July 2, 2024

SCHOTT Optical Glass

How SCHOTT creates high-quality optical glass

Introduction

SCHOTT Academy of Optics is a free, online seminar series designed to take your industry knowledge and expertise to new levels.

Throughout the series, you will learn from leading glass and material experts as they cover various topics pertaining to the optics industry.

Visit our website for more information or to register for an upcoming seminar: schott.com/trainings/academy-of-optics

The quality and performance of optical glass hinges on the rigorous processes involved in its production. SCHOTT precisely controls each step of glass production to minimize imperfections and variations, which can cause distortions or aberrations in transmitted light. We also use advanced techniques such as interferometric measurements to minimize refractive index variation. Leveraging 140 years of experience, SCHOTT is creating innovative glass materials with enhanced properties, paving the way for advancements across a wide range of fields.

1. Basic principles of optical glass melting

Glass production involves several critical steps, beginning with selecting raw materials and progressing to melting into molten glass, cooling and strengthening the glass through coarse and fine annealing, and finally rigorously inspecting the finished products for quality.

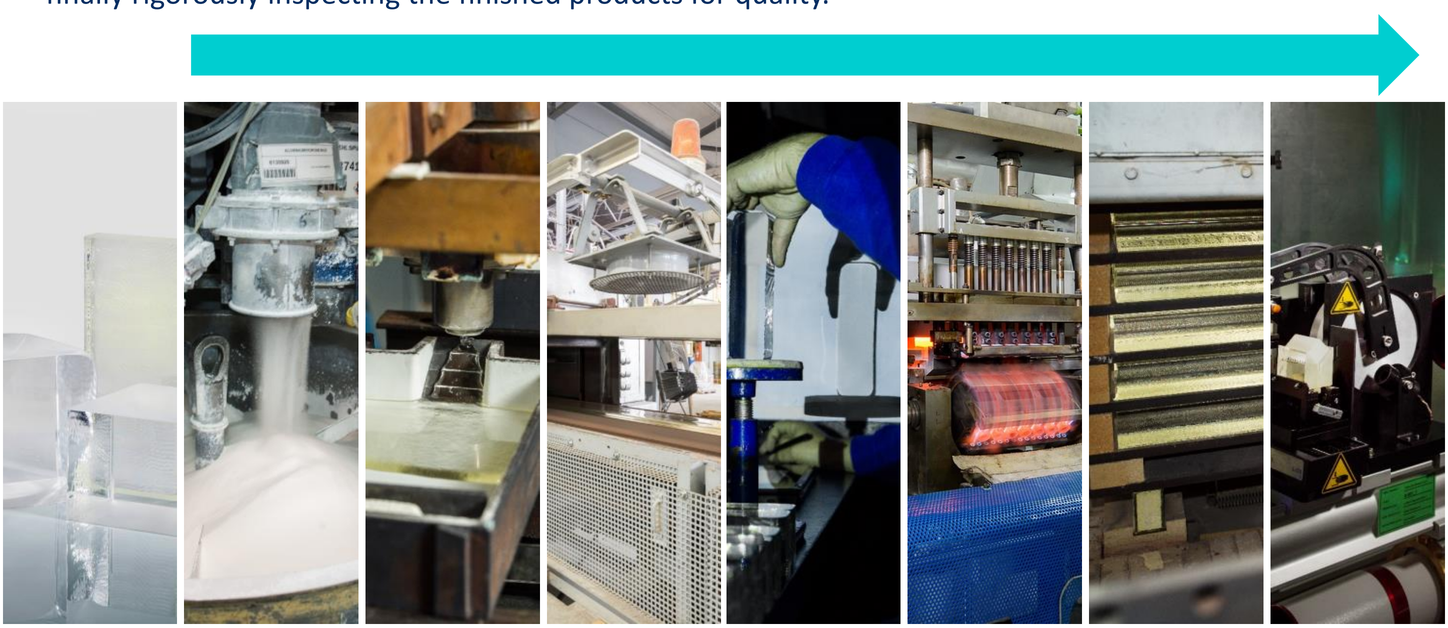


Figure 1: Our production process

Raw materials – The production of high-quality optical glass begins with the careful selection of top-grade raw materials. SCHOTT procures more than 150 different raw materials for glass production. We source these materials from around the globe, searching out suppliers with the highest purity levels available.

