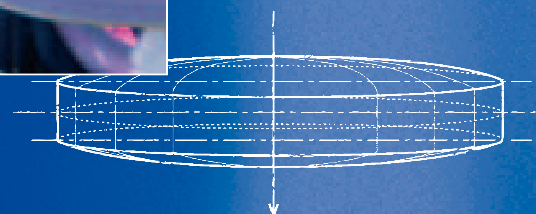
Synthetic Fused Silica

DUV/UV, VIS and IR applications



SCHOTT lithotec

SCHOTT Lithotec Fused Silica

Lithosil® is available in four different inner quality grades.

Key quality features of the different grades are:

- inclusion / bubble free (eg. grades Q0 + Q1)
- excellent UV transmittance
- very low fluorescence
- high laser durability
- low stress birefringence
- high refractive index homogeneity: additional 3D option
- very low thermal expansion coefficient
- high temperature stability

The high laser durability of fused silica makes it the first choice material for inclusion free material according to the ISO 10110 for microlithography illumination, excimer laser optics, beam deliveries, laser fusion and a wide range of other optical applications.

The amorphous synthetic fused silica SiO_2 of high purity complete the application range of optical materials from DUV to IR with a very good transmission ranging from 185 nm to 2.5 µm.

Advantages in optical performance can be achieved with Lithosil® for the following applications: standard optics, excimer laser optics, litho optics, light pipes, laser fusion, optics as well as for technical usage.
Special needs or requirements on specifications can directly be addressed to our sales team and we will spare no effort to fulfil your request (surface qualities: raw, cut, ground or polished; different spectral ranges; irradiation dosage, …).

Lithosil®Q0 is characterized by its high three-dimensional optical homogeneity. Free of striations in any functional direction, it is recommended for high-end resolution requirements in optical elements such as prisms and lenses.

Lithosil®Q1 exhibits high homogeneity and has no striations in the functional direction. Typical applications are optical elements such as lenses, windows and wafers.

Lithosil®Q2 is not specified concerning homogeneity. This grade is recommended for optics in the visible spectral range or optics in the UV with less stringent demands on transmission.

Lithosil®QT is not specified concerning homogeneity, striae and striations. This grade is recommended for technical applications.

Grades, Subgrades and Optical Properties of Lithosil®

Grades:
different material grades are characterized in the functional direction by:

- very low inclusion / bubble level
- low level of refractive index variations and local inhomogeneities especially striation, striae

Grades are:
- Lithosil®Q0
- Lithosil®Q1
- Lithosil®Q2
- Lithosil®QT

Sub Grades:

Excimer Grades
- high internal transmission, wide spectral UV-range (next page)
- qualified for 193 nm or 248 nm LIF (laser induced fluorescence)
- available in Lithosil®Q0 and Q1 grade

3D Material
- refractive index homogeneity qualified in all 3 dimensions depending on geometry
- available in Lithosil®Q0 grade
- 3D Material is available on request

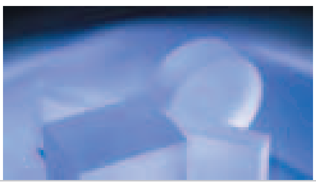
Optical Properties

A large variety of specifications is available but needs to be defined according to your individual requirements regarding dimensions, material and surface quality. Please discuss your request directly with our sales department (Request for Quotation, download on page 7).
Here you find a selection of the typical properties of our products:

Grade	Bubbles and Inclusions[4]		Homogeneity Data		Stress Birefringence
	according to ISO 10110-3	max. Diameter [mm]	local inhomogeneities: striae and striations[1] according to ISO 10110-4	refractive index change Δn[2] "SCHOTT homogeneity classes" [ppm = $1*10^{-6}$] functional directions	Standard[3] [nm/cm]
Lithosil®Q0	1/ 1*0.01	≤ 0.08	2/ 5 ; 5 all directions	≤ 1 ppm abs. ≤ 40 ppm abs. H5 .... H1 (to be specified)	≤ 5
Lithosil®Q1	1/ 1*0.01	≤ 0.08	2/ 5 ; 5 functional directions		≤ 5
Lithosil®Q2	1/ 1*0.01	< 0.1	2/ 5 ; 5 functional directions		≤ 10
Lithosil®QT	not defined	< 0.5	not specified	on request	≤ 10

