Combining High-Tech Glass Innovations with Advanced Laser Technologies

High-quality glass substrates and supporting laser capabilities for semiconductor and microelectronics applications

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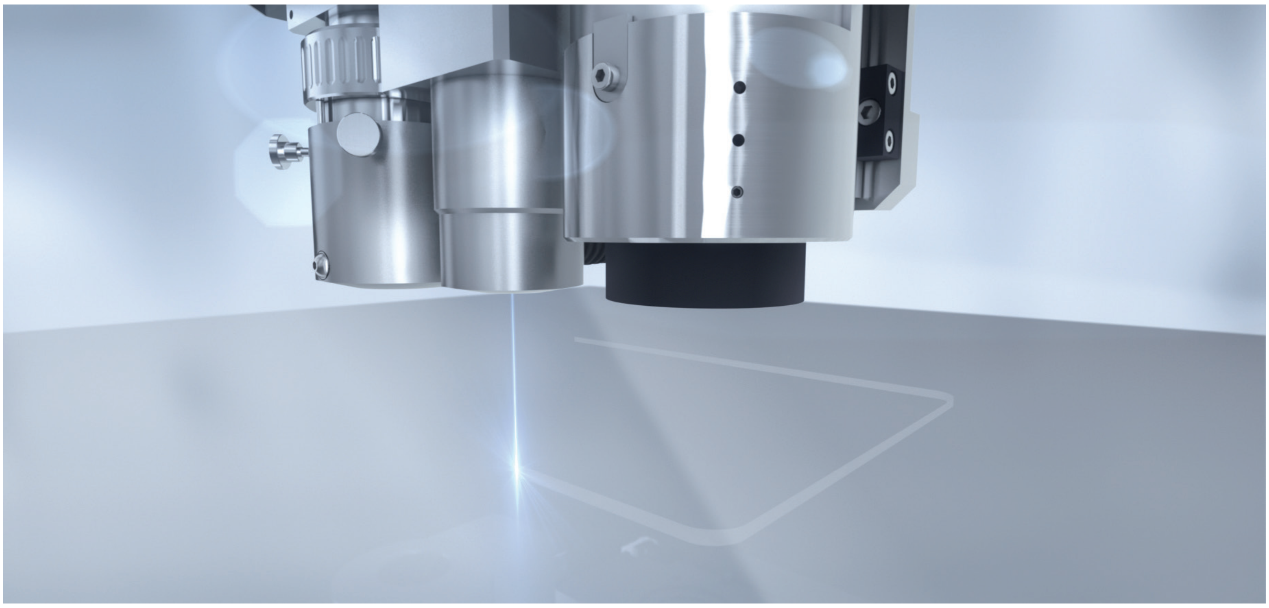

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As glass wafer products become more specialized and die sizes get smaller, the demand for high-speed singulation of glass wafers is increasing. Corning Laser Technologies utilizes the advantages of precise laser dicing to process optimized glass types with adapted CTE values, high transmission, and specific refractive indices to enable existing and emerging applications.

Megatrends like multifunctional compact chips, highly accurate miniaturized sensors, faster seamless connections, and engaging immersive experiences are driving the need for glass in semiconductor and microelectronics processes. Corning is well positioned to enable a variety of applications with customizable glass products that can be tailored to meet demanding customer requirements by using their deep technical expertise and applying their manufacturing excellence to ensure an easy scale-up.

Glass can be categorized by its chemical composition and key physical properties. Critical attributes are, for example, transmittance (T_x) at a given wavelength, refractive index (RI), and coefficient of thermal expansion (CTE). Unlike crystalline materials that are used mainly in the semiconductor industry – such as silicon or sapphire that can be doped to achieve minor changes in material properties – glass can be tailored to achieve the required performance through material composition optimization. This article presents a few examples of how tailored glass attributes can enable specific applications in a more efficient way to excel in performance.

In addition to the physical properties of glass, the scalability of production and processing to provide constant quality and high throughput is also required to fulfill today's demands for high volume and low-cost components, especially for consumer electronics products. Glass is utilized in many applications, including carrier wafers for advanced packaging, advanced substrates for RF applications, and covers for micro-opto-electro-mechanical systems (MOEMS), to name just a few. In other applications, glass is part of the final product in the form of lenses, optical filters and waveguides. Independent of the application, all these glasses need to be processed on a large scale to ensure economic production.

