BOROFLOAT® 33 & Functional Coatings: A Union of Inspiration & Quality

The sum of its properties is what makes it unique.

More than 20 years ago, SCHOTT set up the first micro-float production line for what would soon become one of the most influential specialty glass materials. The result was BOROFLOAT® – the world's first floated borosilicate glass. With high-quality German engineering at its core, BOROFLOAT® quickly became an outstanding example of what seamless interaction between advanced know-how, innovative technology and professional curiosity – all in combination with the developmental drive of our team of experts – can deliver.
The performance requirements for optical filters and mirrors are highly dependent on the material's ability to reflect, absorb, enhance or modify incoming light. This can be accomplished with bulk optical glass materials or through coatings that are applied to a pristine glass substrate. Coatings usually allow significantly more freedom for customized light management design options which can be developed even further when a flat glass material with outstanding optical, thermal, mechanical and chemical properties is used. BOROFLOAT® borosilicate glass is such a unique substrate and has hence become the material of choice for robust high-temperature resistant dichroic filters, hot and cold mirrors.

Specialized coating companies have discovered BOROFLOAT® glass as a substrate for advanced coatings capable of performing under the most challenging conditions.

BOROFLOAT® – The sum of its properties is what makes it unique for functional coatings

- Exceptionally high transparency
- Outstanding thermal resistance
- Excellent mechanical strength
- Broad range of sizes and thicknesses

BOROFLOAT® glass with functional coatings offers exceptionally high transparenc

BOROFLOAT® glass - the industrial float glass with the lowest level of iron and other absorbing impurities in the market - offers exceptional light transmission. High UV transparency down to 300 nm, greater than 92 % light transmittance in the visible and near IR wavelength range, outstanding clarity, low auto-fluorescence and low solarization are specific characteristics of BOROFLOAT® glass substrates used in many optical fields.

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Optical data

Abbe number ($\nu_e = (n_e - 1) / (n_{F'} - n_{C'})$)	65.41
Refraction index (n_d ($\lambda_{587.6\ nm}$))	1.47140
Dispersion ($n_F - n_C$)	71.4 x 10^{-4}
Stress-optical coefficient (K)	4.0 x 10^{-6} mm² N^{-1}

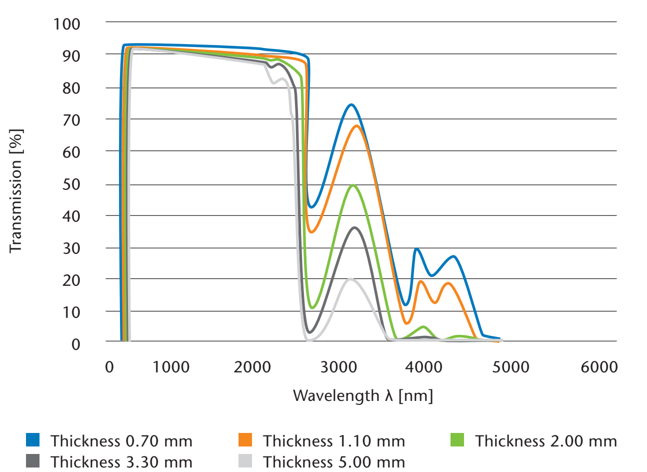
Average reference values, not guaranteed values.

Optical index of refraction

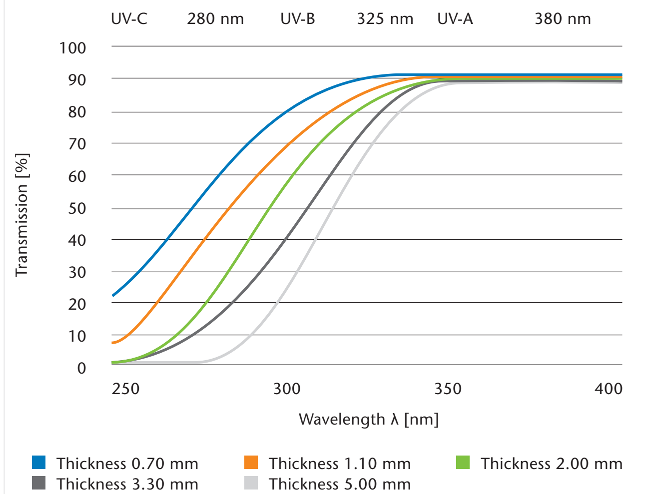
Wavelength λ (nm)	Refraction index n
435.8	1.48015
479.9	1.47676 ($n_{F'}$)
546.1	1.47311(n_e)
589.3	1.47133
643.8	1.46953 ($n_{C'}$)
656.3	1.46916

Mean reference values, not guaranteed values.