SCHOTT homogeneity classes: defined within the refractive index homogeneity only

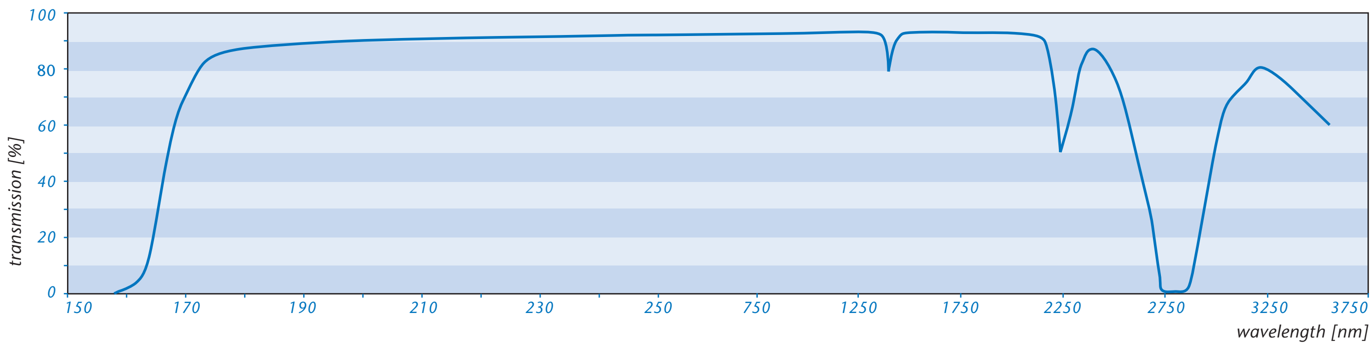
Refractive Index Homogeneity @ 633 nm									
abs. ppm	≤ 0.5	≤ 1	≤ 1.5	≤ 2	≤ 3	≤ 4	≤ 5	≤ 10	≤ 40
rel. ppm	-	H5	-	H4	-	H3	-	H2	H1
	-	+- 0.5	-	+- 1.0	-	+- 2.0	-	+- 5.0	+- 20.0
PV	SCHOTT homogeneity classes H1 ...... H5								

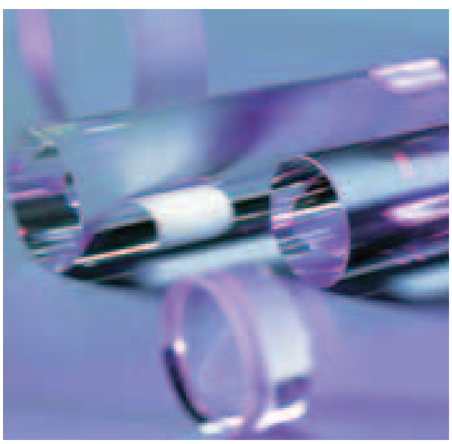


Notes
1) *Shadow method, polarizer and interferometer are used for striae and striation detection.*
2) *Homogeneity Δn is tested interferometrically (5% outer edge exclusion). Classification according to SCHOTT optical glass nomenclature.*
3) *Lower values with respect to size and processing available on request.*
4) *Bubbles and inclusions < 0.08 mm in diameter are not mentioned in ISO 10110.*

Spectral Transmission

Typical Transmission of Lithosil®Q0/Q1 including Fresnel reflection losses (10 mm path length)





Grade	Sub Grade	Internal Transmittance [%] per 10 mm sample thickness		OH Content	Other Contaminants
		λ = 193 nm	λ = 248 nm	[ppm]	[ppm]
Q0		≥ 98.0	≥ 99.5	appr. 1200	≤ 0.05
Q1		≥ 98.0	≥ 99.5	appr. 1200	≤ 0.05
Q2		-	≥ 98.0	800 - 1400	≤ 0.6
QT		-	-	800 - 1400	≤ 0.6
Q0[1)]	Q0 - E 193	≥ 99.3	≥ 99.8	appr. 1200	≤ 0.05
Q1[1)]	Q1 - E 193	≥ 99.3	≥ 99.8	appr. 1200	≤ 0.05
Q0[1)]	Q0 - E 248	≥ 99.0	≥ 99.8	appr. 1200	≤ 0.05
Q1[1)]	Q1 - E 248	≥ 99.0	≥ 99.8	appr. 1200	≤ 0.05
	All grades show an internal transmittance of 99.9 % for wavelengths > 250 nm. All grades show a hydrogen content of appr. $1*10^{18}$ Mol. / cm^3 H_2.				

1) Max. LIF factor (fluorescence signal ratio at 650 nm of Lithosil®Q-E to reference) can be individually agreed and guaranteed on request.

