Corning® HPFS® 7979, 7980, 8655 Fused Silica

Optical Materials Product Information
Specialty Materials Division

HPFS® 7979, 7980 and 8655 Fused Silica

HPFS® Fused Silica glasses are known throughout the industry for their consistent, repeatable performance. We offer many different grades of fused silica to support various product applications. Glass codes 7979, 7980, and 8655 are high purity non-crystalline silica glasses with excellent optical qualities. Product characteristics include extraordinarily low refractive index variations leading to state-of-the-art homogeneity values, low birefringence values, large size capabilities, exceptional transmittance from the deep ultraviolet through the infrared region, and an ultra-low thermal expansion coefficient; all of which are critical to our customers' demanding needs.

HPFS® Laser Resistance

Our strength is in material chemistry and development, and we are committed to be a technology leader by continuing our development of new materials. Optical materials are at the heart of the semiconductor industry. Microlithography projects a pattern from a photomask through an optical system to create IC chips using ultraviolet laser light. Optical inspection microscopes provide test capabilities for both masks and wafers at several different stages of the printing process. With the drive to smaller and smaller structures, the semiconductor industry continues its quest for better and better optical systems, and this in turn drives the requirements for the optical materials.

HPFS® Summary of Key Attributes

Attribute	Fused Silica						
	7980 Standard Grade	7980 KrF Grade	7980 ArF Grade	7980 Mirror Grade	7980 Industrial Grade	7979 IR Grade	8655 ArF Grade
Visible Transmittance	■	■	■	■	■	■	■
UV Transmittance	■	■	■				■
Infrared Transmittance						■	■
Homogeneity Certified in Use-Axis AA, A, C, F (By Size)	■	■	■			■	■
Inclusion Class Certified 0, 1, 2, 5	■	■	■	■		■	■
Striae Certified ISO 10110-4 Class 5 (None)	■	■	■	■		■	■
Homogeneity Certified in Off-Axis AA, A, C, F (By Size)	■	■	■			■	■
Low Birefringence	■	■	■	■		■	■
UV Laser Resistant (Data available upon request)		■	■				■
Economical (No certification of any properties except visible transmission. Tooling applications.)					■		

Quality Grade Selection Chart

For Mirror Grade - see chart on next page

Inclusion Class			Homogeneity[3,4] [ppm] Grade							
Class	Total Inclusion Cross Section[1] [mm²]	Maximum Size[2] [mm]	AA ≤ 0.5	A ≤ 1	B ≤ 1.5	C ≤ 2	D ≤ 3	E ≤ 4	F ≤ 5	G NS[5]
0	≤0.03	0.10	■	■	■	■	■	■	■	■
1	≤0.10	0.28		■	■	■	■	■	■	■
2	≤0.25	0.50			■	■	■	■	■	■
3	≤0.50	0.76				■	■	■	■	■
4	≤1.00	1.00				■	■	■	■	■
5	≤2.00	1.27				■	■	■	■	■

1. Defines the sum of the cross section in mm² of inclusions per 100 cm³ of glass. Inclusions with a diameter ≤ 0.10 mm are disregarded.
2. Refers to the diameter of the largest single inclusion.
3. Index homogeneity: the maximum index variation (relative), measured over the clear aperture of the blank.
4. Index homogeneity is certified using an interferometer at 632.8 nm. The numerical homogeneity is reported as the average through the piece thickness. Blanks with a diameter up to 450 mm can be analyzed over the full aperture. Larger parts can be analyzed using multiple overlapping apertures. The minimum thickness for index homogeneity verification is 20 mm. For thinner parts, the parent piece is certified.
5. NS (Not Specified)