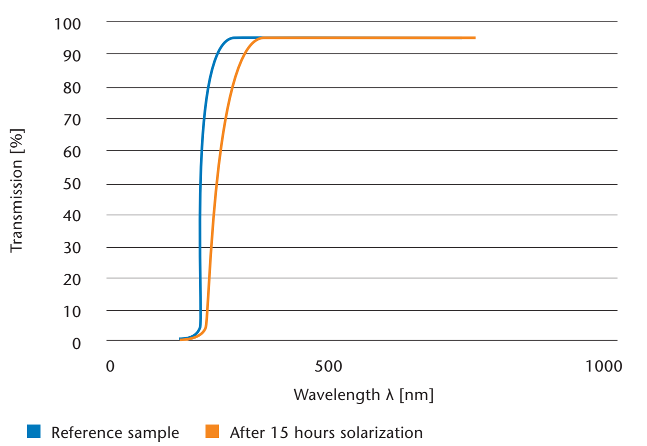
Transmission



Transmission in UV range

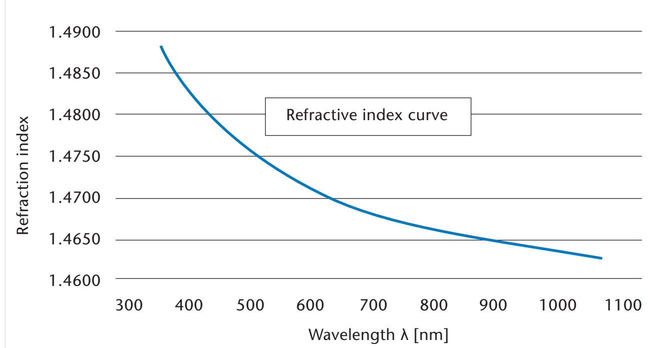


Solarization



The glass sample of a size 30 x 15 x 1 mm³ is radiation-exposed by using the high-pressure mercury vapor lamp HOK 4/120. This lamp works with a radiation intensity of 850 W/cm² and with a main wavelength of 365 nm.

Dispersion



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BOROFLOAT® glass - ideal for hot and cold mirrors due to its outstanding thermal resistance

Hot and cold mirrors either reflect or transmit infrared light and hence require high thermal resistance. The high boron content in BOROFLOAT® glass lowers the thermal expansion coefficient to $3.25\ 10^{-6} K^{-1}$ resulting in excellent resistance to thermal shock and temperature gradients.
The thermal properties of BOROFLOAT® glass (uncoated substrate) are shown below. Maximum thermal resistance of coated filters and mirrors varies depending on the filter supplier.

Maximum operating temperatures	
Maximum Operating Temperature For short-term usage (< 10 h)	500 °C
For long-term usage (≥ 10 h)	450 °C

Resistance to Thermal Gradients (RTG) and Resistance to Thermal Shock (RTS) must be considered when determining max. operation temperatures.

Thermal properties	
Coefficient of Linear Thermal Expansion (C.T.E.) $\alpha_{(20-300\,°C)}$	$3.25 \times 10^{-6}\ K^{-1}$ *
Specific heat capacity $c_{p\ (20-100\,°C)}$	0.83 kJ/(kg·K)
Thermal conductivity $\lambda_{(90\,°C)}$	1.2 W/(m·K)

* According to ISO 7991.

