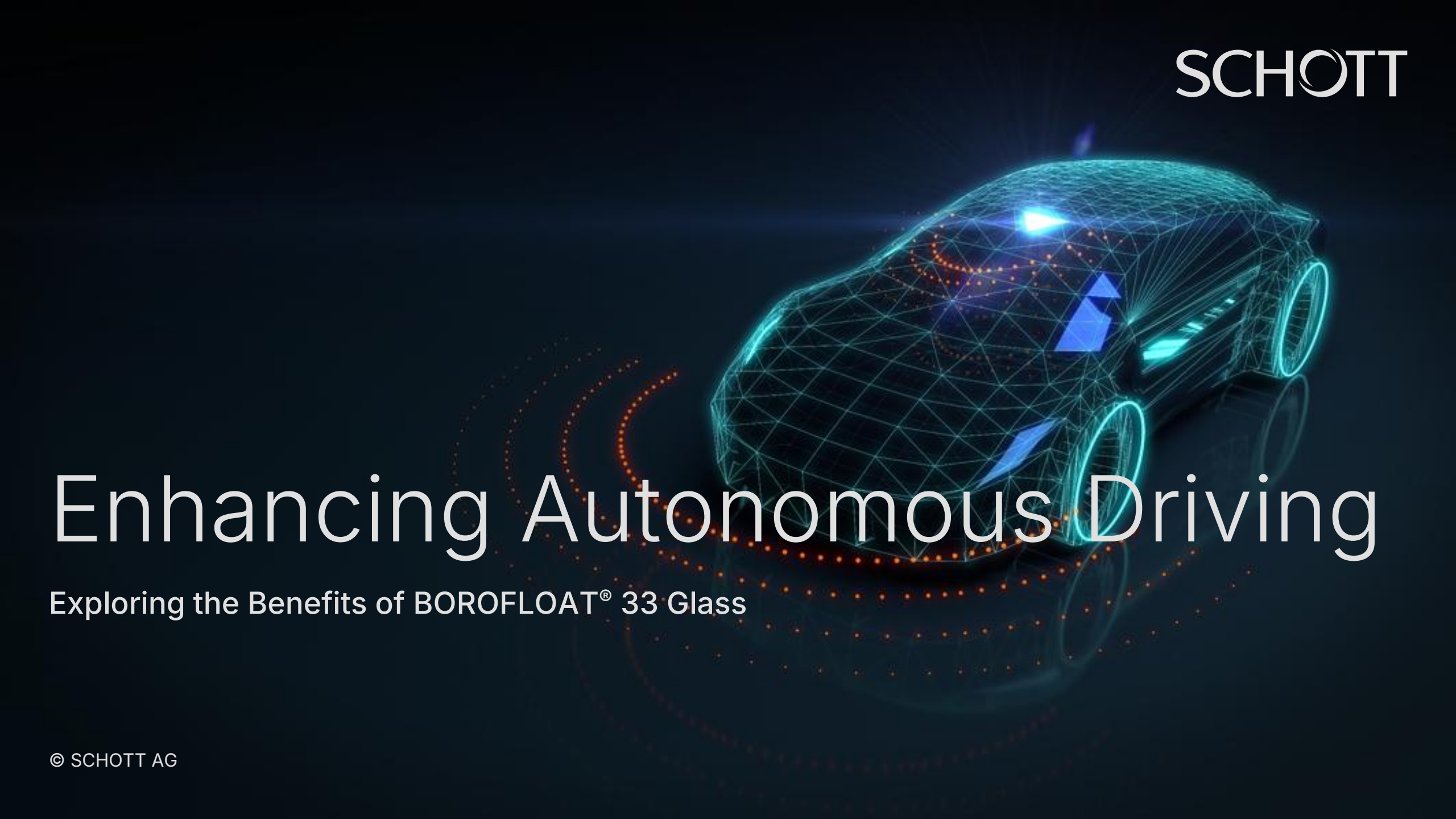
SCHOTT



Enhancing Autonomous Driving

Exploring the Benefits of BOROFLOAT® 33 Glass

About SCHOTT

Making impossible things possible since 1884

SCHOTT is a reliable global technology group for specialty glass, glass-ceramics, and innovative material solutions.

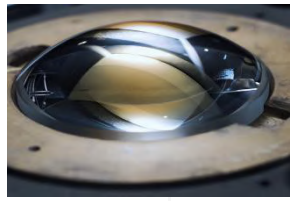
SCHOTT embraces our customers' visionary ideas and explores unique ways to make a real difference in the world.

With 17,400 employees in over 30 countries, SCHOTT is a highly skilled partner serving global high-tech industries.