HPFS® Data and Properties

	Inclusion Class	Homogeneity Grade	Birefringence Lower specifications available upon request [nm/cm]	Striae ISO 10110-4 Class	Metallic Impurities [ppb]	OH Content [ppm]
7979 IR Grade	0, 1, 2	AA, A, C, F	≤ 5	5	< 100	< 1
7980 Standard Grade**	0 - 5	AA - F	≤ 5	5	< 1000	800 - 1000
7980 KrF Grade*	0, 1, 2	AA, A, C, F	≤ 1	5	< 500	800 - 1000
7980 ArF Grade*	0, 1, 2	AA, A, C, F	≤ 1	5	< 100	800 - 1000
7980 Mirror Grade	See below	NS	≤ 5	1	NS	800 - 1000
7980 Industrial Grade	NS	NS	≤ 5	1	NS	800 - 1000
8655 ArF Grade*	0, 1, 2	AA, A, C, F	≤ 1	5	< 10	< 1

** No visible fluorescence when exposed to deuterium source from 215 nm - 400 nm. Material contains hydrogen to minimize absorption under UV exposures.*
*** HPFS® 7980 Standard Fluorescence-free Grade available upon request.*

Mechanical Properties

Unless otherwise stated, all values @ 25 °C	
Elastic (Young's) Modulus	73 GPa
Shear Modulus	31 GPa
Modulus of Rupture, abraded	52.4 MPa
Bulk Modulus	35.9 GPa
Poisson's Ratio	0.16
Density	2.20 g/cm^3
Knoop Hardness (100g load)	522 kg/mm^2
Tensile Strength	54 MPa
Compressive Strength	1.14 GPa