Furthermore, there is a clear trend towards miniaturization for many electronic and optical devices to enable mobility, connectivity, and precision sensing for consumer electronic products. Wafer-level processes are essential to achieve the goal of miniaturization

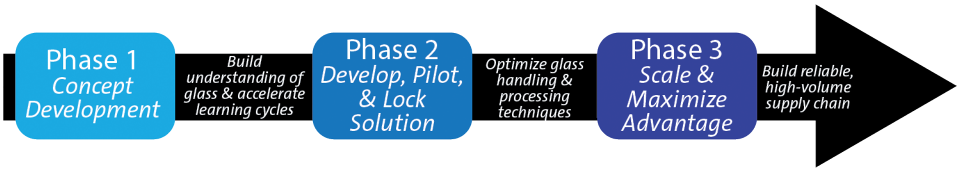

Fig. 1 The customer's journey from development to production where Corning offers support for each phase

of optical devices, and the industry is adopting these processes accordingly to parallelize production and increase yields. A vital advantage of wafer-level processes is that they are well-known from silicon microelectronics fabrication and can be scaled. In fact, many processes on 6" and 8" glass wafers are already established, and the adoption of larger scales will be increasing in the coming years to enhance utilization, throughput, and yields.

The scalability and reliability of these miniaturized, high-volume products largely depends on the quality and specifications of the glass materials. Within Corning, the Precision Glass Solutions (PGS) business unit serves this advanced industry with high quality materials, and Corning Laser Technologies (CLT) focuses on laser-based processing for these applications to solve the toughest technical challenges. This article focuses on these two requisites for glass adoption in the semiconductor industry: key physical properties and key processing solutions.

From development to volume production

Corning offers invaluable engineering support to guide customers from the concept development phase to a product solution. In the first stage, fundamental understanding of glass and its properties is essential to understand material performance and analyze failure root causes. This comes with deep application engineering and fast prototyping to accelerate learning cycles, thus reducing cost and enabling a quick and reliable transition from product development to volume production. Corning provides a stable and scalable supply of glass materials, proven by the long-term supply of glass for the display and consumer electronic industries. Flexible manufacturing platforms allow for customization and stable supply. A proprietary fusion process delivers quality glass with pristine surfaces, low thickness tolerances, and low thickness variation (TTV), allowing further surface finishing and polishing to be omitted for many applications. In addition, this platform can easily be scaled to high volume glass supply, which is crucial for this consumer market [1].

As the volume of glass materials will scale with its adoption in microfabrication processes, glass processing solutions, especially glass cutting, will also need to increase to meet the expectation for speed, quality, and reliability. Processes where the production costs increase with volume adoption, such as polishing or blade dicing, can create limitations to scalability. Laser cutting and dicing technologies provide a solution to move more simply from development to production, also allowing the cost per part to decrease with volume adoption. Another key advantage of this technology for miniaturization and material utilization is the zero-kerf loss property.

Glass properties for specific applications

Tailored glass products that meet specific application requirements are shown in the following section. **Table 1** gives a general overview about industry application needs and Corning's solutions [2].

Advanced packaging and glass carriers

There is a wide range of glass compositions tailored for various applications. For example, the fusion-drawn SG 3.4 glass with CTE matched to silicon (Si) is suitable as carrier wafer for semiconductor back-grinding applications. Substrates can also be offered with ultra-low TTV, which is required for high-precision thinning in RF devices as well as in advanced processing applications like nano imprint lithography.

In addition to these fusion formed glasses, specialized glass wafers with customized CTEs are available in order to provide ideal performance for given product designs. This is most relevant in packaging processes to reduce warpage that is induced due to different CTEs of the materials [3].