Enabling next-generation innovative applications


Semiconductor & Datacom


Industrial & Energy


Optics


Home & Living


Automotive


Aviation, Astro & Space


Health


Consumer Electronics

17,400 employees

+30 countries Global presence

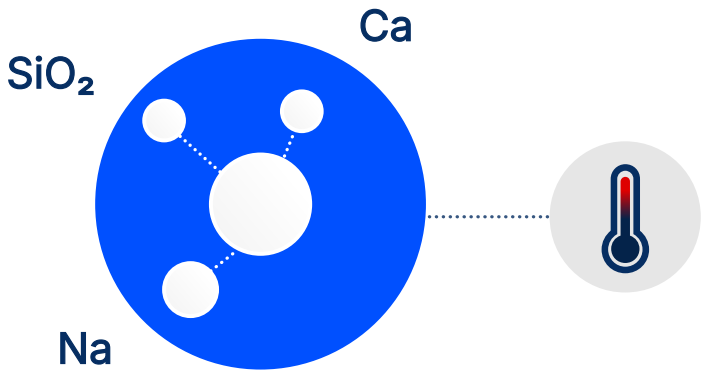
447 million EUR Capital investments

2.8 billion EUR Global sales

3,800 Patents

Specialty glass - high-tech material

Glass is made by melting quartz sand and other raw materials

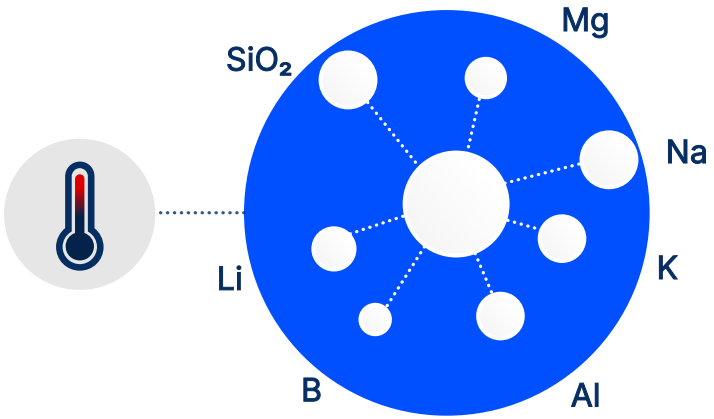


Soda-lime glass

Melting point up to 1,400 °C

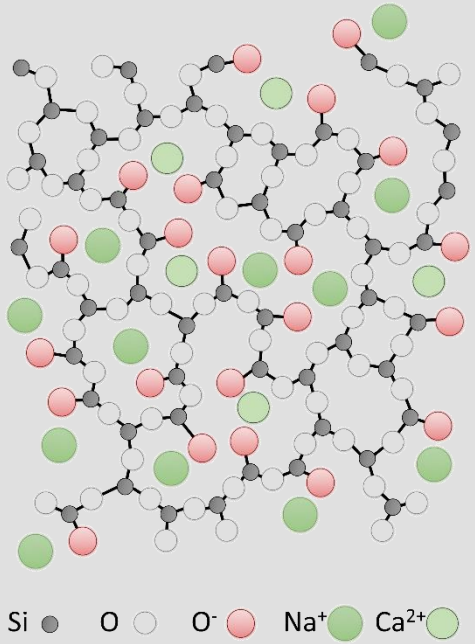
Specialty glass and glass ceramics

Application designed melting point
up to 1,700 °C



The chemical composition determines the network structure and therefore the properties of the glass

Soda-lime glass
Soda-lime float glass



Selected Properties

Coefficient of linear thermal expansion
α (20-300°C)

