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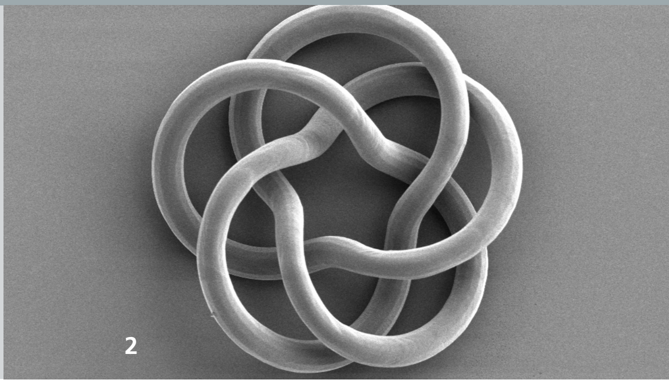

1 3D knot fabricated via SLE

2 3D knot fabricated via 2PP

LASER PROCESSING

OF GLASS AND POLYMERS FOR MICROFLUIDIC AND OPTICAL APPLICATIONS

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Fraunhofer Institute for Laser Technology ILT and Fraunhofer Institute for Silicate Research ISC together with Lightfab from Aachen are developing an entirely new process chain for the manufacturing of three-dimensional devices. This chain includes the polishing of three-dimensional microfluidic cells and the addition of microstructures inside the channels. The employed laser-based process steps include:

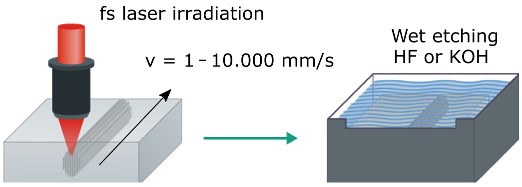
Selective Laser Etching (SLE)

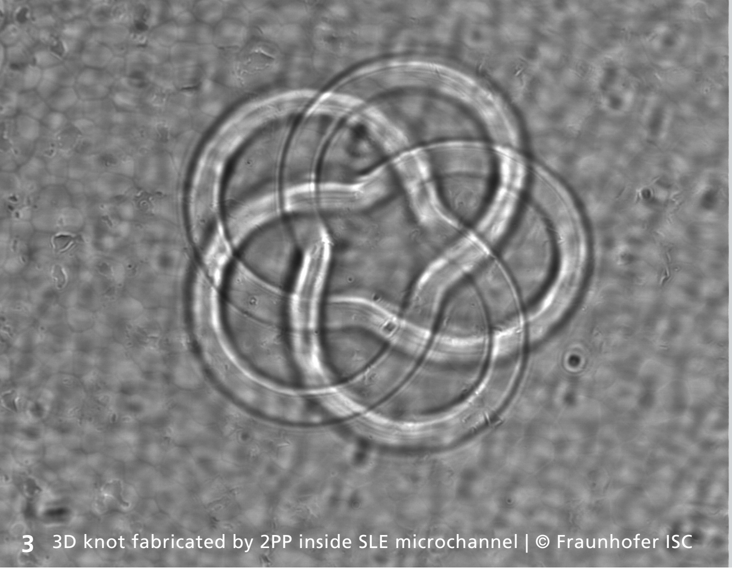
By focusing ultrashort (300 - 3000 fs) laser-pulses into fused silica the material's solubility in e. g. KOH can be increased by a factor of 1000. Thus, 3D scanning of the focal volume inside the glass with a subsequent etching step enables the precise manufacturing of three-dimensional cavities in and on glass substrates.