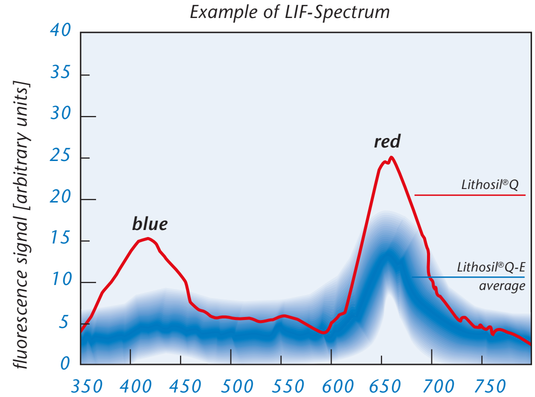
Fluorescence

Lithosil®Q-E
Excimer Grade Fused Silica with very low Fluorescence

- Excellent transmission at 193 nm and 248 nm
- Lowest level of Laser Induced Fluorescence (LIF)
- Literature is available via internet link (see page 7)

Red fluorescence: sensitive criteria for absorbing NBOHC (Non Bridgeing Oxygen Hole Center). *Literature link: 1, 2, 5, 6*
Low level of the red fluorecence is charactaristic for a high hydrogen content and a very high transmission.
Blue fluorescence: sensitive criteria for absorbing ODC (oxygen deficiency centers). *Literature link: 3*
Best comparability of every sample by routine LIF-measurement to a calibration standard.

Example of LIF-Spectrum



Measurements performed at IPHT Jena

Irradiation parameters for LIF-qualification:
· laser wavelength 193 nm
· energy density 210 mJ / cm²
· repetition rate 10 Hz

Model for radiation induced defect generation

Radiation induced effects for long term irradiation are very well described by a model for 248 nm and 193 nm.

Absorption, Hydrogen consumption, Compaction, Rarefaction

- radiation induced absorption saturation
- radiation induced hydrogen consumption saturation
- preponderance of compaction or rarefaction strongly depends on energy density, pulse length and pulse number. *Literature link: 1, 2*

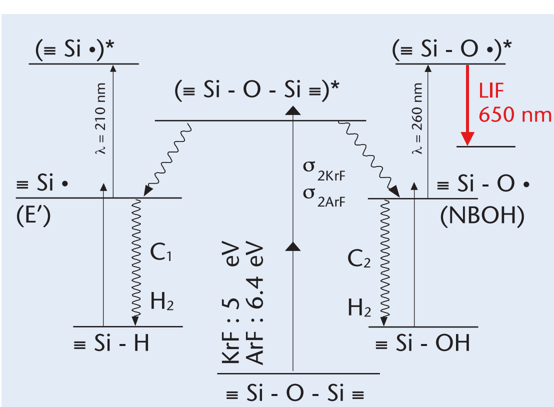
A radiation induced effect on short term basis is the rapid damage RDP which describes the dependence of transmission on to the variation of energy density, pulse number and repetition rate. *Literature link: 4*

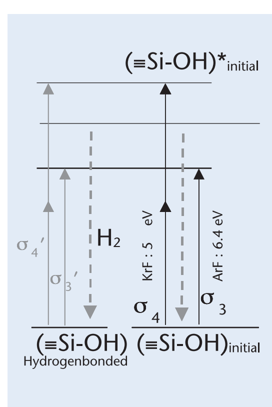
SCHOTT Lithotec offers material with a laser durability up to highest requirements which is categorized by an internal classification method. In addition to volume characteristics, laser durability is also dependent on surface quality (with increasing laser energies) and on laser operating conditions.

Absolute numbers can only be given for known irradiation conditions for your special application, therefore please see the literature links and contact our sales team directly.

Radiation induced defect generation at i-Line (365 nm):

No transmission loss was observed after the following irradiation conditions: 500 hours, cw-irradiation with 2.8 W.





Properties of Lithosil®

n_d = 1.45843	ν_d = 67.83	$n_F - n_C$ = 0.00676
n_e = 1.46004	ν_e = 67.68	$n_{F'} - n_{C'}$ = 0.00680

Refractive Indices $n(N_2)$ (at 20°C; nitrogen atmosphere; 1013 hPa)		
	λ_{vac} [nm]	n
n_{2325}	2325.59	1.43290
n_{1970}	1970.56	1.43849
n_{1530}	1530	1.44424
n_{1060}	1060	1.44965
n_t	1014.25	1.45021
n_s	852.35	1.45243
n_r	706.71	1.45511
n_C	656.45	1.45633
$n_{C'}$	644.03	1.45667
$n_{He\text{-}Ne}$	632.98	1.45698
n_D	589.46	1.45837
n_d	587.73	1.45843
n_e	546.23	1.46004
n_F	486.27	1.46309
$n_{F'}$	480.13	1.46347
n_g	435.96	1.46666
n_h	404.77	1.46958
n_i	365.12	1.47450
n_{334}	334.24	1.47973
n_{312}	312.66	1.48446
n_{296}	296.82	1.48870
n_{280}	280.43	1.49401
n_{248}	248.35	1.50837
n_{194}	194.23	1.55887
n_{193}	193.37	1.56022
n_{184}	184.95	1.57497