$9 * 10^{-6}K^{-1}$	vs	$3.25 * 10^{-6}K^{-1}$

Refractive index n_d

1.50	vs	1.47

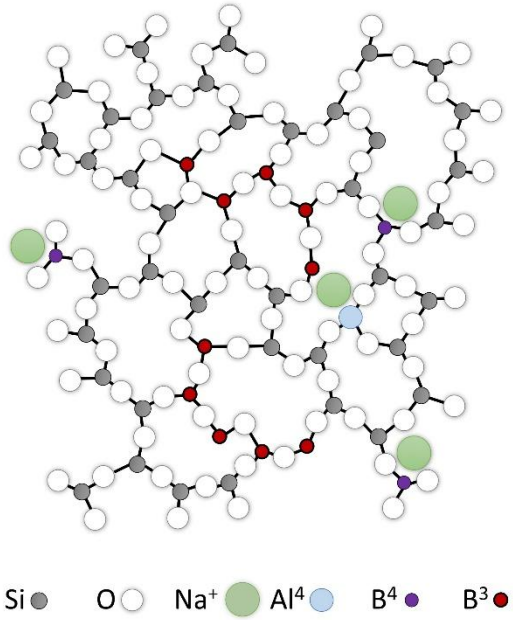
Density ρ

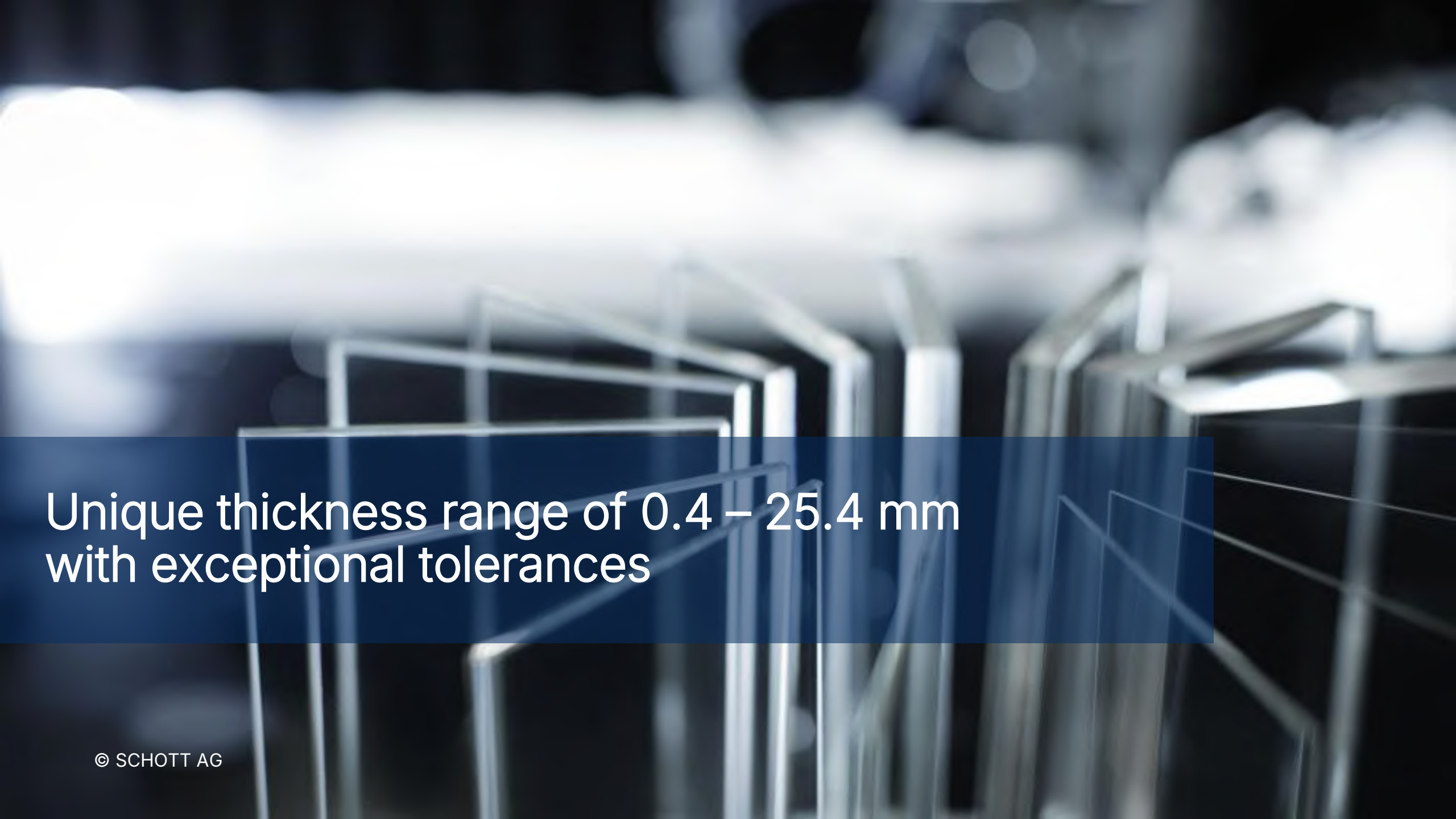
2.52 g/cm³	vs	2.23 g/cm³

Youngs Modulus E

72 kN/mm²	vs	64 kN/mm²

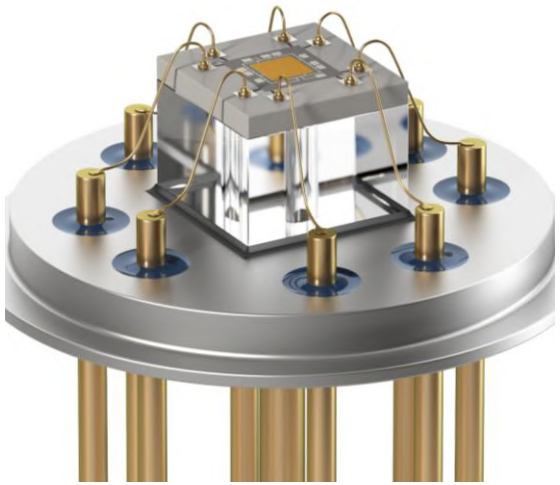
Borosilicate glass
BOROFLOAT® 33



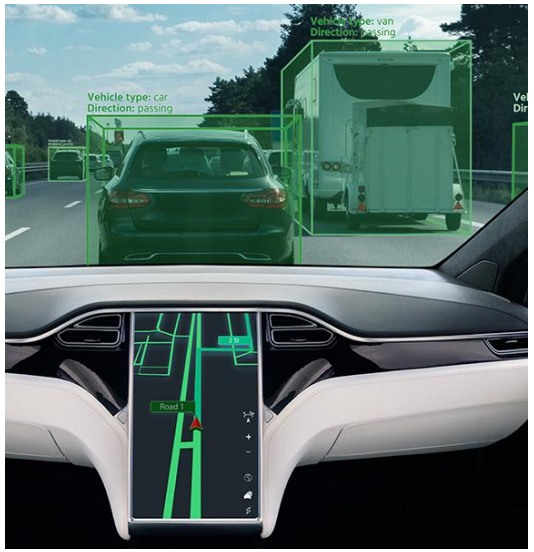


Unique thickness range of 0.4 – 25.4 mm with exceptional tolerances

BOROFLOAT® moments in automotive solutions

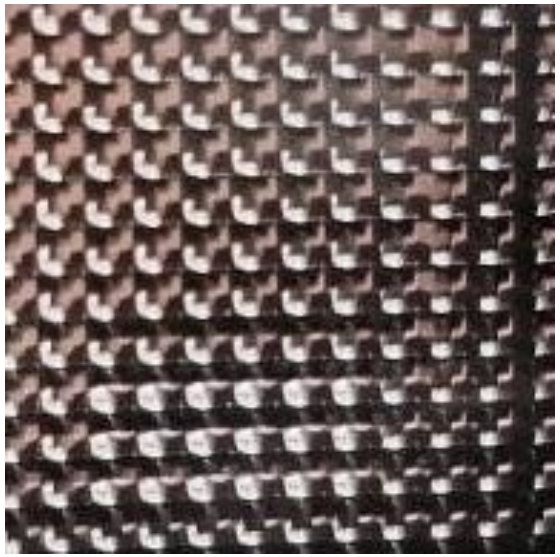


Micro-structured glass anodically bonded to MEMS sensors for reliable functionality and longevity



Protective window for LiDAR systems with outstanding transmittance

Unparalleled stone-impact resistance ensuring durability against road debris in windshields



Thermal shock resistant microlens arrays provide best performance for projection and lighting

Enhancing sensor performance with specialty float glass BOROFLOAT® 33

Exceptionally high transparency
- Outstanding visual quality and optical clarity
- Broadband transmittance optimized from UV-A to NIR into SWIR
- Low inherent fluorescence and solarization tendency

Outstanding thermal resistance
- Withstands high temperature differences and thermal shocks due to low C.T.E. of 3.25 ppm/K