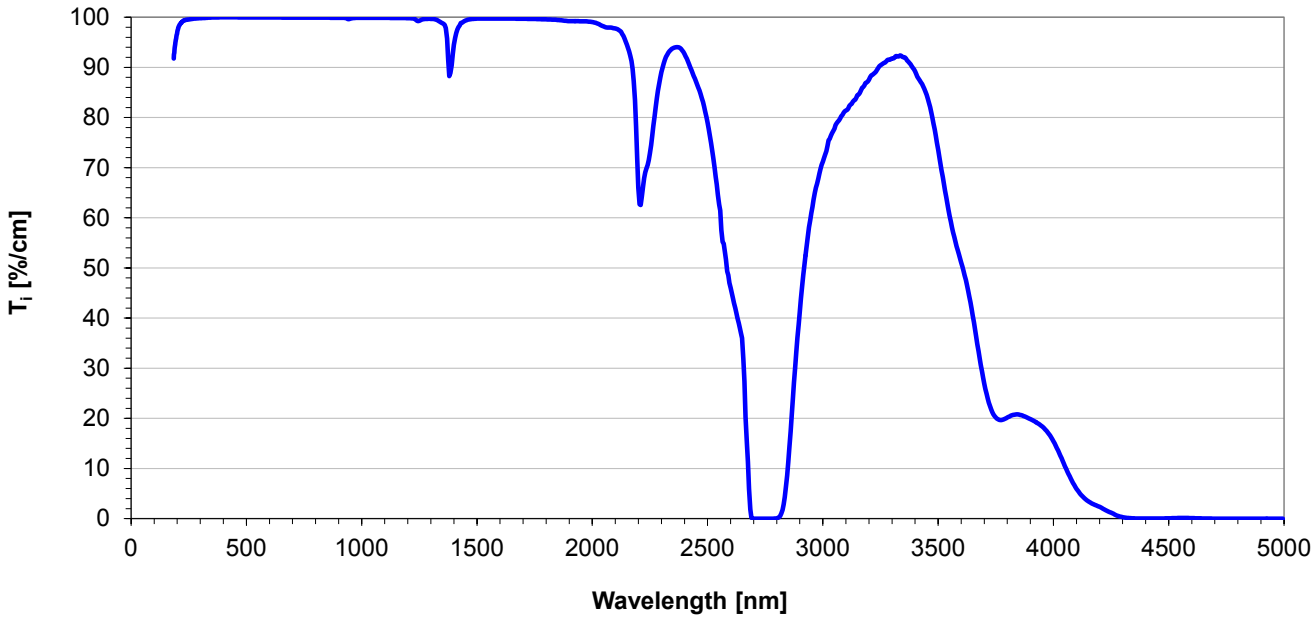
Thermal Properties

Glass Code:	**7980**	**7979**	**8655**	**Viscosity**
Softening Point*	1585 °C	1627 °C	1627 °C	$10^{7.6}$ poises
Annealing Point*	1042 °C	1180 °C	1180 °C	10^{13} poises
Strain Point*	893 °C	1068 °C	1068 °C	$10^{14.5}$ poises
Specific Heat			0.770 J/(g K)	
Thermal Conductivity			1.38 W/(m K)	
Thermal Diffusivity			0.0075 cm^2/s	
Thermal Expansion** (ppm/C):				
5 °C to 35 °C			0.52 x 10^{-6}	
0 °C to 200 °C			0.57 x 10^{-6}	
-100 °C to +200 °C			0.48 x 10^{-6}	
ASTM Procedures - *C-598, **E-228				

Mirror Quality Grade Selection Chart

Mirror Grade: Inclusion Classes			
Critical Zone:	**Blank Dimensions (Diameter or Diagonal)**		
	< 508 mm (20")	508 - 1143 mm (20 - 45")	1143 - 2286 mm (45 - 90")
Max. Mean Diameter	0.254 mm (0.010")	0.762 mm (0.030")	1.524 mm (0.060")
Max. Avg. #/mm^3 (#/in^3)	2 ppm (0.04)	3 ppm (0.05)	5 ppm (0.08)
Non-Critical Zone:	**Blank Dimensions (Diameter or Diagonal)**		
	< 508 mm (20")	508 - 1143 mm (20 - 45")	1143 - 2286 mm (45 - 90")
Max. Mean Diameter	1.016 mm (0.040")	1.524 mm (0.060")	3.81 mm (0.150")
Max. Avg. #/mm^3 (#/in^3)	3 ppm (0.05)	3 ppm (0.05)	9 ppm (0.15)

