**SELECTIVE LASER ETCHING OF GLASS AND SAPPHIRE**

**Fraunhofer Institute for Laser Technology ILT**

The Fraunhofer Institute for Laser Technology ILT is worldwide one of the most important development and contract research institutes of its specific field. The activities cover a wide range of areas such as the development of new laser beam sources and components, precise laser based metrology, testing technology and industrial laser processes. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and rapid manufacturing.

Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modeling as well as in the entire system technology. We offer feasibility studies, process qualification and laser integration in customer specific manufacturing lines. The Fraunhofer ILT is part of the Fraunhofer-Gesellschaft.
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With the novel technology »Selective Laser Etching (SLE)« the Fraunhofer Institute for Laser Technology ILT has made a process available for generating microchannels and shaped holes and cuts in transparent parts made of sapphire, ruby, fused silica and borosilicate glass. SLE can produce structures and entire parts directly from 3D CAD data at a micrometer scale.

The Process
When ultrashort pulsed laser radiation is focused in the volume of a transparent workpiece, the pulse energy is absorbed exclusively in the focus volume on account of multiphoton processes. In this focus volume, the optical and chemical characteristics of the material (for example glass or sapphire) are not only changed without the material cracking, but also in such a way that the irradiated material can be selectively removed with wet-chemical etching. When the focus is guided with a microscanner, contiguous areas are modified and subsequently removed with wet-chemical etching. This makes it possible to produce microchannels, shaped holes, structured parts and even complex, assembled mechanical systems in glass or sapphire.

Greater Efficiency for Small and Large Series
The SLE process is characterized by high energy efficiency (melting instead of vaporizing), high material efficiency (kerfs of just a few µm), great precision in three dimensions (1 µm focus, no deposits). Furthermore, it can be scaled up to high speed by means of laser beam sources with high pulse repetition rates. These properties have been achieved for the first time at the Fraunhofer ILT in cooperation with the Chair for Laser Technology LLT at RWTH Aachen University. Thanks to the current development of rapid deflection systems, individual microstructured parts of glass and sapphire can be produced at costs only obtainable today with masking techniques or molding processes for identical plastic parts manufactured in large series.

SLE can be implemented in the industry because it can be scaled up to cycle times of just a few seconds. In the medium term, this process will be able to produce low-cost glass and sapphire parts that will be more resistant than present plastic parts and easier to clean and sterilize. In the long term, SLE can also exploit the enormous potential for individualized mass production because it does not require expensive masks or molding tools, meaning that no part-specific fixed costs are incurred. Parts can be generated within seconds directly from the software (CAD data); see Figure 3.4. As a result, the SLE process makes it possible to manufacture prototypes as well as parts in small and large series whose process parameters can be transferred to others, and to produce customized mechanical microsystems with completely new functional properties, all at cost and time savings.

Outlook
Fraunhofer ILT has continuously been developing and optimizing the SLE process for customer-specific applications. Its primary goals are to reduce surface roughness, extend the range of materials that can be processed and increase the feed speed using new high-power femtosecond lasers with mean output power in the range of 200 to 1000 W.

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Microstructural 3D Parts
The SLE process can also be used to produce microstructured parts in sapphire and glass for precision applications such as watchmaking, micro-optics and medical engineering. In fused silica, for example, any form of a component can be generated down to a substrate thickness of 7 mm at single-sided modifying.

Microfluidic systems can be produced using SLE in thermally and chemically resistant materials such as fused silica, borosilicate glass and sapphire for applications such as those found in medical diagnosis (Fig. 1). In fused silica the volume modified by the laser radiation is etched 1000 times faster than in unmodified glass. Indeed, the aspect ratios of the channels reflect this selectivity. For instance, minimal channel diameters of 10 µm with a length of a few mm are feasible. By means of scanning or laser-beam movement, channels, branches and any kind of hollow structure can be produced.

Microchannels inside Glass and Sapphire
Microfluidic systems can be produced using SLE in thermally and chemically resistant materials such as fused silica, borosilicate glass and sapphire for applications such as those found in medical diagnosis (Fig. 1). In fused silica the volume modified by the laser radiation is etched 1000 times faster than in unmodified glass. Indeed, the aspect ratios of the channels reflect this selectivity. For instance, minimal channel diameters of 10 µm with a length of a few mm are feasible. By means of scanning or laser-beam movement, channels, branches and any kind of hollow structure can be produced.

Shape Cutting and Drilling
In precision mechanics and medical engineering, the SLE process is commonly used to cut out parts made of sapphire and glass. In these applications, the process achieves extremely narrow cut widths, e. g. < 5 µm in a material thickness of 1 mm. By means of a special microscanner, the process can cut shapes of any configuration down to a precision of 1 µm. The resulting shaped holes and cut components exhibit a surface roughness of $R_z < 1 \, \mu m$. In thin glass (< 200 µm, non-alkaline borosilicate glass), shaped holes < 50 µm have been generated.

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