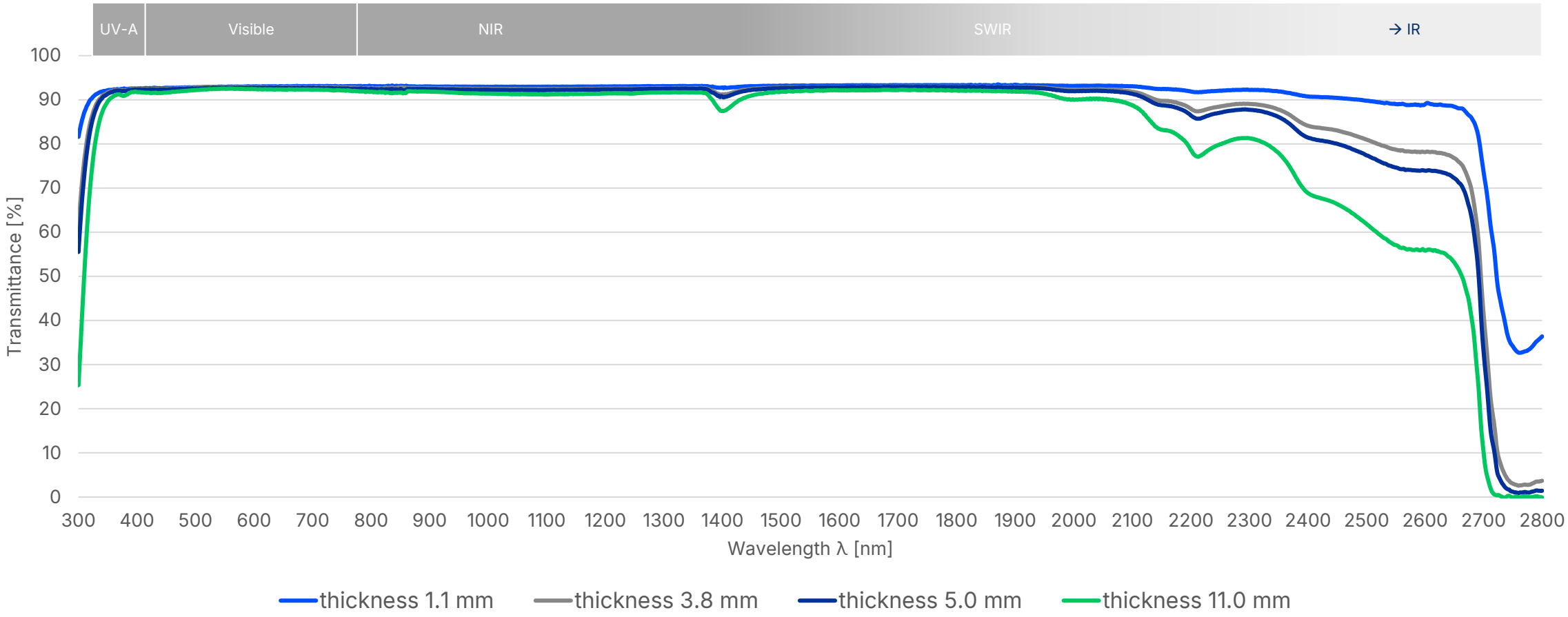
Unique combination of dielectrical properties
- Low dielectric constant in combination with low loss tangent for connected cars
- Sensor combination possible

Excellent mechanical strength
- Enhanced resistance to sharp impacts
- Less prone to abrasion and scratches
- Low specific weight of 2.230 $kg*m^{-3}$

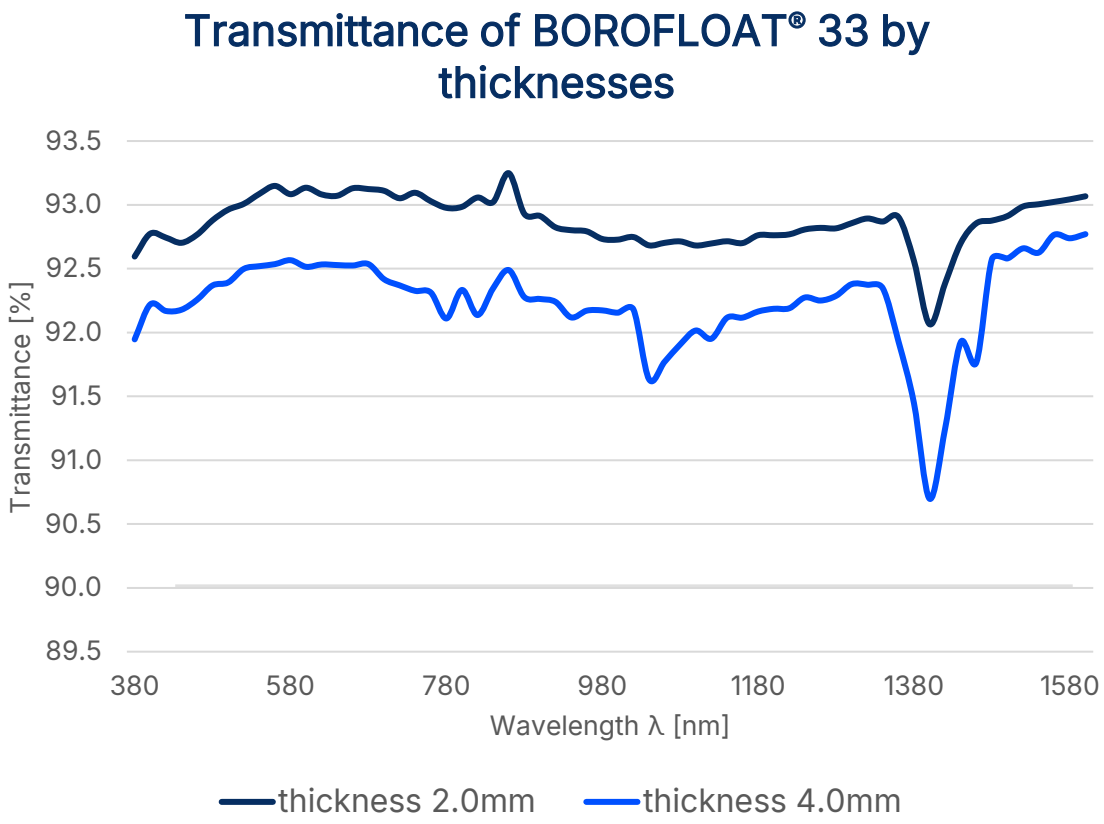
High chemical durability
- High hydrolytic resistance
- Excellent resistance to acids
- High resistance to alkalis