Internal Transmittance 7980

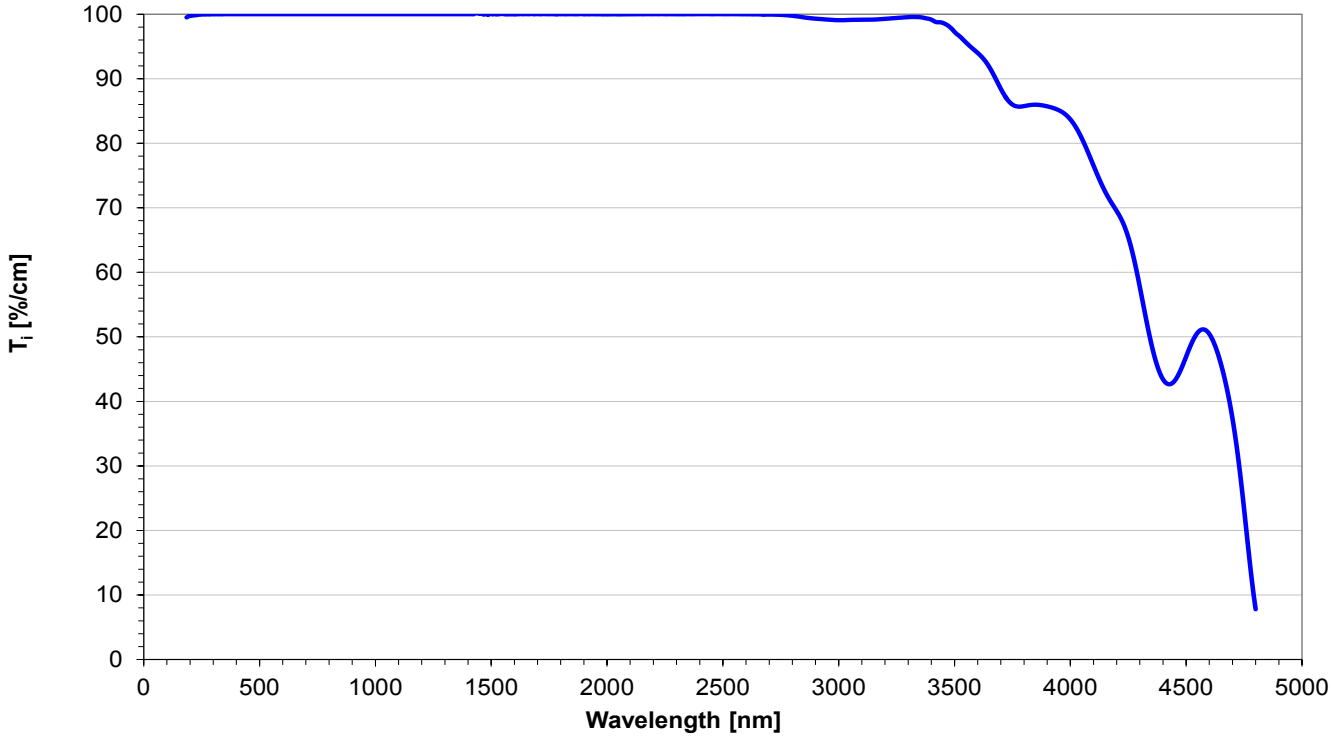


HPFS® 7980 Standard Grade meets high $T_i \geq 88.00$ %/cm @185 nm. (Equivalent to $T_e \geq 80.00$ %/cm @185 nm)

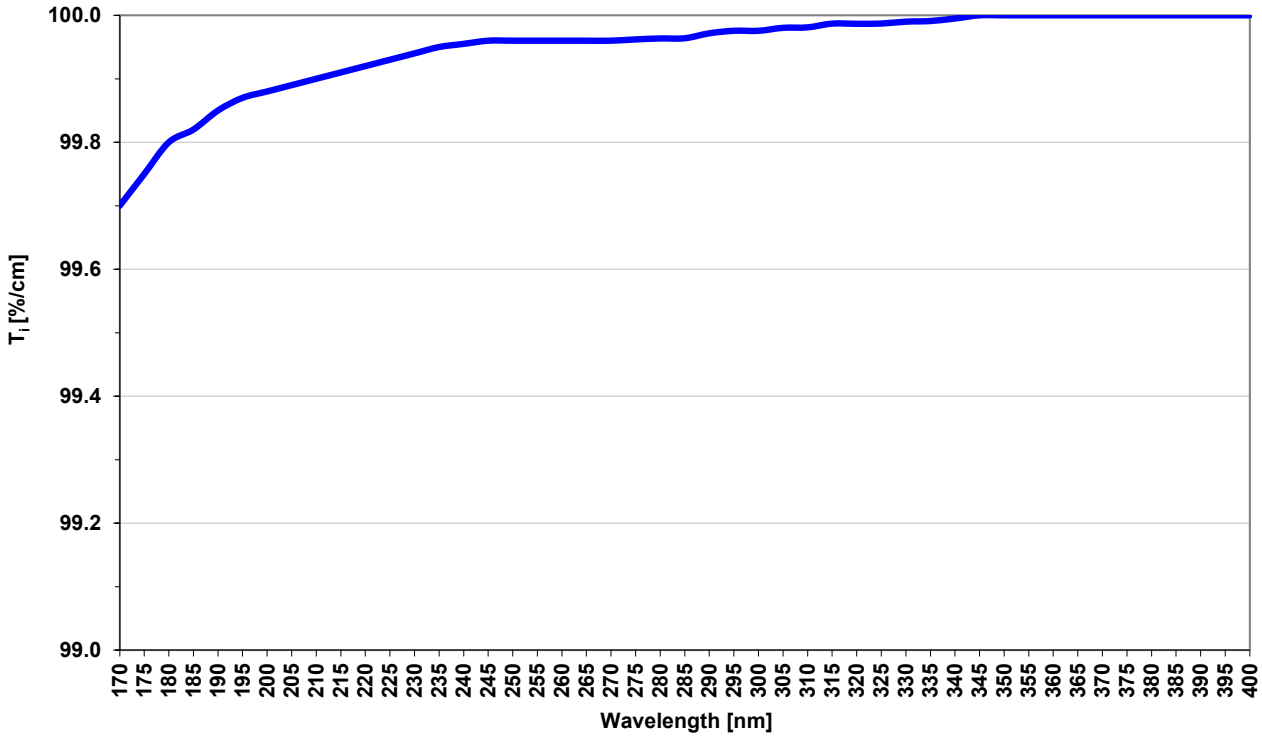
HPFS® 7980 KrF Grade meets high $T_i \geq 99.90$ %/cm @248 nm.
HPFS® 7980 ArF Grade meets high $T_i \geq 99.50$ %/cm @193 nm.

