test diameter is 430 mm. Larger pieces are measured using overlapping interferograms.

- ⑥ Does not apply to drawn rods.
- ⑥ Lower values available on request.
- ⑦ The residual strain values refer to the measured phase difference per cm light path. The residual strain value is specified over 90% of the diameter or edge length of a fine ground piece, or 80% of a raw formed ingot.
- ⑥ Typically less than 10·10⁻⁶.
- ⑥ The chemical composition, and therefore, the optical properties of natural quartz can vary.

Refractive index

at 20°C and 1 bar

The given values are interpolated from measured values. More accurate data available upon request.

In contrast to other optical glasses, quartz glass shows very little difference in refractive index from melt to melt.

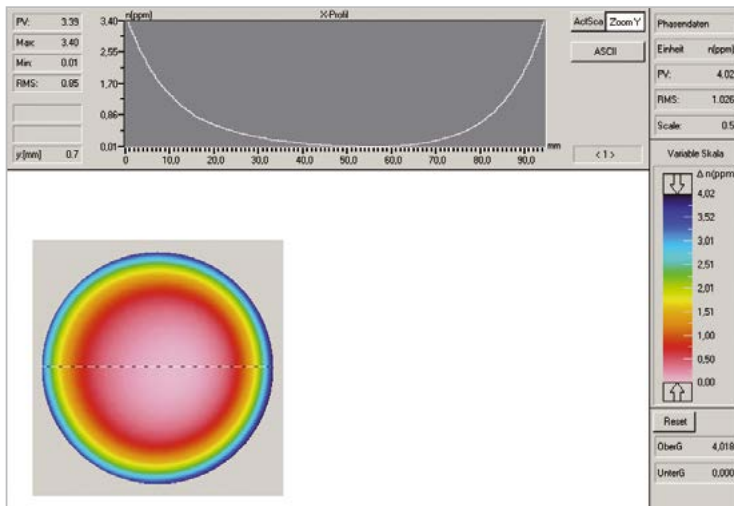
Residual Strain nm/cm ^⑥	Fluorescence	OH-Content
	Excitation by Hg-Lamp@ λ= 254 nm and UG 5-filter; Lamp-power: 8W; Detection: adapted eye	ppm (µg/g)
≤ 5	free	≤ 300
≤ 5	free	≤ 300
≤ 5	free	≤ 300
≤ 6	slight blue	≤ 1
≤ 6	slight blue	≤ 1
≤ 5	slight blue	≤ 1
≤ 2	free	≤ 20
≤ 3	free	≤ 20
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 20	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	free	≤ 1300
≤ 5	blue-violet	≤ 8
≤ 5	blue-violet	≤ 8
≤ 10	blue-violet	ca. 30

Wavelength nm	Suprasil®- family	Suprasil® 3001/3002/300	Infrasil® / HQ®
ArF	190	1,5657	-
	193,4	1,5601	-
	200	1,5505	-
	202,54	-	1,5473
	220	1,5285	-
	232,94	-	1,5287
	240	1,5133	-
	248,4	1,5083	-
	260	1,5024	1,5026
4 x Nd:YAG	266	1,4997	-
	274,87	1,4961	1,4999
	280	1,4942	-
	300	1,4878	1,4944
XeCl	308	1,4856	-
	320	1,4827	1,4880
HeCd	325	1,4816	-
N2	337	1,4792	1,4818
	340	1,4787	-
	360	1,4753	1,4794
(ni)	365,48	1,4745	-
	380	1,4725	1,4788
	400	1,4701	1,4726
(nh)	404,65	1,4696	1,4704
(ng)	435,83	1,4667	1,4698
HeCd	441,6	1,4662	1,4699
Kr	447,1	1,4658	1,4670
(nF)	486,13	1,4631	1,4663
Ar	488	1,4630	1,4665
Ar	514,5	1,4616	1,4659
2 x Nd:YAG	532	1,4607	1,4632
(ne)	546,07	1,4601	1,4631
(nd)	587,56	1,4585	1,4617
HeNe	632,8	1,4570	1,4608
(nc)	656,27	1,4564	1,4602
Ruby	694,3	1,4554	1,4604
Kr	752,5	1,4542	1,4600
	800	1,4533	1,4604
	850	1,4525	1,4604
	900	1,4518	1,4573
GaAs	905	1,4517	1,4571
	1000	1,4504	1,4571
Nd:YAG	1064	1,4496	1,4565
HeNe	1153	1,4486	1,4555
	1200	1,4481	1,4557
Nd:YAG	1319	1,4467	1,4545
	1400	1,4458	1,4543
	1600	1,4434	1,4536
	1800	1,4409	1,4528
	2000	1,4381	1,4520
	2200	1,4350	1,4519
	2400	1,4316	1,4518
	2600	1,4279	1,4507
	2800	1,4238	1,4499
	3000	1,4193	1,4497
	3200	1,4143	1,4489
	3400	1,4088	1,4481