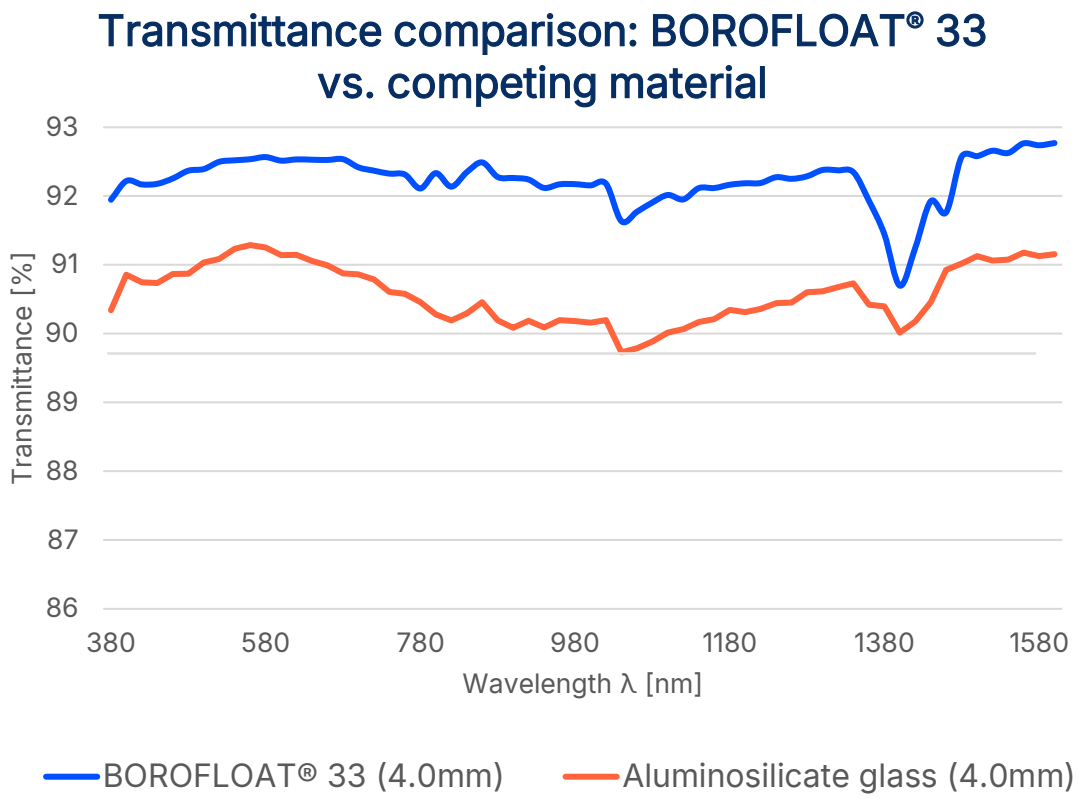
Trusted material for processing
- Precise structuring via state-of-the-art chemical and physical technologies
- Proven substrate for coatings

Exceptionally high transparency - optimized accross UV-A to SWIR

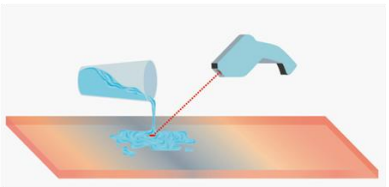


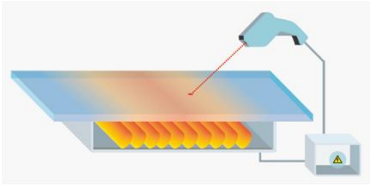
Light throughput perfected for maximum output





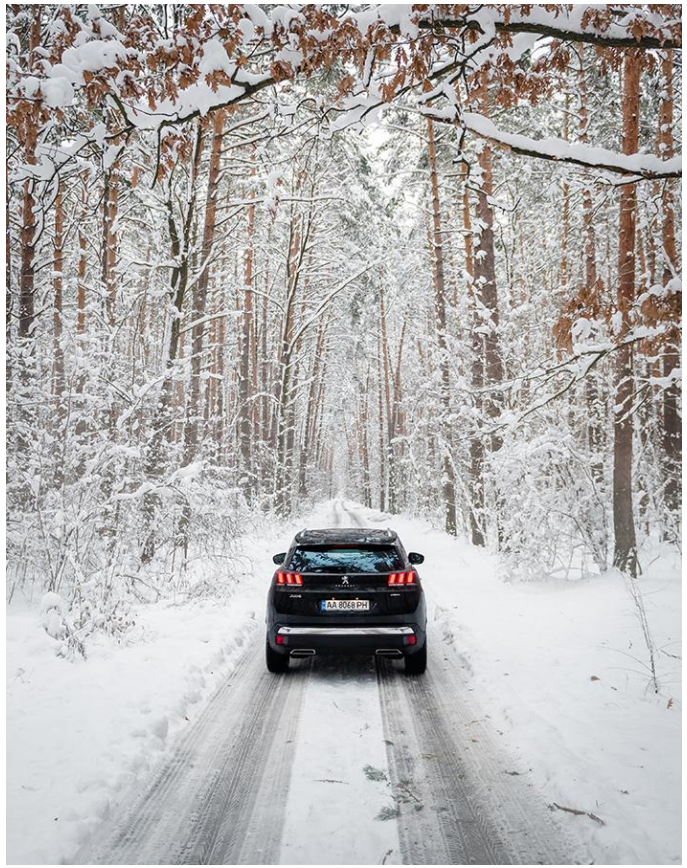
Outstanding thermal resistance – reliable operation in extreme conditions

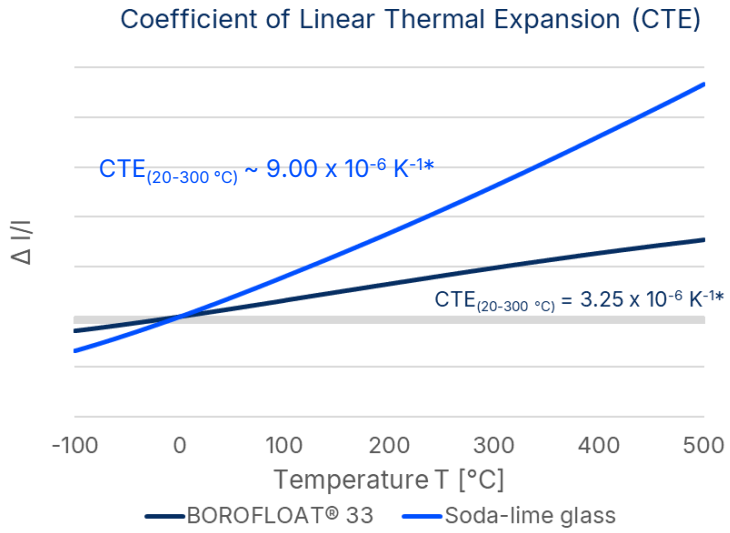




Thermal properties:	Soda-lime	Borosilicate
Thermal expansion $\alpha_{(20 - 300\ °C)}$ in $10^{-6}\ K^{-1}$	9.03	3.25 **Perfect match to silicon**
RTS	50 K	160 K
RTG	30 K	110 K

To simulate damage that can occur in practical use, the samples are abraded with 220 grid sandpaper before testing.