Melting – At SCHOTT, raw materials are formed into glass using either pot melting or tank melting. Pot melting is a discontinuous process typically used for small lot sizes and aggressive glass types, and, in some cases, for larger formats. Most of our glasses are produced continuously using tank melting. This involves melting the batch material in a crucible through a process that makes 1-2 tons of material per day. Tank melting is more economical than pot melting and better suited for maintaining consistent glass quality across larger volumes.

Coarse annealing - After melting and exiting the nozzle, the material flows into the coarse annealing lehr. This slows down the cooling process to avoid cracks that might form due to high stress levels. The glass is then inspected for bubbles, inclusions, and striae.

Fine annealing - Although tight control of the chemical composition is used to achieve the desired refractive index, the fine annealing step tunes the refractive index to its final value, achieving accuracy up to the sixth decimal place. To accomplish this, annealing ovens reheat the glass above a threshold that is dependent on the glass type. In addition to the refractive index, the cooling rate used also determines other final features like Abbe number, stress birefringence, and homogeneity.

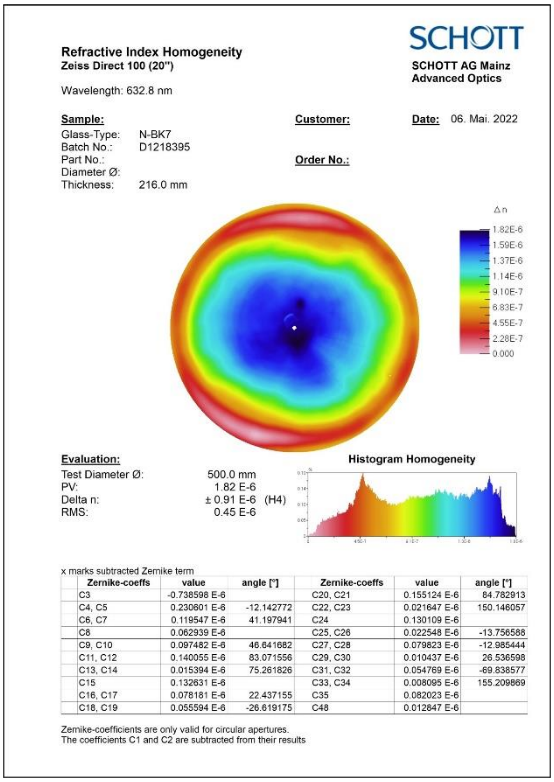
Final products and quality control - SCHOTT produces continuous glass strips that are typically 160 mm wide and several tens of millimeters thick. Molded blocks with a typical edge length of 200 mm or disks up to 1000 mm diameter are also possible. We use exhaustive quality control processes to make sure that our optical glass complies with customers' technical drawings and specifications.

2. Delivering a high refractive index homogeneity

For high-end applications of optical glass, there is a focus on achieving a high homogeneity for the refractive index. Ideally, a perfect optical glass with polished surfaces would allow a laser with a perfect wavefront to pass through without any distortions, maintaining a perfectly flat wavefront. However, small deviations in the refractive index distribution are inevitable. The challenge is to control and minimize these deviations to maintain high refractive index homogeneity.

Achieving good homogeneity and minimal refractive index variation requires meticulous hot forming and fine annealing as well as precision measurements. The goal is to balance production efficiency with high-quality standards for optical glass. SCHOTT uses high-end interferometers to measure refractive index deviations with high sensitivity – up to the sixth or even to the seventh decimal place.

