Novel Material Made of High-Purity Quartz Glass Can Be Processed like a Thermoplastic

Glass Parts from an Injection Molding Machine

Glass is a high-performance material with properties that are indispensable for many industries. High-precision molded parts made of glass are required in the optics, chemical and medical technology industries. However, traditional glass-processing methods impose limits on parts design, especially for tiny structures. Here, injection molding offers an alternative that is also more energy-efficient, more economical and more sustainable. Glassomer and Engel are jointly tapping into this potential.

From micro to macro: High-precision structures can be created by glass injection molding. © Engel

The new process developed by Glassomer GmbH makes it possible to process transparent quartz glass on standard plastic injection molding machines that meet very high precision requirements [1]. Both thick-walled and thin-walled parts and complex shapes can be produced from quartz glass in this way (**Title figure**). This new approach offers huge potential in terms of efficiency and economy. A look at traditional glass-processing technologies shows why (**Fig. 1**).

Traditionally, glass is cast, ground or etched in accordance with the size and requirements imposed on the intended part. In any event, shaping requires either very high temperatures or the use of toxic chemicals. For casting, the material must be kept permanently at temperatures of around 1500 °C to prevent solidification. After shaping, the part must be cooled very carefully to prevent it from breaking.

Casting is useful for fabricating precision structures in the millimeter range. Finer structures in the sub-millimeter range are mostly produced by etching and lasering, with compression methods being employed for certain types of glass. Precision glass molding (PGM) is deemed to be a modern molding method. For this, small glass blanks are heated, liquefied and pressed directly between two molds. One of its disadvantages is long cycle times. Another is that it requires expensive precision molds that are capable of withstanding the high temperatures.

Etching with a chemical entails the use of lithography to coat parts of a solid glass blank to selectively create

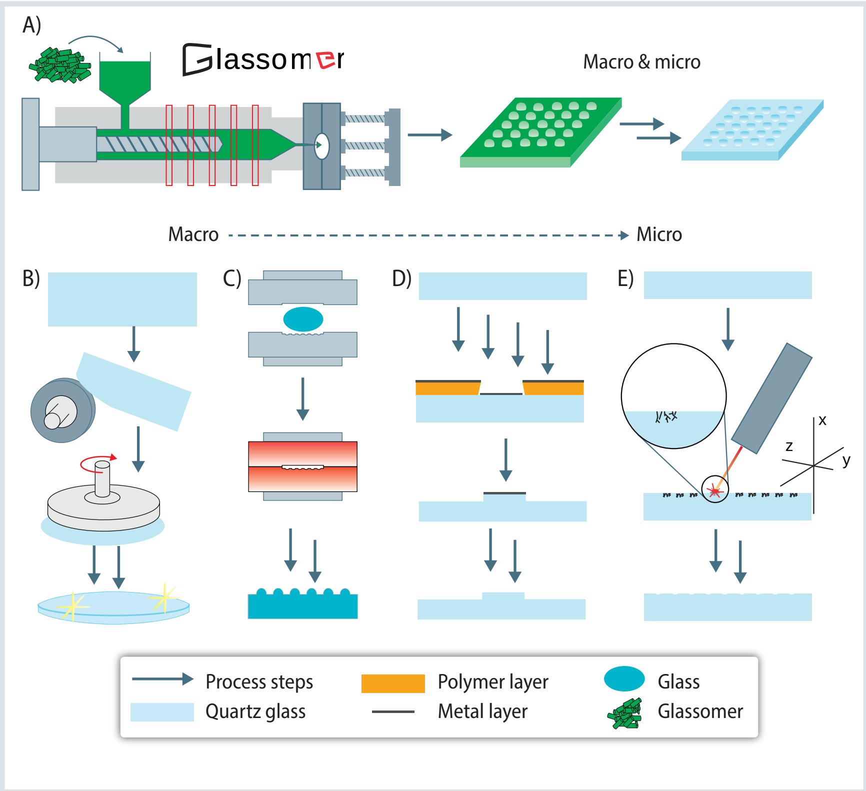

Fig. 1. Traditional glass-manufacturing methods compared with the Glassomer process (A): grinding, polishing and lapping (B), precision glass molding (C), conventional lithography and etching processes for fabricating glass structures at wafer level (D), laser-assisted structuring and downstream etching and polishing (E). Source: Glassomer; graphic: © Hanser

structures. The etching process is preceded by laser pre-processing. However, etching can only produce certain profiles and shapes and yields rough surfaces.

Novel Granulate Made from High-Purity Quartz Glass

Compared with conventionally formed glass parts, thermoplastics can be injection molded into almost any shape in a very short time and at relatively low temperatures. It is this versatility that has provided the motivation to injection-mold glass. The use of injection molding to shape glass not only promotes design freedom, but also improves the energy balance of glass production.

The injection molding process for shaping transparent glass is based on a new type of granulate that has a high content of glass particles. The particles originate from the fabrication of moldings for glass fiber production and are therefore particularly pure. However, it is also possible to use glass particles sourced from cosmetics production, where they serve, for example, as thickeners. The granulate is produced by mixing the high-purity glass powder with a resin, followed by extrusion and granulation. The granulate can be injection-molded like a filled polymer, i.e. at temperatures in the region of 130 °C and with cycle times lasting less than 20 s.