Resistance to Thermal Shock (RTS)

Glass Thickness	RTS (5 %-Fraktil)
≤ 3.8 mm	175 K
5.0 – 5.5 mm	160 K
6.5 mm	155 K
11 mm	142 K
18 mm	144 K
25 mm	128 K

Panels measuring 20 x 20 cm² (8 x 8 inches) are heated in an oven with circulating air and afterwards doused in the center with 50 ml of cold water (68 °F). The temperature is controlled via pyrometer. The RTS value is the difference in temperature between the hot panel and the cold water, at which breakage occurs in less than or equal to 5 % of the samples. In order to simulate damage that can occur in practical use, the samples are abraded with 220 grid sandpaper before testing.

Resistance to Thermal Gradients (RTG)

Glass Thickness	Tempering	RTG	
		T_{change} *	$T_{heat\text{-}up}$ *
3.8 mm	No	123 K	136 K
6.5 mm	No	119 K	132 K
11 mm	No	52 K	173 K
18 mm	No	31 K	188 K
6 mm	Thermal	> 300 K	

Edges ground or polished

* T_{change}: sudden temperature change
$T_{heat\text{-}up}$: continuous heat-up

Panels measuring 25 x 25 cm² (10 x 10 inches²) are heated in the center of the panel to a defined temperature; the edges are maintained at room temperature. The temperature is increased within one minute to a level that initiates breakage of the test panel. The temperature is controlled via pyrometer. The RTG value is the difference in temperature between the hot center of the panel and the cool panel edge, at which breakage occurs in less than or equal to 5 % of the samples. In order to simulate damage that can occur in practical use, the samples are abraded with 220 grid sandpaper before testing.

BOROFLOAT® glass - process robustness guaranteed

Mechanical strength and robustness during manufacturing are essential for high quality substrates for functional coatings. BOROFLOAT® glass has a very strong microstructure with a relatively low amount of non-bridging oxygen resulting in better scratch resistance, excellent abrasion resistance and lower darkening behavior during high intensity radiation exposure than other flat glass types.

Mechanical properties	
Density ρ (25 °C)	2.23 g/cm³
Young's Modulus E (according to DIN 13316)	64 kN/mm²
Poisson's Ratio μ (according to DIN 13316)	0.2
Knoop Hardness $_{0.1/20}$ (according to ISO 9385)	480
Bending Strength σ (according to DIN 52292 T 1)	25 MPa
Impact resistance	

The impact resistance of BOROFLOAT® 33 depends on the way it is fitted, the size and thickness of the panel, the type of impact involed, presence of drill holes and their arrangement as well as other parameters.

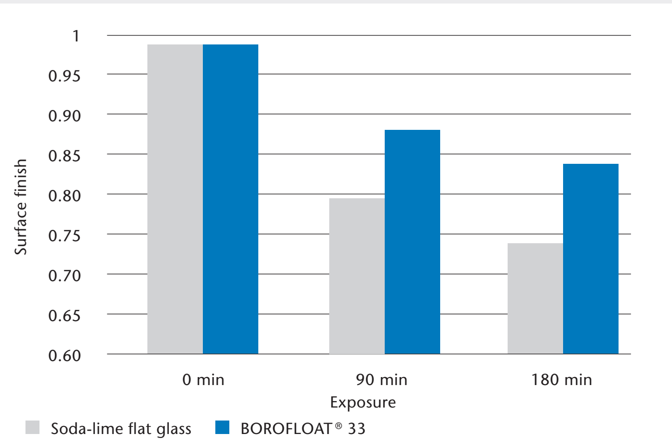
Reference values, not guaranteed values.

Critical forces

Material	Mean value F_c [mN]	Stadev.* [mN]
BOROFLOAT® 33	363.8	4.3
Other borosilicate glass	271.2	1.9
Soda-lime flat glass	214.4	4.6

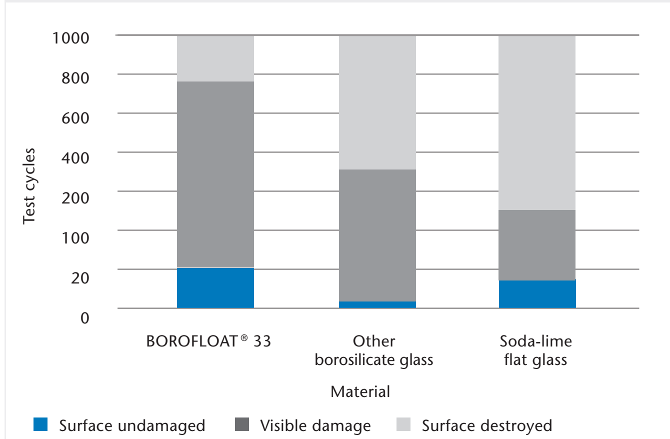
Summary of critical forces in Scanning-Scratch-Test.
*Standard deviation