All refractive indices are interpolated from values measured under dry nitrogen; λ_{vac} = vacuum wavelength.
Tolerances of refractive indice: ± 2.0 · 10^{-5}

Sellmeier Dispersion Formula (according to SCHOTT Technical Information TIE29 *Literature link: 9*)
$n^2\text{-}1 = B_1\,\lambda^2/(\lambda^2\text{-}C_1) + B_2\,\lambda^2/(\lambda^2\text{-}C_2) + B_3\,\lambda^2/(\lambda^2\text{-}C_3)$ with λ in µm

valid for 184 nm < λ < 2326 nm (20°C; 1013 hPa); n = $n(N_2)$; λ = λ_{vac}

Constants of formula for dn_{abs}/dT in vacuum	
D_0	$2.06 \cdot 10^{-5}$
D_1	$2.51 \cdot 10^{-8}$
D_2	$-2.47 \cdot 10^{-11}$
E_0	$3.12 \cdot 10^{-7}$
E_1	$4.22 \cdot 10^{-10}$
λ_{TK}[µm]	0.16

valid for 365 nm < λ < 1014 nm and for -100°C ≤ T ≤ +140°C

Constants of Sellmeier Dispersion Formula for λ_{vac} and $n(N_2)$	
B_1	$6.69422575 \cdot 10^{-1}$
B_2	$4.34583937 \cdot 10^{-1}$
B_3	$8.71694723 \cdot 10^{-1}$
C_1	$4.48011239 \cdot 10^{-3}$
C_2	$1.32847049 \cdot 10^{-2}$
C_3	$9.53414824 \cdot 10^{1}$

	Differential Temperature Coefficients of the Refractive Index					
	$\Delta n_{rel}/\Delta T$ [10^{-6}/K]*			$\Delta n_{abs}/\Delta T$ [10^{-6}/K]**		
λ_{vac} [nm]	1060.0	546.23	365.12	1060.0	546.23	365.12
-40/-20 [°C]	8.9	9.4	10.2	6.9	7.3	8.1
+20/+40 [°C]	9.4	9.9	10.9	8.1	8.6	9.6
+60/+80 [°C]	9.8	10.4	11.5	8.8	9.4	10.4

) relative to nitrogen* *) relative to vacuum*

Relative Partial Dispersion	
$P_{s,t}$	0.3287
$P_{C,s}$	0.5770
$P_{d,C}$	0.3102
$P_{e,d}$	0.2388
$P_{g,F}$	0.5277
$P_{i,h}$	0.7283

Deviation of Relative Partial Dispersions from "Normal Line"	
$\Delta P_{C,t}$	0.0390
$\Delta P_{C,s}$	0.0159
$\Delta P_{F,e}$	-0.0017
$\Delta P_{g,F}$	-0.0020
$\Delta P_{i,g}$	0.0054

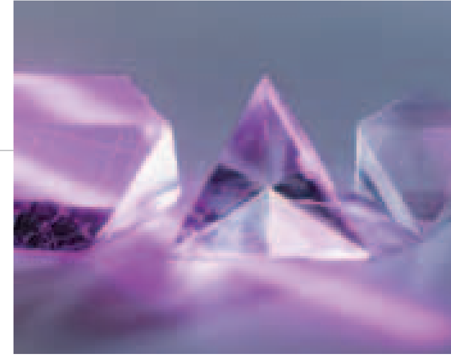
Typical Trace Contaminants [ppm]		
Trace elements	Lithosil® Q0/Q1	Lithosil® Q2
Al	≤ 0.05	0.20
Na	≤ 0.02	0.50
Ca	≤ 0.02	0.60
K	≤ 0.01	0.20
Fe	≤ 0.005	0.10
Ti	≤ 0.01	0.05
Cu	≤ 0.005	0.05
Cr	≤ 0.005	0.01
Mn	≤ 0.005	0.01