Targeted Control over Surface Properties

The material has deliberately been developed for low-abrasion processing. All of the granulate's ingredients are non-toxic and contain regular polymer resins. Most of the resin in the green body produced in the injection molding process is removed in a water bath and the remainder is burned out in an oven at 600 °C. This yields a compacted "brown" powder part that is stable due to the large overall surface area of the glass particles. The "brown" part is then sintered to yield high-purity glass (**Fig. 2**).

The glass is sintered to full density in the process. When this is done properly, no air pockets remain. Shrinkage during sintering amounts to about 16 %, but can be controlled via the quantity of powder used. Since the part shrinks isotropically, the shrinkage can be calculated readily and with precision during the planning stage, and the parts produced are dimensionally accurate, e.g. holes are completely spherical (**Fig. 3**).

The surface finish can be controlled directly via the nature of the mold-cavity surfaces. The parts can be milky or transparent. Suitably high-quality optical molds yield optical-grade surfaces that do not require post-treatment. »

Fig. 2. The various process steps from granulate to injection-molded "green" part to ready-to-use glass part, as exemplified by a perforated plate. © Glassomer

Manufacturing Process Requires Precision

Processing of the Glassomer material may sound simple, but it requires a high-precision injection molding machine, because even the slightest defect in the injection-molded green part would be visible in the sintered glass part. Glassomer has therefore opted for machines from Engel's e-motion TL series (**Fig. 4**). These all-electric, tie-bar-less machines are so precise that they are also used to produce smartphone camera lenses made of polycarbonate and cycloolefin copolymers.

The e-motion TL has a specially designed frame for ensuring particularly high platen parallelism throughout the molding process, combined with uniform clamping force distribution over the entire mold fixing platen. All principal movements are servo-electrically controlled, which allows the parallel movements to be synchronized.

Fig. 4. The e-motion TL all-electric, tie-bar-less injection molding machine produces high-precision camera lenses from thermoplastics – and now also glass parts. © Engel

Parts of the Highest Purity and Optical Quality

The Engel injection molding machines transform the Glassomer materials into high-precision, transparent parts of high-purity silica. These include not only thick-walled and thin-walled parts, but also complex shapes. The medical technology part shown (**Fig. 5**) is proof that molds designed for processing thermoplastics can also be used for glass injection molding without modification. Structures and wall thicknesses larger than those depicted are also feasible.

The quartz glass employed is characterized by high thermal stability, coupled with a vanishingly small coefficient of thermal expansion. Even large temperature differences give rise to only slight expansion or contraction. For example, treatment at 800 °C can be followed by quenching with cold water, without any problems. This is a property needed in the field of optics, and others, where the fabrication of ever-smaller light sources for generating increasingly higher energy densities requires fine lens structures in a glass that is chemically and thermally highly stable. Other applications lie in sensor technology, where, again, the operating temperatures and ambient conditions often fluctuate extensively.

In many applications, Glassomer's injection-moldable materials even outperform conventional quartz glass. The quality of quartz glass depends on the content of hydroxyl groups, the impurities it contains in the form of positively charged ions and the associated negative charges in the glass framework. A high content of metal impurities, for example, reduces transparency in the lower UV range, whereas a large quantity of hydroxyl groups gives rise to significant absorption in the infrared range. In contrast, because Glassomer's quartz glass for optical applications is sintered under vacuum, it contains only small quantities of hydroxyl groups. The Glassomer materials are highly transparent, having transmission values of >92 % in the 300 to 1000 nm range, 84 % at 200 nm, and >90 % in the infrared range between 1000 and 3400 nm.

A Collaboration with a Future

Glassomer and Engel have already implemented the first glass injection mold-

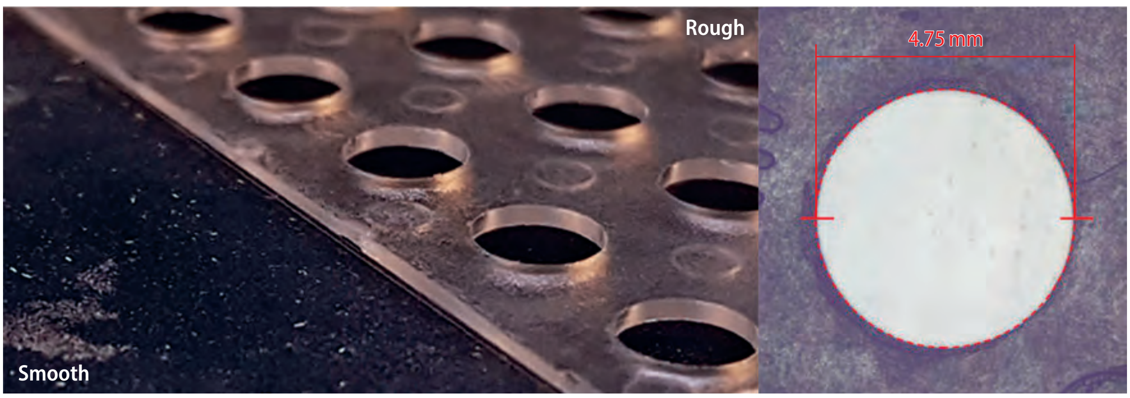

Fig. 3. The multi-stage manufacturing process can produce different surface finishes. As shrinkage can be calculated, a high degree of dimensional accuracy is achieved. © Glassomer