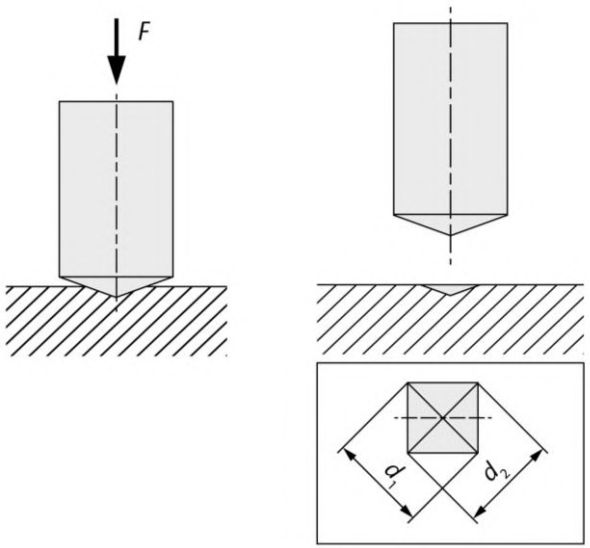




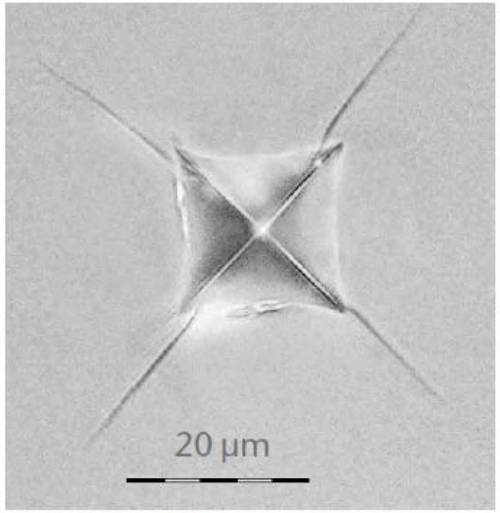
*according to ISO 7991

Excellent mechanical strength- validated through Vicker‘s testing

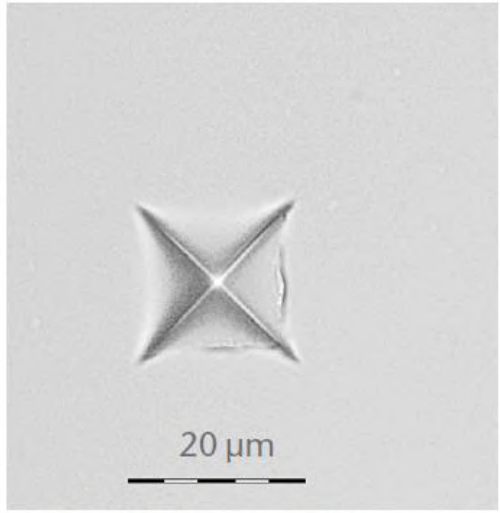
BOROFLOAT® 33 is particularly resistant due to its glass structure



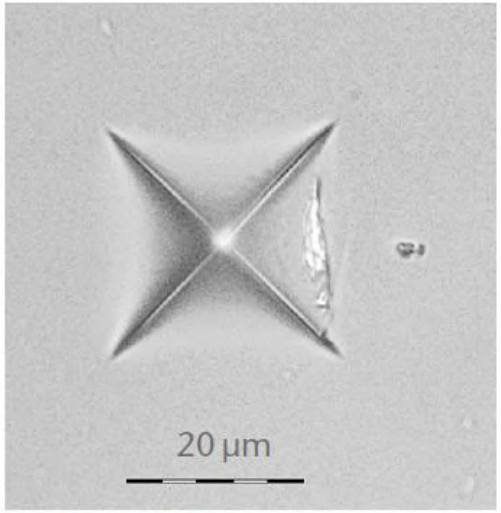
Hardness measurement
Vicker’s indentation
(diamond tip)