Thermal Properties	
Strain point $T_{10^{14.5}}$ [°C]	980
Annealing point $T_{10^{13.0}}$ [°C]	1080
Softening point $T_{10^{7.6}}$ [°C]	1600
Max working temperature continuously [°C] shortterm [°C]	 930 1180
Mean specific heat c_p (20°–100°C) [J/g · K]	0.79
Heat conductivity λ (32°C) [W/(m · K)]	1.31
Linear thermal expansion coefficient $\alpha_{(25°–100°C)}$ [10^{-6}/K] $\alpha_{(25°–200°C)}$ [10^{-6}/K] $\alpha_{(25°–300°C)}$ [10^{-6}/K] $\alpha_{(25°–600°C)}$ [10^{-6}/K]	 0.5 0.52 0.55 0.51

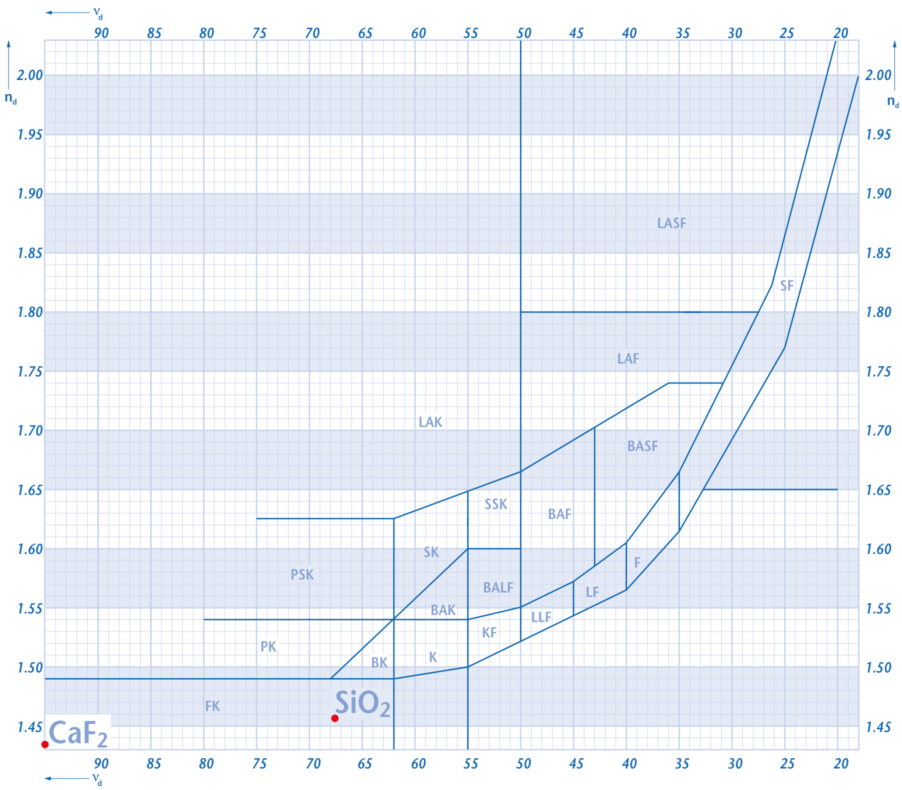
Electrical Properties	
Dielectric constant ε_r	3.8 ± 0.2
Dielectric loss angle φ (25°C/1MHz)	89.92° ± 0.03°
tan δ (δ = 90° – φ) (25°C/1MHz)	(14 ± 5) · 10^{-4}
Electrical resistivity (20°C) [Ω · cm]	1.15 · 10^{18}

Mechanical Properties	
Young's modulus (25°C) [GPa]	72
Shear modulus (25°C) [GPa]	31
Compressive strength [N/mm²]	1250
Bending strength [N/mm²]	80–100
Poisson's ratio µ	0.17
Knoop HK 0.1/20	580
Mohs	5–6
Density ρ [g/cm³]	2.2
Stress optical coefficient [1/Pa]	3.4 · 10^{-12}
Longitudinal ultrasonic velocity [m/s]	5940
Transversal ultrasonic velocity [m/s]	3770
Internal damping (25°–500°C)	2.0 · 10^{-5}

For further technical information please see Lit: 8,9,10!



Abbe Diagram




CERTIFICATE OF APPROVAL

SCHOTT Lithotec AG
Otto-Schott-Str. 13, 07745 Jena
Germany

DIN EN ISO 9001:2000

Development, production and sales of advanced materials and components for lithography applications

The following downloads are available at:

http://www.schott.com/lithotec

http://www.schott.com/optics_devices

- Request for Quotation (RfQ)
- Material Safety Data Sheet (MSDS)
- RoHS Statement (Restriction of Hazardous Substances)
- ISO 9001 Certificate
- Optical Glass: Description of Properties
- Technical Data Sheets (ASCII, Zemax Format)
- Abbe Diagram

SCHOTT Lithotec
is certified according to ISO 9001.

List of Literature *(alphabetical)*

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