Optical Homogeneity and Stress Induced Birefringence

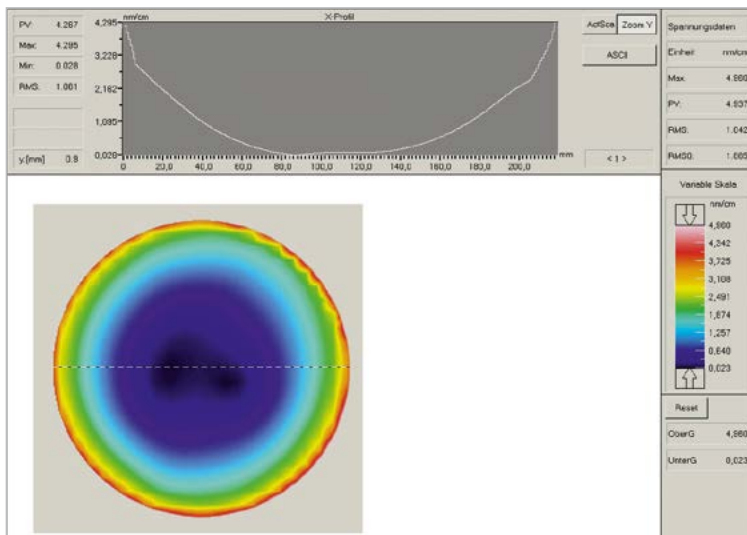
The false colour diagram below shows the typical two-dimensional refraction-index distribution. The interferogram belongs to a circular blank.

The sectional view along the diameter shows the refraction-index distribution across the blank. One can clearly see the very low value in the center of the plate and the rise close to the edge.



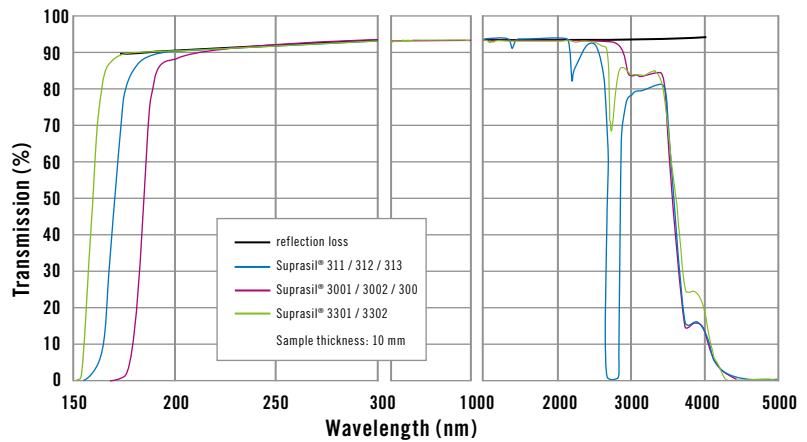
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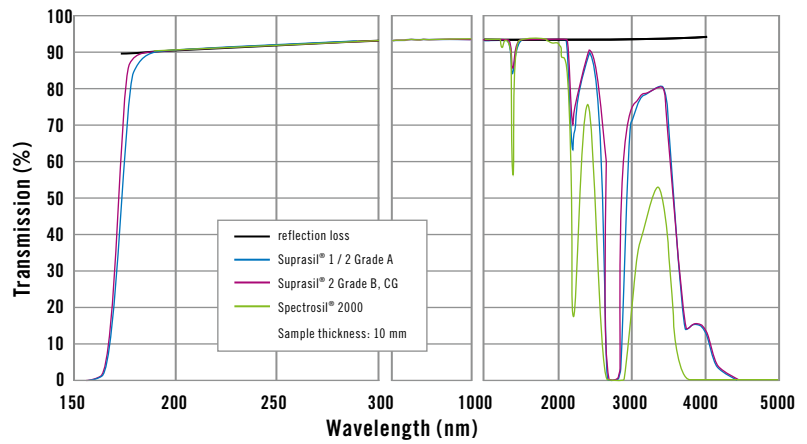