Comparison of sand abrasion BOROFLOAT® 33 & soda-lime flat glass



According to a study conducted by the Fraunhofer Institute for Applied Optics and Precision Engineering, BOROFLOAT® 33 displayed the highest resistance to mechanical forces in comparison to other Materials.

Resistance to abrasion



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The right size and thickness for any application

Forms supplied

BOROFLOAT® 33 is available in the following standard thicknesses and tolerances:

Standard thicknesses			
Thickness mm (inch)		**Tolerance** mm (inch)	
0.70	(0.027)	± 0.05	(0.002)
1.10	(0.043)	± 0.05	(0.002)
1.75	(0.069)	± 0.05	(0.002)
2.00	(0.079)	± 0.05	(0.002)
2.25	(0.089)	± 0.05	(0.002)
2.75	(0.108)	± 0.10	(0.004)
3.30	(0.130)	± 0.20	(0.008)
3.80	(0.150)	± 0.20	(0.008)
5.00	(0.197)	± 0.20	(0.008)
5.50	(0.216)	± 0.20	(0.008)
6.50	(0.256)	± 0.20	(0.008)
7.50	(0.295)	± 0.30	(0.012)
9.00	(0.354)	± 0.30	(0.012)
11.00	(0.433)	± 0.30	(0.012)
13.00	(0.512)	± 0.30	(0.012)
15.00	(0.590)	± 0.40	(0.016)
16.00	(0.630)	± 0.50	(0.020)
19.00	(0.748)	± 0.50	(0.020)
21.00	(0.827)	± 0.70	(0.027)
25.40	(1.000)	± 1.00	(0.040)

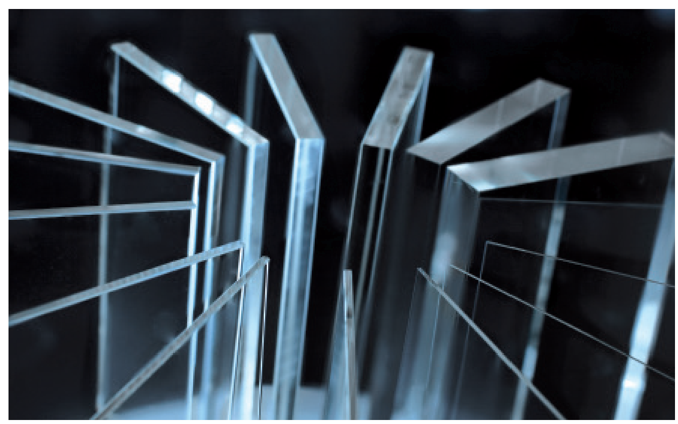
Panel thickness is continuously measured during production using laser thickness measuring equipment. Further thicknesses and tolerances are available on request.

Sizes

BOROFLOAT® 33 is available in the following standard sizes:

Standard sizes	
Size	**Thickness**
1,150 x 850 mm (45.3 x 33.5 in.)	0.7 – 25.4 mm (0.027 to 1.000 in.)
1,700 x 1,300 mm (66.9 x 51.2 in.)	16.0 – 21.0 mm (0.630 to 0.827 in.)
2,300 x 1,700 mm (90.5 x 66.9 in.)	0.7 – 15.0 mm (0.027 to 0.590 in.)

Standard sizes of BOROFLOAT® 33.



BOROFLOAT® 33 is available in a broad range of thicknesses.

Home Tech
SCHOTT North America, Inc.
5530 Shepherdsville Road
Louisville, KY 40228
USA
Phone +1 (502) 657-4417
Fax +1 (502) 966-4976
borofloat@us.schott.com
www.us.schott.com/borofloat/om

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