Higher transmittance is available upon request.

Internal Transmittance 7979



Internal Transmittance 8655



HPFS® 8655 Grade meets high $T_i \geq 99.75$ %/cm @193 nm.

Higher transmittance is available upon request.

Typical initial absorption k: ≤ 0.0005 ppm/cm at 193 nm.

Refractive Index and Dispersion: HPFS® 7980

Conditions: 22 °C, 760 mm Hg, N_2

Wavelength [Vacuum] [nm]	Refractive Index[2] n	Thermal Coefficient Δn/ΔT[3] [ppm/C]	Polynomial Dispersion Equation Constants[1], 22 °C	
1128.950	1.448866	9.6	A_0	2.104025406E+00
1014.260 n_t	1.450241	9.6	A_1	-1.456000330E-04
852.344 n_s	1.452463	9.7	A_2	-9.049135390E-03
706.714 n_r	1.455144	9.9	A_3	8.801830992E-03
656.454 n_C	1.456364	9.9	A_4	8.435237228E-05
632.990	1.457016	10.0	A_5	1.681656789E-06
587.725 n_d	1.458461	10.1	A_6	-1.675425449E-08
546.227 n_e	1.460076	10.2	A_7	8.326602461E-10
486.269 n_F	1.463123	10.4		
435.957 n_g	1.466691	10.6	Sellmeier Dispersion Equation Constants[2], 22 °C	
404.770 n_h	1.469615	10.8	A_1	0.68374049400
365.119 n_i	1.474539	11.2	A_2	0.42032361300
334.244	1.479764	11.6	A_3	0.58502748000
312.657	1.484493	12.0		
253.728	1.505522	13.9	B_1	0.00460352869
228.872	1.521154	15.5	B_2	0.01339688560
214.506	1.533722	17.0	B_3	64.49327320000
206.266	1.542665	18.1		
194.227	1.558918	20.3	Δn/ΔT Dispersion Equation Constants[3], 20-25 °C	
184.950	1.575017	22.7	C_0	9.390590
			C_1	0.235290
			C_2	-1.318560E-03
			C_3	3.028870E-04

Other Optical Properties	
nF'-nC'	0.006797
Stress Coefficient	35.0 nm/cm MPa
Abbe Constants:	
V_e	67.6
V_d	67.8

**1 Polynomial Equation:* $n^2 = A_0 + A_1 \lambda^4 + A_2 \lambda^2 + A_3 \lambda^{-2} + A_4 \lambda^{-4} + A_5 \lambda^{-6} + A_6 \lambda^{-8} + A_7 \lambda^{-10}$ *with λ in μm*

**2 Sellmeier Equation:* $n^2\text{-}1 = A_1\lambda^2/(\lambda^2 - B_1) + A_2 \lambda^2/(\lambda^2 - B_2) + A_3 \lambda^2/(\lambda^2 - B_3)$ *with λ in μm*

**3* $\Delta n/\Delta T$ *Equation:* $\Delta n/\Delta T\ [ppm/C] = C_0 + C_1\lambda^{-2} + C_2\lambda^{-4} + C_3\lambda^{-6}$ *with λ in μm*