Typical transmission including Fresnel reflection losses $(1-R)^2$

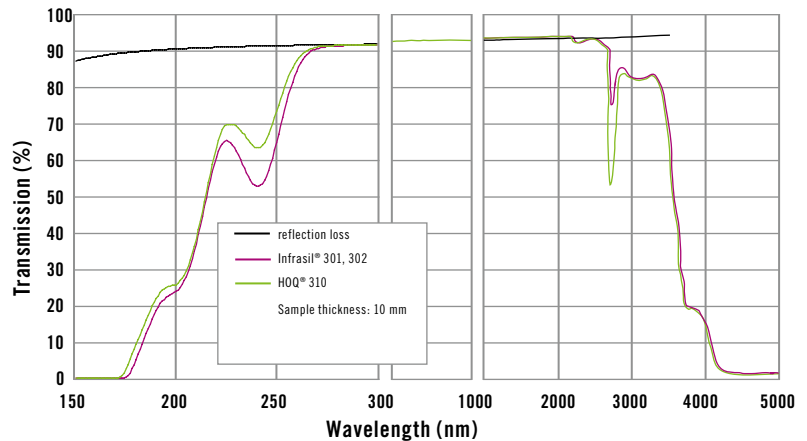
Suprasil® 311, 312, 313
 Suprasil® 3001, 3002, 300
 Suprasil® 3301, 3302



Suprasil® 1, 1 ArF / KrF
 Suprasil® 2 Grade A, 2 ArF / KrF
 Suprasil® 2 Grade B, Suprasil® CG
 Spectrosil® 2000



HQ® 310
 Infrasil® 301, 302



The uppermost curves in the transmission graphs indicate the calculated Fresnel reflection losses for two uncoated surfaces.

Technical Properties

Internal transmission (%)

Values of pure transmissions of a 10 mm thick sample for selected UV-Wavelengths.

Wavelength nm	Suprasil® ArF/ KrF - specified -	Suprasil®- family - typical -
193,4	≥ 99,30	98,50
248,4	≥ 99,80	99,50
266	99,90	99,90

Relative temperature coefficients of the refractive index in 10⁻⁶ K⁻¹

Wave-length nm	Suprasil®-family, Spectrosil®		Infrasil® / HOQ®	
	0...20°C	20...40°C	0...20°C	20...40°C
237,8	14,6	14,9	15,2	15,3
365	11	11,2	11,5	11,6
546,1	9,9	10,1	10,6	10,7
587,6	9,8	10,0	10,5	10,6
643,8	9,6	9,8	10,4	10,5

Abbe constant

$v_d = \frac{n_d - 1}{n_f - n_c}$	67,8 ± 0,5
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Birefringence constant @ 633 nm

$\frac{\text{nm}}{\text{cm} \cdot \text{bar}}$	3,54 ± 0,05	3,61 ± 0,05
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Refraction index dispersion

Dispersion constants (Sellmeier)