Soda-lime glass – 2 N



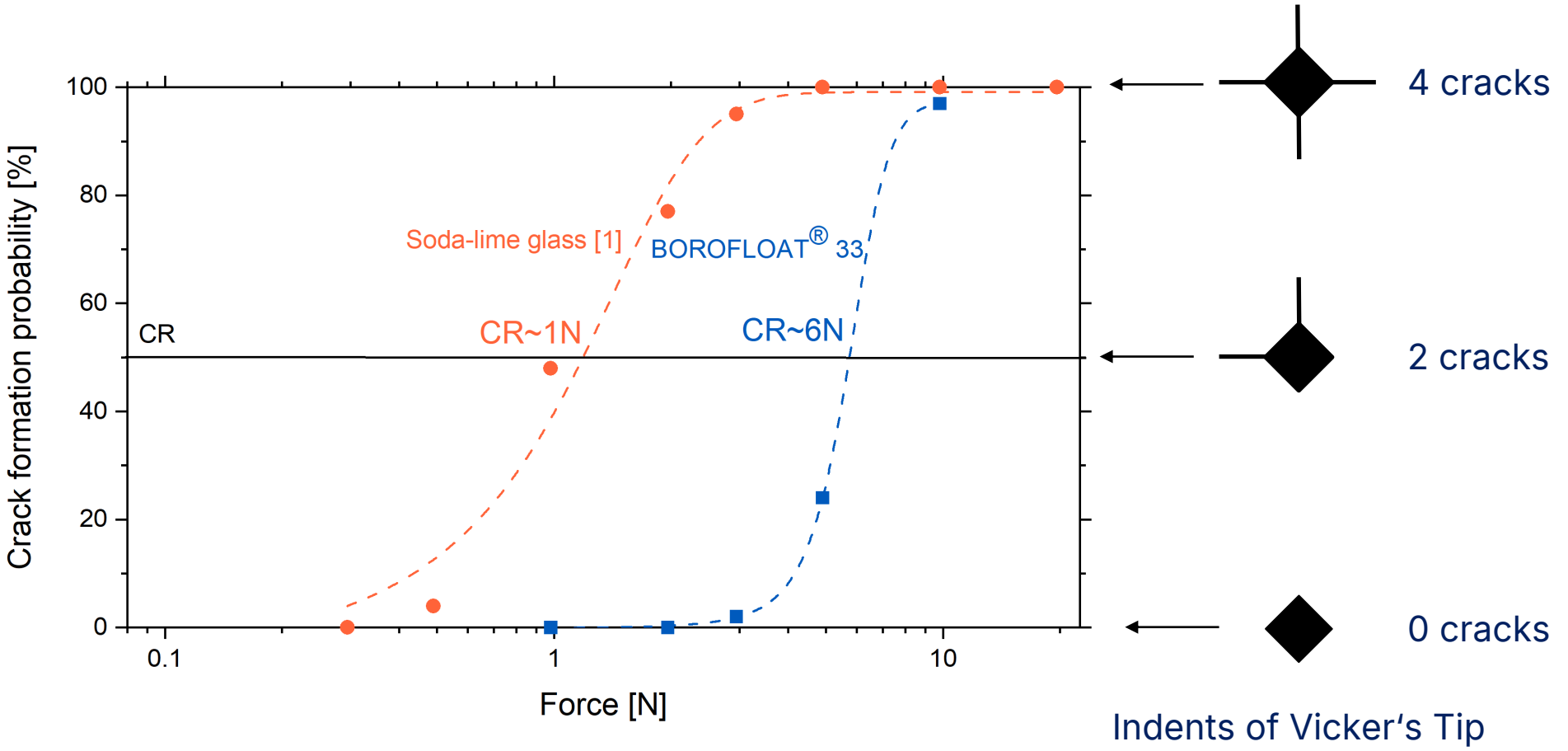
BOROFLOAT® 33 – 2 N



BOROFLOAT® 33 – 4 N

Crack initiation load is much higher for BOROFLOAT® 33 than for Soda-lime glass.

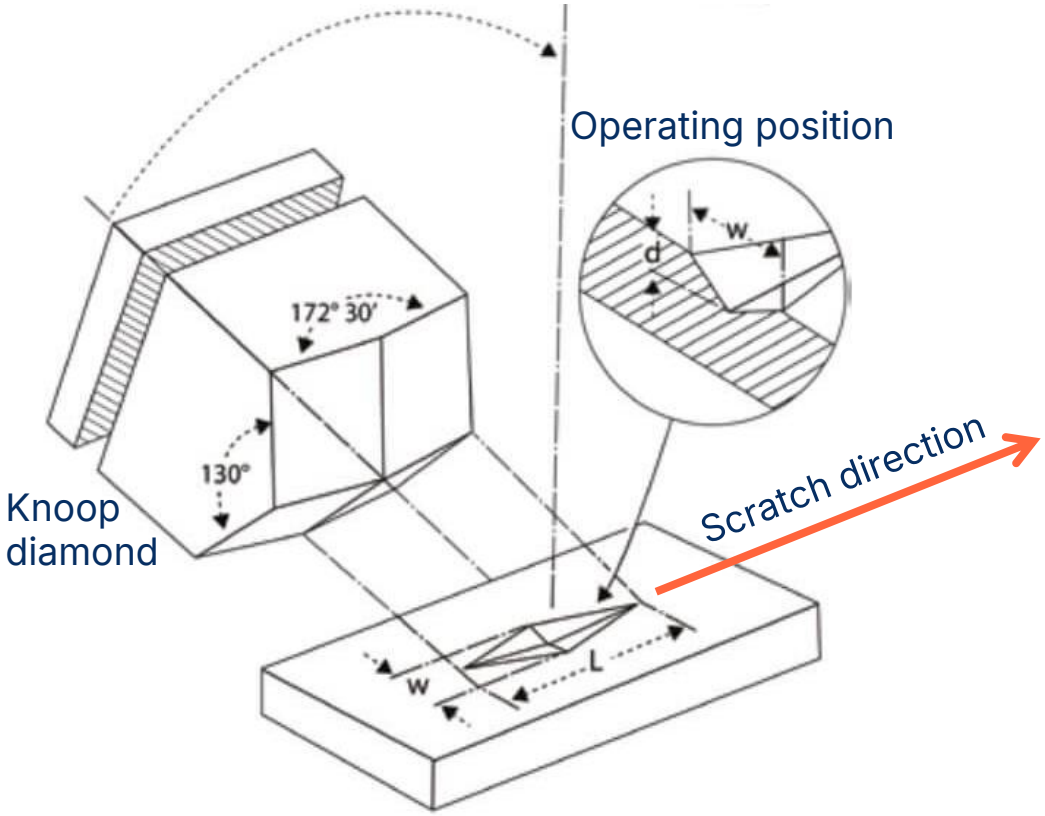
Vicker‘s – Indentation Test



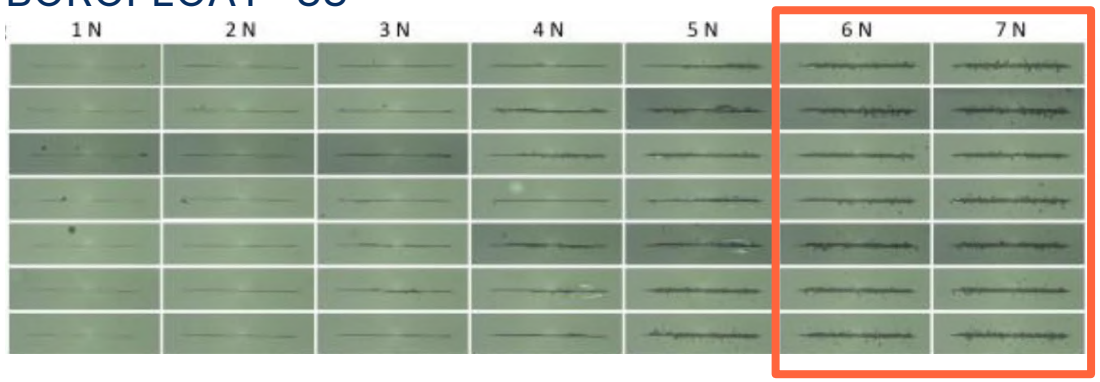
[1] raw data from Limbach et al., Non.Cryst.Solids, 2014