For high refractive index homogeneity, it's important to keep the tank melting process as stable as possible over time. We accomplish this by measuring the refractive index and Abbe number from glass samples every few hours and using this information to provide feedback to the production engineers. The monitoring data also helps identify which areas of the glass have the highest homogeneity.



Refractive Index Homogeneity
Zeiss Direct 100 (20")

Wavelength: 632.8 nm

SCHOTT
SCHOTT AG Mainz
Advanced Optics

Sample:
Glass-Type: N-BK7
Batch No.: D1218395
Part No.:
Diameter Ø:
Thickness: 216.0 mm

Customer:

Order No.:

Date: 06. Mai. 2022

Evaluation:
Test Diameter Ø: 500.0 mm
PV: 1.82 E-6
Delta n: ± 0.91 E-6 (H4)
RMS: 0.45 E-6

Histogram Homogeneity

x marks subtracted Zernike term

	Zernike-coeffs	value	angle [°]	Zernike-coeffs	value	angle [°]
	C3	-0.738598 E-6		C20, C21	0.155124 E-6	84.782913
	C4, C5	0.230601 E-6	-12.142772	C22, C23	0.021647 E-6	150.146057
	C6, C7	0.119547 E-6	41.197941	C24	0.130109 E-6	
	C8	0.062939 E-6		C25, C26	0.022548 E-6	-13.756588
	C9, C10	0.097482 E-6	46.641682	C27, C28	0.079823 E-6	-12.985444
	C11, C12	0.140055 E-6	83.071556	C29, C30	0.010437 E-6	26.536598
	C13, C14	0.015394 E-6	75.261826	C31, C32	0.054769 E-6	-69.838577
	C15	0.132631 E-6		C33, C34	0.008095 E-6	155.209869
	C16, C17	0.078181 E-6	22.437155	C35	0.082023 E-6	
	C18, C19	0.055594 E-6	-26.619175	C48	0.012847 E-6	

Zernike-coefficients are only valid for circular apertures.
The coefficients C1 and C2 are subtracted from their results

For each optical glass, we provide a homogeneity test certificate that includes a color map representing refractive index variations and Zernike coefficients, which are useful for optical design. Optical grades are based on peak-to-valley refractive index variations, with ISO 12123 and ISO 10110 standards specifying the specific grades. Typically, a higher homogeneity (H4, H5) requires precise aperture definitions, and large glass blocks can have high homogeneity in specific sub-apertures. Thanks to recent production improvements, SCHOTT can now achieve exceptional homogeneity in large NBK7 glass formats that are as large as 1 m in diameter, with some parts exhibiting variation as low as 2 ppm.

Figure 2: Homogeneity test certificate

3. New developments

In an era of rapid technological advancements, anticipating future trends is crucial. SCHOTT works to stay ahead by developing advanced optical glass solutions tailored to meet emerging needs. These include the increasing demand for glass tailored to specialized applications such as color correction and SWIR and UV wavelengths. We are also creating glass with higher refractive indices and improved homogeneity in all three dimensions as well as larger geometries. Another key development focus is the transition from plastic lenses to glass components in mobile devices, where glass aspheres, prisms, and other elements offer enhanced quality and performance.

SCHOTT has recently launched a variety of new optical glasses. For example, we have a new light weight glass with a high refractive index for augmented reality applications. For digital projectors, we now offer a stabilized glass that maintains a constant transmission even when exposed to intense light irradiation. Our new solarization-stabilized glass is useful for satellites and other space applications, which require glass that is lightweight and resistant to UV radiation.

In a world where reliability and sustainability are paramount, choosing a partner that prioritizes these values is crucial. Supply security is a significant concern for many customers, and SCHOTT has consistently demonstrated its reliability, even during global challenges like COVID-19. As we strive to become climate neutral by 2030, our commitment to sustainability has earned us multiple awards in recognition of our successes and dedication over the past few years.

Want to learn more about optical glass?

For more information and resources visit our website:
schott.com/products/optical-glass