# HPFS® Fused Silica KrF Grade
## Semiconductor Optics

*HPFS® KrF Grade, Corning code 7980, is a high purity synthetic amorphous silicon dioxide manufactured by flame deposition. The noncrystalline, colorless, silica glass combines a very low thermal expansion coefficient with excellent optical qualities and exceptional transmittance in the deep ultraviolet. KrF Grade was developed for 248 nm lithography systems. In order to satisfy the challenging quality requirements of our customers in leading edge applications such as microlithography, Corning is dedicated to continuous improvement. Our investments in research and development, combined with Corning's quality systems, support our technology leadership position and ensure that we meet our customer's requirements on time, every time.*

### Quality Grade Selection Chart — HPFS® KrF Grade

Corning defines and certifies the quality of HPFS® glass using two criteria: inclusions and homogeneity grade.

| Inclusion Class | | | Homogeneity [3,4] ppm | | | |
|---|---|---|---|---|---|---|
| | | | Grade | | | |
| Class | Total Inclusion[1] Cross Section [mm²] | Maximum[2] Size [mm] | AA ≤ 0.5 | A ≤ 1 | C ≤ 2 | F ≤ 5 |
| 0 | ≤ 0.03 | 0.10 | ■ | ■ | ■ | ■ |
| 1 | ≤ 0.10 | 0.28 | | ■ | ■ | ■ |
| 2 | ≤ 0.25 | 0.50 | | | ■ | ■ |

**NOTES:**

1. Defines the sum of the cross section in $mm^2$ of inclusions per 100 $cm^3$ 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.

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## Mechanical and Thermal Properties:

Unless otherwise stated, all values @ 25°C

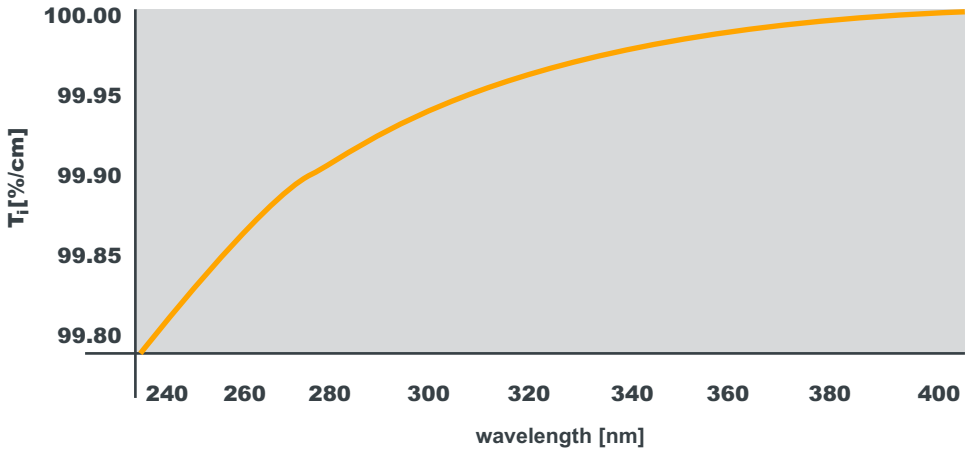
| | |
|---|---|
| Elastic (Young's) Modulus | 72.7 GPa |
| Shear Modulus | 31.4 GPa |
| Modulus of Rupture, abraded | 52.4 MPa |
| Bulk Modulus | 35.4 GPa |
| Poisson's Ratio | 0.16 |
| Density | 2.201 g/cm$^3$ |
| Knoop Hardness (100 g load) | 522 kg/mm$^2$ |

| | | |
|---|---|---|
| Softening Point | | 1585°C ($10^{7.6}$ poises) |
| Annealing Point | | 1042°C ($10^{13}$ poises) |
| Strain Point | | 893°C ($10^{14.5}$ poises) |
| Thermal Conductivity | | 1.30 W/m K |
| Thermal Diffusivity | | 0.0075 cm$^2$/s |
| Average C.T.E. | 0.52 ppm/K | 5°C-35°C |
| | 0.57 ppm/K | 0°C-200°C |
| | 0.48 ppm/K | -100°C-200°C |

## Chemical Durability and Impurities

| Solution | | Time | Weight Loss [mg/cm$^2$] | Impurities |
|---|---|---|---|---|
| 5% HCL by weight | @ 95°C | 24 h | < 0.010 | OH content (by weight): 800-1000 ppm |
| 5% NaOH | @ 95°C | 6 h | 0.453 | Impurities other than OH: ≤ 500 ppb |
| 0.02N $NA_2CO_3$ | @ 95°C | 6 h | 0.065 | |
| 0.02N $H_2SO_4$ | @ 95°C | 24 h | < 0.010 | |
| Deionized $H_2O$ | @ 95°C | 24 h | 0.015 | |
| 10% HF by weight | @ 25°C | 20 m | 0.230 | |
| 10% $NH_4F$*HF by weight | @ 25°C | 20 m | 0.220 | |

## Internal Transmittance: Code 7980 KrF Grade




HPFS® KrF Grade is certified to meet $T_i \geq 99.8\%/cm$ @248 nm when measured through a polished, uncoated sample.