Enhanced durability – less prone to scratches

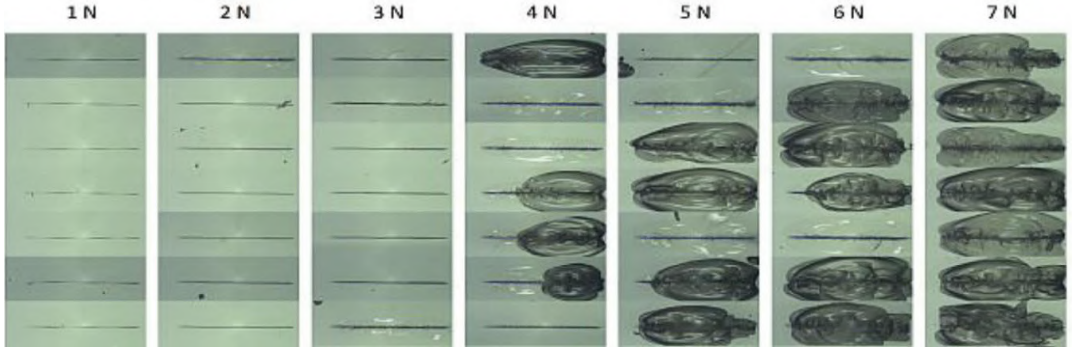
Scratch test with Knoop diamond



BOROFLOAT® 33



Soda-lime glass



*each scratch = 1mm

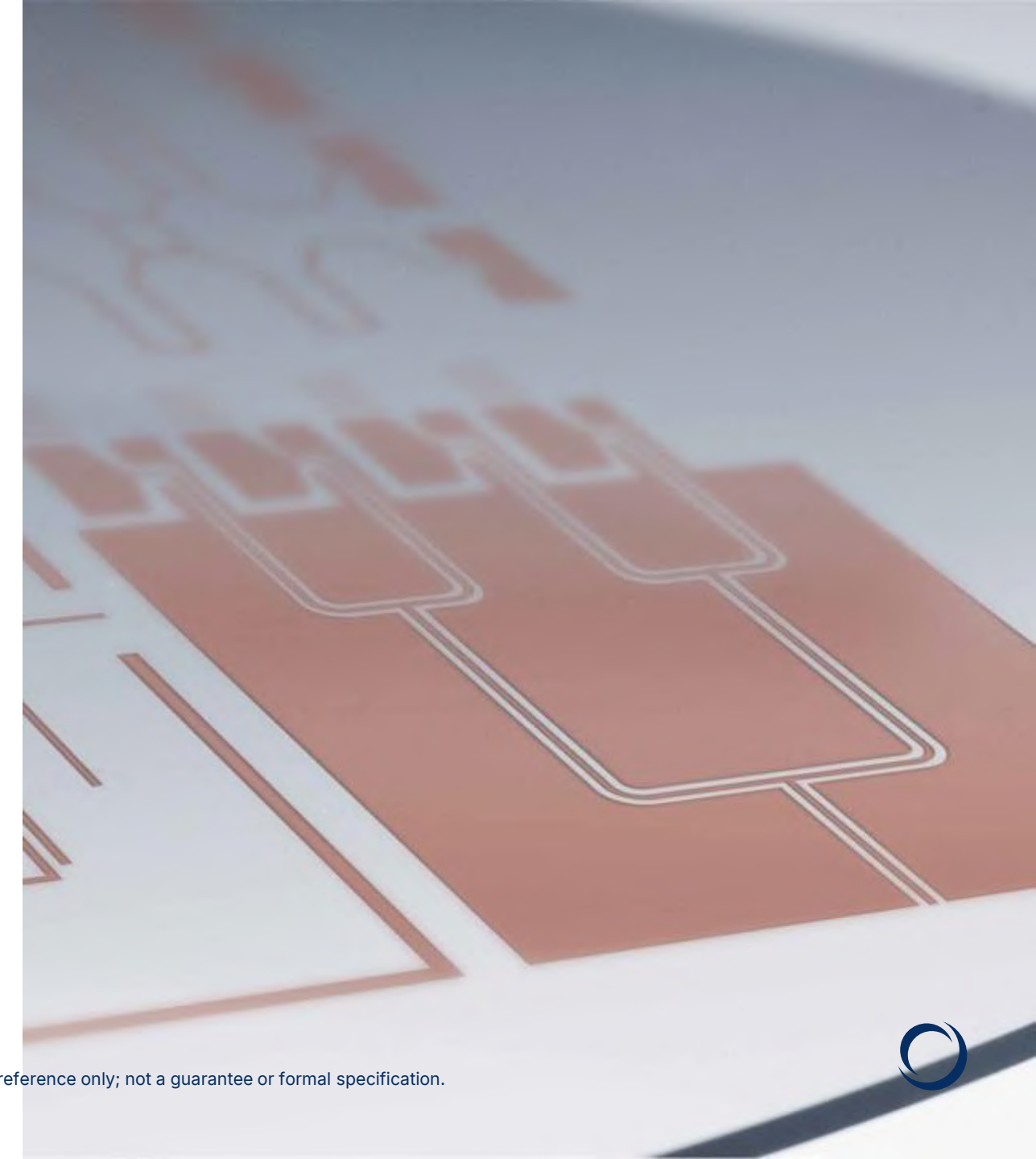
Unique combination of dielectrical properties

> 77 GHz radar range

24 GHz – 100 GHz 5G mm wave range

Frequency [GHz]	2.45	5	10	15	24	77	110
Dielectric constant* (permittivity) ε_r	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Loss tangent** tan(δ) [10^{-4}]	58	66	75	82	91	127	152

*Values are rounded to one decimal place according to the applicable rounding rules.
**The data ranging from 1 GHz to 15 GHz was measured using a split-post-dielectric resonator method (SPDR) and has an accuracy of approx. 10-5. The date ranging from 20 GHz to 110 GHz was obtained using a Fabry-Perot Open Resonator (FPOR).
All measurements were done at room temperature (25°C +/- 3°C)



BOROFLOAT® 33 @ a glance

Exceptionally high transmission

Outstanding thermal resistance

Unique combination of dielectrical properties

High hydrolytic & chemical durability

Superior mechanical strength

Excellent coating performance

Excellent flatness

Any questions? Contact us.

Dipl.-Ing. Sandra von Fintel

Senior Global Product Manager
BOROFLOAT®

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MECHANICAL PROPERTIES

CHEMICAL PROPERTIES

THERMAL PROPERTIES

OPTICAL PROPERTIES

SCHOTT

Let’s pioneer the impossible.