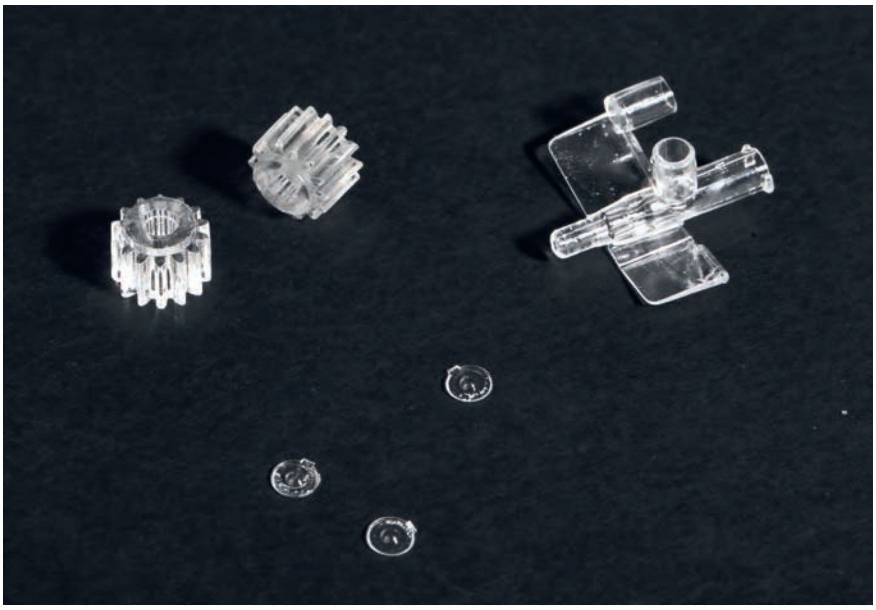

Fig. 5. Different sample parts were produced at Glassomer. The medical technology part (top right) here served as a feasibility study. It showed that the new quartz glass material could also be processed in molds originally designed for thermoplastic injection molding. © Engel

ing applications on an industrial scale. Glassomer's new production facilities in Freiburg im Breisgau, Germany, are injection-molded glass parts at high throughput levels.

The collaboration is benefiting from Engel's know-how and longstanding expertise in the areas of optics and micro injection molding on one hand and its experience with high-volume series production on the other. The aim of the collaborative development work is to lower the barriers to entry for this new technology through the use of highly efficient, economical processes and machines, thus paving the way for the mass production of glass parts on injection molding machines.

Fine structuring of glass in particular will play an increasingly important role in coming years, with one area of application being that of chemical and pharmaceutical synthesis. The future here lies, for example, in the parallel production of active ingredients in lab-on-a-chip systems. Fine channels, reactors and mixer structures can optimize the synthesis and open up new ways to screen active ingredients (**Fig. 6**).

Medical technology offers further potential. Minimally invasive procedures require optically transparent, sterilizable and durable material that will not release undesirable substances. While ions are very easily leached out of traditional borosilicate and soda lime glass, this is not the case for high-purity quartz glass. ■

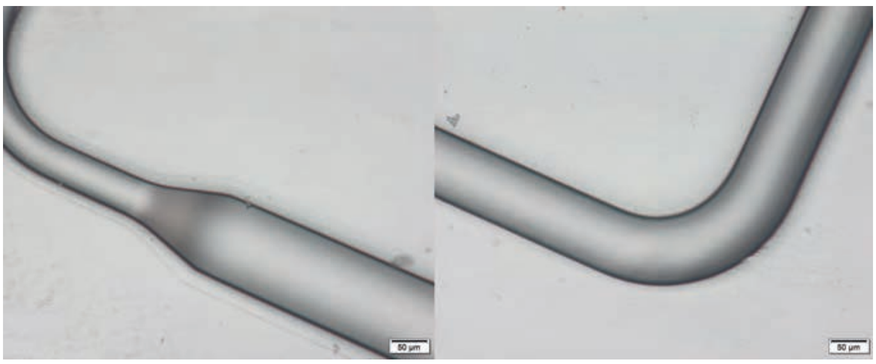

Fig 6. Fine structuring of glass is becoming increasingly important, for example in the field of chemical and pharmaceutical synthesis. High-precision channels can already be produced by the new process. © Glassomer

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Award-Winning Development

Glassomer GmbH was founded as a start-up in 2018 and has already received numerous awards, including the Lothar Späth Award 2021, the Freiburg Innovation Award 2019 and the Neuland Transfer Award 2019. The company founders have also been been honored with the MIT Technology Review Innovators Under 35 Europe, the German Study Award, the Südwestmetall Promotion Award and the Gips-Schüle Young Talent Award.
www.glassomer.com

References

You can find the list of references at
www.kunststoffe-international.com/archive