	Advanced Packaging Carrier	Back-thinning Carrier	Wafer Level Optics	Micro-Fluidics
Why glass?	CTE tunability to reduce in-process warp Transparency for debonding and inspection Scalability with long development cycles	Transparency for laser debonding and inspection CTE tunability to match Si CTE Cost reduction by recycling	Optical materials Constant beam path length and low thermal expansion/high stiffness	Good SNR for optical measurement Low contamination level Bio-compatibility
What Corning offers	Adapted CTE with fine granularity Tailored stiffness Excellent flatness Short lead times	Si-matched CTE Ultra-Low TTV High UV transmittance Alkali-free carrier material	High purity fused silica for front-end processes Broad range of available thickness Low thickness tolerance High transmission and processability	High UV transmission Low auto-fluorescence Chemical durability Compatibility for surface structuring

Tab. 1 Summary of Corning's offerings for the respective market segments

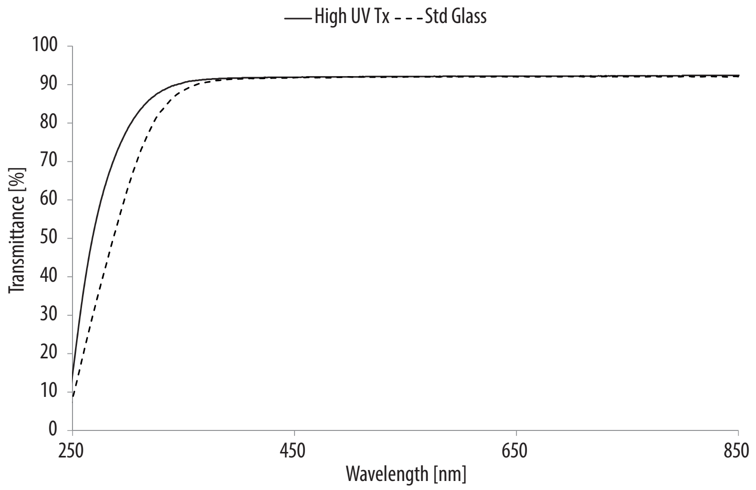

Fig. 2 The transmittance of Corning's standard glass carriers in comparison to a transmission optimized composition at a thickness of 0.7 mm.

A high transmission glass was designed that provides up to twenty percent higher transmission at 280 nm wavelength to meet the requirements for laser debonding in the UV range (**Fig. 2**). This high UV transmittance enables very efficient laser debonding, bringing with it a longer tool lifetime due to lower input power consumption.

Wafer-level optic solutions

Lens substrates used for lighting applications require a material with good optical transmittance that also allows for robust designs. In addition, it needs to be processable by using photolithography, surface structuring, reactive ion etching, direct laser beam writing, or specific coatings.

Corning HPFS fused silica is often used for these types of applications. Because of its excellent transmittance, low CTE, and processability, this is a material of choice for many optical applications. Surface structuring is also possible using different methods such as wet etching, reactive ion etching, and mechanical machining. Its high purity ensures that it can be introduced seamlessly into the semiconductor front-end lines for high-volume production. It is ideal for precise 3D sensing applications, using diffractive optical elements or meta surfaces, in mobile devices. The close to zero thermal expansion coefficient enables precise optical alignment of the beam path across wide operating temperatures. In other words, HPFS is least susceptible to temperature changes, which enables better imaging accuracy than alternative materials [4].

Back end processes, like chip scale packaging of CMOS image sensors (CIS), are well established in the industry. Here, Corning's SG 3.4 glass may be used for its Si-matched CTE value in combination with excellent optical quality and geometric tolerances such as thickness tolerance, TTV, and warpage.

A range of suitable glass compositions is available for novel back-end applications such as the fabrication of microlens arrays and other optical components for diverse end markets. SG 7.1 and SG 7.8 glasses, for example, have high CTE and good optical transmittance. The key difference between these glasses is mechanical stiffness as shown in **Fig. 3**. SG 7.1 has a higher Young's modulus that reduces in-process warp and ensures stability during processing and for the final product.