A typical internal transmittance curve for HPFS® KrF Grade fused silica is shown here.

## *Refractive Index and Dispersion*

Data in 22ºC in 760mm Hg dry nitrogen gas

| Wavelength [air] λ [nm] | Refractive Index *2 n | Thermal Coefficient Δn/ΔT*3 (ppm/K) |
|---|---|---|
| 1128.64 | 1.448870 | 9.6 |
| 1064.00 | 1.449633 | 9.6 |
| 1060.00 | 1.449681 | 9.6 |
| 1013.98 $n_t$ | 1.450245 | 9.6 |
| 852.11 $n_s$ | 1.452469 | 9.7 |
| 706.52 $n_r$ | 1.455149 | 9.9 |
| 656.27 $n_C$ | 1.456370 | 9.9 |
| 643.85 $n_{C'}$ | 1.456707 | 10.0 |
| 632.80 $n_{He-Ne}$ | 1.457021 | 10.0 |
| 589.29 $n_D$ | 1.458406 | 10.1 |
| 587.56 $n_d$ | 1.458467 | 10.1 |
| 546.07 $n_e$ | 1.460082 | 10.2 |
| 486.13 nF | 1.463132 | 10.4 |
| 479.99 $n_{F'}$ | 1.463509 | 10.4 |
| 435.83 $n_g$ | 1.466701 | 10.6 |
| 404.66 $n_h$ | 1.469628 | 10.8 |
| 365.01 $n_i$ | 1.474555 | 11.2 |
| 334.15 | 1.479785 | 11.6 |
| 312.57 | 1.484514 | 12.0 |
| 308.00 | 1.485663 | 12.1 |
| 248.30 | 1.508433 | 14.2 |
| 248.00 | 1.508601 | 14.2 |
| 214.44 | 1.533789 | 17.0 |
| 206.20 | 1.542741 | 18.1 |
| 194.17 | 1.559012 | 20.4 |
| 193.40 | 1.560208 | 20.5 |
| 193.00 | 1.560841 | 20.6 |
| 184.89 | 1.575131 | 22.7 |

### Polynomial Dispersion Equation Constants*1

| | |
|---|---|
| A0 | 2.104025406 |
| A1 | $-1.456000330 \times 10^{-4}$ |
| A2 | $-9.049135390 \times 10^{-3}$ |
| A3 | $8.801830992 \times 10^{-3}$ |
| A4 | $8.435237228 \times 10^{-5}$ |
| A5 | $1.681656789 \times 10^{-6}$ |
| A6 | $-1.675425449 \times 10^{-8}$ |
| A7 | $8.326602461 \times 10^{-10}$ |

### Sellmeier Dispersion Equation Constants *2

| | |
|---|---|
| B1 | 0.68374049400 |
| B2 | 0.42032361300 |
| B3 | 0.58502748000 |
| C1 | 0.00460352869 |
| C2 | 0.01339688560 |
| C3 | 64.49327320000 |

### Δn/ΔT Dispersion Equation Constants *3

| | |
|---|---|
| C0 | 9.390590 |
| C1 | 0.235290 |
| C2 | -1.318560 x 10-3 |
| C3 | 3.028870 x 10-4 |

### Other Optical Properties

| | |
|---|---|
| $\nu_d$ | 67.79 |
| $\nu_e$ | 67.64 |
| $n_F - n_C$ | 0.006763 |
| $n_{F'} - n_{C'}$ | 0.006802 |
| Stress Coefficient | 35.0 nm/cm MPa |
| Striae | ISO 10110-4 Class 5/Thickness Direction |
| Birefringence | ≤ 1 nm/cm, lower specifications available |

*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: $n^2-1 = B_1 \lambda^2/(\lambda^2-C_1) + B_2 \lambda^2/(\lambda^2-C_2) + B_3 \lambda^2/(\lambda^2-C_3)$ with λ in µm
*3 Δn/ΔT Equation (20-25ºC) = $C_0 + C_1 \lambda^{-2} + C_2 \lambda^{-4} + C_3 \lambda^{-6}$ with λ in µm

## Resistance to Laser Damage

Samples of HPFS® KrF Grade are regularly tested for induced absorption at Corning's Metrology Laboratory, Sullivan Park Research Center, to maintain the high standards to which Corning is committed.