The above dispersion equations for SiO_2 *were fit to the refractive indices of 20 wavelengths from 1129 nm to 185 nm.*

Refractive Index and Dispersion: HPFS® 8655 and 7979

Conditions: 22 °C, 760 mm Hg, N_2

Wavelength [Vacuum] [nm]	Refractive Index[1] n	Thermal Coefficient[2] Δn/ΔT [ppm/C]	Sellmeier Dispersion Equation Constants[1], 20 °C	
2326.050	1.433027	8.7	A_1	7.033574317E-02
2058.650	1.437307	9.3	A_2	7.241205497E-01
1970.630	1.438601	9.6	A_3	3.097807778E-01
1813.570	1.440776	9.1	A_4	9.309957497E-01
1530.000	1.444337	9.7	B_1	-2.301552288E-03
1128.950	1.448930	9.7	B_2	6.272886117E-03
1014.26 n_t	1.450304	9.6	B_3	1.415449740E-02
852.344 n_s	1.452526	9.5	B_4	1.016434845E+02
780.237	1.453731	9.5		
706.714 n_r	1.455205	9.9	Sellmeier Dispersion Equation Constants[1], 22 °C	
656.454 n_C	1.456425	10.1	A_1	3.550277875E-02
644.025 $n_{C'}$	1.456763	10.1	A_2	7.353314507E-01
632.990	1.457077	9.9	A_3	3.334560303E-01
587.725 n_d	1.458522	10.2	A_4	9.269506614E-01
546.227 n_e	1.460135	10.5	B_1	-4.826183477E-03
486.269 n_F	1.463183	10.4	B_2	5.808687673E-03
480.126 $n_{F'}$	1.463561	10.4	B_3	1.399572492E-02
435.957 n_g	1.466751	10.7	B_4	1.012182926E+02
404.770 n_h	1.469674	10.9		
388.975	1.471446	10.9	Sellmeier Dispersion Equation Constants[1], 25 °C	
365.119 n_i	1.474599	11.3	A_1	2.623483282E-02
340.463	1.478646	11.6	A_2	7.306029048E-01
334.244	1.479824	11.7	A_3	3.475321572E-01
312.657	1.484554	12.0	A_4	9.216052441E-01
296.814	1.488798	12.5	B_1	-5.783959035E-03
289.444	1.491056	12.5	B_2	5.600103210E-03
253.728	1.505585	14.0	B_3	1.389808930E-02
228.872	1.521218	15.3	B_4	1.006578079E+02
226.572	1.523018	15.9		
214.506	1.533786	16.8	Δn/ΔT Dispersion Equation Constants[2], 20-25 °C	
213.923	1.534371	17.0	D_o	9.545124E+00
206.266	1.542731	18.2	D_1	-9.835579E-02
202.613	1.547213	18.3	D_2	2.003170E-01
194.227	1.558985	20.4	D_3	2.209816E-03
184.950	1.575091	22.1	D_4	1.980644E-04

Other Optical Properties	
nF'-nC'	0.006797
Stress Coefficient	35.0 nm/cm MPa
Abbe Constants:	
V_e	67.6
V_d	67.8

**1 Sellmeier Equation:* $n^2\text{-}1 = A_1 \lambda^2/(\lambda^2 - B_1) + A_2 \lambda^2/(\lambda^2 - B_2) + A_3 \lambda^2/(\lambda^2 - B_3) + A_4 \lambda^2/(\lambda^2 - B_4)$ *with λ in μm*

**2 Δn/ΔT Equation:* $\Delta n/\Delta T\ [ppm/C] = D_0 + D_1\lambda^2 + D_2\lambda^{-2} + D_3\lambda^{-4} + D_4\lambda^{-6}$ *with λ in μm*

The above Sellmeier dispersion equation for SiO2 was used to fit the refractive indices of 35 wavelengths from 2326 nm to 185 nm.

Worldwide Accessibility

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