For applications where a rigid and thermally stable glass material is needed, SG 3.7 glass shows excellent performance with a glass transition temperature of 752 °C, roughly 80 °C degrees higher than SG 3.4 and only 150 °C lower than HPFS. With respect to Young's modulus, SG 3.7 shows an even higher Young's modulus of >80

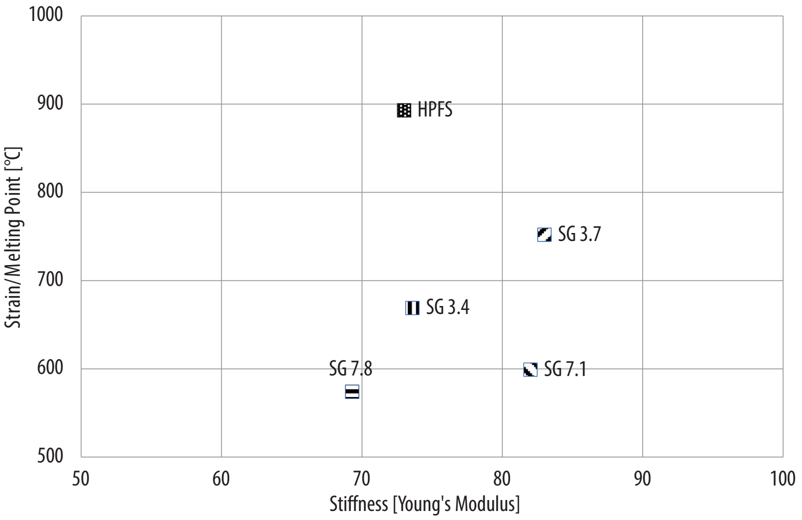

Fig. 3 Differences in strain point temperatures against their Young's modulus to show the range of rheological behaviors the different glass types can cover.

Company

Corning Advanced Optics

We serve the semiconductor and consumer electronic industries by supplying optimized glass compositions with tailored properties in wafer and panel formats. In addition to glass, Corning offers supporting capabilities including laser cutting systems for highly accurate wafer dicing as well as world-class metrology instruments for inspection. Corning enables the fabrication of innovative products by combining unique glass manufacturing and superior processing capabilities to offer total solutions to customers, not only solving various technical challenges from glass supply to inspection and processing, but also reducing design cycle time and cost.

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compared to HPFS. This glass also has an outstanding surface quality with respect to TTV and flatness in combination with a high transmission of visible wavelengths.

Microfluidics

Glasses for microfluidic applications need to be etchable and bondable, but also be resistive against acids for functionality. As shown in **Fig. 4**, SG 7.1 provides a much better acid resistivity than SG 3.4, whereas the best acid resistivity is shown by HPFS. On the other hand, SG 7.1 provides better performance on HF acid structuring in comparison to HPFS and even SG 3.4. Together with its high purity, surface quality, and transmission performance, SG 7.1 can enable new applications for flow cells.

In addition to good processability, the transmittance of SG 7.1 enables outstanding performance in optical metrology for a variety of applications.

Laser singulation for wafer-level processing

While glass wafers are becoming more specialized and end products are becoming smaller, more complex, and more valuable, the requirements for singulation of devices are increasing. Glass wafer substrates are being adopted at a 300 mm diameter whereas die sizes shrink. This is leading to increasing diamond sawing challenges when dicing final products. This is leading to increasing diamond sawing challenges when dicing final products.

Laser glass dicing of different glass compositions, from thick glasses (e.g. 3.5 mm) to very thin glasses (e.g. 0.3 mm), as well as from small die sizes (e.g. 5 mm) to free-formed products (e.g. 30 mm circles) enables many different applications. The key property of laser dicing is zero-kerf cutting performance: the laser process does not remove material in order to singulate the dies, instead it modifies the glass with the desired separation geometry to enable singulation. Compared to a blade dicing approach where the kerf loss is in the range of several hundred microns for a die size of 2 mm, for example, the material utilization could be increased by >10 %. An even greater advantage can be demonstrated in throughput: the typical processing time for laser dicing is in the range of minutes per wafer, depending on the die and wafer size.