	Suprasil®-family, Spectrosil®	Infrasil® / HOQ®
B1	4,73115591 · 10 ⁻¹	4,76523070 · 10 ⁻¹
B2	6,31038719 · 10 ⁻¹	6,27786368 · 10 ⁻¹
B3	9,06404498 · 10 ⁻¹	8,72274404 · 10 ⁻¹
C1	1,29957170 · 10 ⁻²	2,84888095 · 10 ⁻³
C2	4,12809220 · 10 ⁻³	1,18369052 · 10 ⁻²
C3	9,87685322 · 10 ¹	9,56856012 · 10 ¹

Sellmeier Equation:

$$n^2 - 1 = B_1 \lambda^2 / (\lambda^2 - C_1) + B_2 \lambda^2 / (\lambda^2 - C_2) + B_3 \lambda^2 / (\lambda^2 - C_3)$$

Wavelength λ in μm at 20°C

Typical trace impurities in quartz glass

Impurities	Suprasil®-family, Spectrosil® ppm	Infrasil® / HOQ® ppm
Al = aluminium	≤ 0,010	20
Ca = calcium	≤ 0,015	1
Cr = chrome	≤ 0,001	0,1
Cu = copper	≤ 0,003	0,1
Fe = iron	≤ 0,005	0,8
K = potassium	≤ 0,010	0,8
Li = lithium	≤ 0,001	1
Mg = magnesium	≤ 0,005	0,1
Na = sodium	≤ 0,010	1
Ti = titanium	≤ 0,005	1

Mechanical data		Suprasil®-family, Spectrosil® Infrasil® / HOQ®
Density	g/cm ³	2,20
Mohs-hardness		5,5.....6,5
Micro-hardness	N/mm ²	8600.....9800
Knoop-hardness	N/mm ²	5800.....6200
Modulus of elasticity (at 20°C)	N/mm ²	7,0 · 10 ⁴
Modulus of torsion	N/mm ²	3 · 10 ⁴
Poisson's ratio		0,17
Compressive strength	N/mm ²	1150
Tensile strength	N/mm ²	50
Bending strength	N/mm ²	67
Torsional strength	N/mm ²	30
Sound velocity	m/s	5720

Electrical data		
Resistivity in Ω·m		
20°C		10 ¹⁶
400°C		10 ⁸
800°C		6,3 · 10 ⁴
1200°C		1,3 · 10 ³
Dielectric strength in kV/mm (Layer thickness ≥ 5 mm)		
20°C		40...50
500°C		4...5
Dielectric loss angle (tg δ)		
1kHz		0,0005
1...1000MHz		< 0,001
3 · 10 ⁴ MHz		0,0004
Dielectric constant (ε)		
20°C	0...1 MHz	3,7
23°C	0...1000 MHz	3,80
23°C	3 · 10 ⁴ MHz	3,81

Thermal data		Suprasil®- Family, Spectrosil®	Infrasil®/ HOQ®
Softening temperature	°C	~ 1600	~ 1730
Annealing temperature	°C	~ 1120	~ 1180
strain temperature	°C	~ 1025	~ 1075
Max. working temperature			
continuous	°C	~ 950	~ 1150
short-term	°C	~ 1200	~ 1300
Mean specific heat J/kg · K			
	0...100°C	772	
	0...500°C	964	
	0...900°C	1052	
Heat conductivity W/m · K			
	20°C	1,38	
	100°C	1,46	
	200°C	1,55	
	300°C	1,67	
	400°C	1,84	
	950°C	2,68	
Mean thermal expansion coefficient K⁻¹			
	-160...0°C	0	
	-50...0°C	2,7 · 10 ⁻⁷	
	0...100°C	5,1 · 10 ⁻⁷	
	0...200°C	5,8 · 10 ⁻⁷	
	0...300°C	5,9 · 10 ⁻⁷	
	0...600°C	5,4 · 10 ⁻⁷	
	0...900°C	4,8 · 10 ⁻⁷	

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