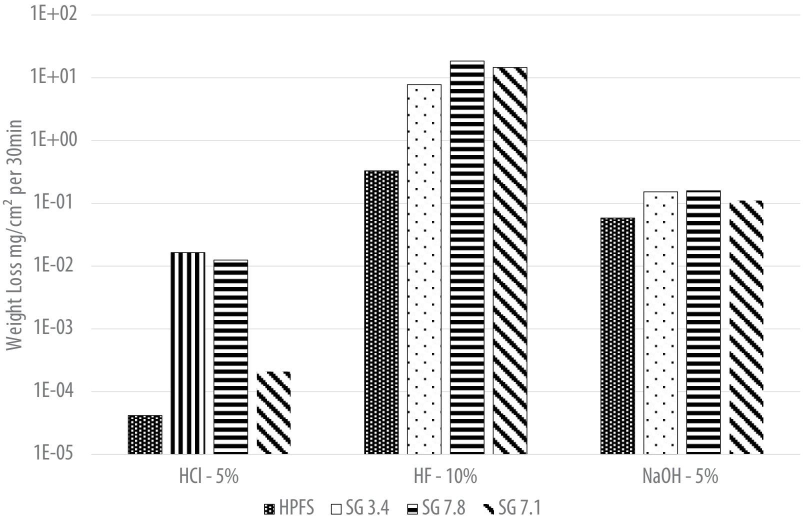

Fig. 4 Weight loss with different reactants (at different temperatures, please refer to specification sheets for details) for glass products covering a wide range of CTE values.

CLT has established a two-step process for dicing glass wafers that first introduces zero-kerf modifications into the glass within a microns-wide zone through the entire glass wafer thickness. The second step, which is to singulate the dies, can be achieved best by thermal laser interaction, which provides fast processing in combination with flexible part geometries. Alternatively, depending on the customer's designs and materials, mechanical breaking along straight dicing lines or wet etching can be the separation method. With the optimal combination of these processes, CLT offers a game-changing solution to increase processing speed, accuracy, cleanliness, and material utilization.

Summary

Corning offers high-quality glass substrates for multiple applications in the semiconductor and microelectronics industries in combination with innovative laser cutting solutions that excel in processing time and material utilization. In addition to these glass offerings and processing machines, engineering support from development to high-volume production is available. This not only enables customers to find the most suitable solution for their specific application and learn about glass fundamentals, but also allows for continuous improvement during the development and engineering cycles. Solving technical challenges is key for the fabrication of innovative products that involve unique

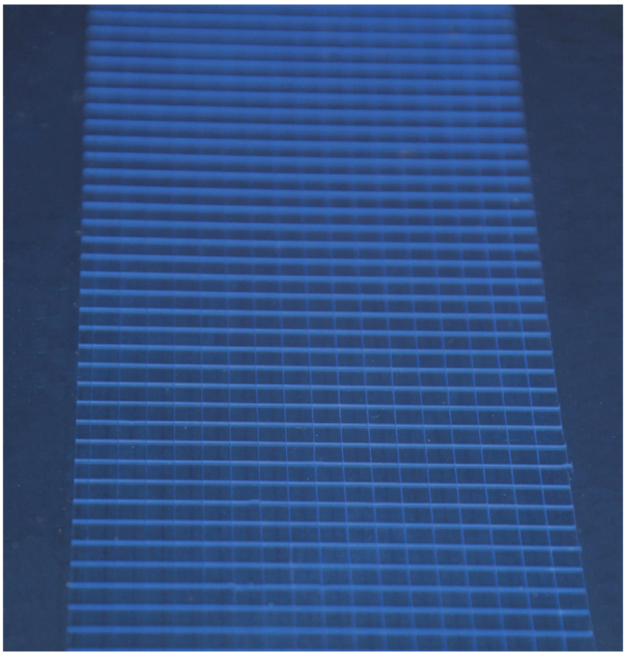

Fig. 5 A fully diced and separated glass panel on stretch tape to ensure mounting for follow up pick'n'place processes. The gap between the dies is >100 µm and has been realized by Corning's zero-kerf laser processing with subsequent stretching.

glass compositions and the processing technologies described above. The company is a valued partner with a proven track record for glass supply in the display and consumer electronics industries: Corning Precision Glass Solutions is focused on glass adoption across the semiconductor and microelectronics industries where the customers rely on the smart processing that can be provided by Corning Laser Technologies.

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Authors

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