Typical specifications

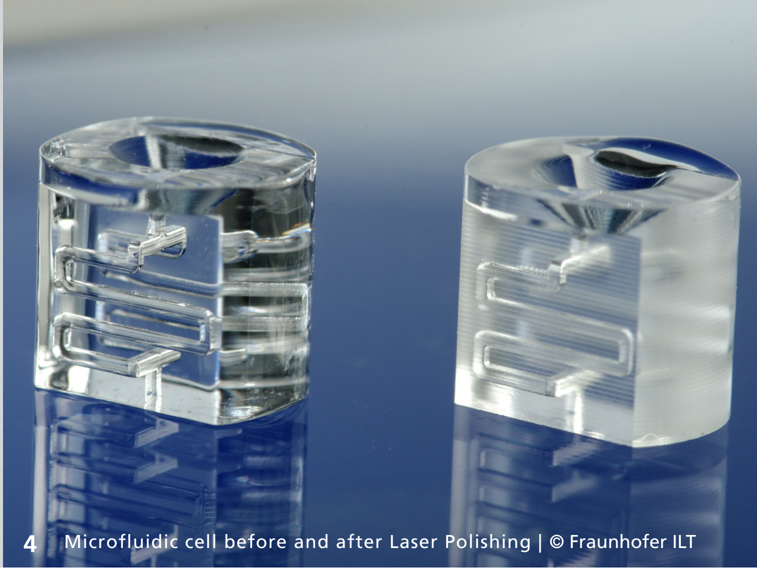
Velocity | thoughput:	200 mm/s – approx. 1-2h for strucuture (see figures)
Accuracy:	< 10 µm
Roughness:	≈ 0.2 µm RMS
Typical dimensions:	< 100 x 100 x 7 mm³

Processflow SLE





3 3D knot fabricated by 2PP inside SLE microchannel | © Fraunhofer ISC



4 Microfluidic cell before and after Laser Polishing | © Fraunhofer ILT

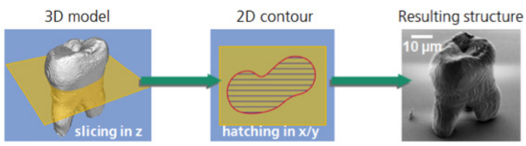
Two-Photon Polymerization (2PP)

Similar to SLE ultrafast laser pulses are tighly focused into the material. However, in this technology a liquid photopolymer – and not glass – is patterned. Laser intensities inside the focal volume are sufficiently large to trigger two-photon absorption (TPA) which leads to a confined solidification of the polymer. Again, 3D scanning of the focal volume and a development step for removal of the uncured resin allow the additive manufacturing of true 3D microstructures.

Typical specifications

Velocity:	typ. 10 mm/s
Accuracy:	< 1 µm
Roughness:	< 50 nm RMS
Typical dimensions:	Bounding box ≈ 50^3 µm³ up to 1 mm³

Processflow 2PP



Laser Polishing

Polishing glass and plastic materials with CO_2 laser radiation is based on the absorption of the radiation in a thin border layer of the work piece such that temperatures just below the evaporation temperature are attained on the surface. As a result, the viscosity of the material is reduced so that the roughness flows and the surface is smoothened due to surface tension. In comparison to conventional polishing methods, laser polishing achieves a favorable smaller micro roughness. It can be adapted to a variety of surface shapes and does not remove material.

Typical specifications

Throughput:	up to 1 cm²/s
Roughness:	PV < 0.5 µm;
	RMS < 1 nm
Typical dimensions:	Ø 1″

Combination of all three methods

The combination of these three laser-based processes enables the manufacturing of devices that can not be realized with conventional methods. This is due to compensation of process-specific drawbacks and particularly by the implementation of new functionalities.

Amongst others, the advantages of the new process chain are:

- Arbitrary 3D patterning of fused silica and photopolymers
- Additional functionality of glass devices with polymer microstructures (particularly in microfluidic channels)
- Polymer microoptics on glass substrates and in glass microfluidics (lenses, mirrors, etc…)
- Smoothing of otherwise rough surfaces from SLE processing ⇨ Optical quality and microscopic imaging in micro-fluidic channels

The ability to perform both SLE and 2PP on the same hardware platform is an additional benefit for lowering manufacturing costs.

The new process chain enables new functional devices for different application fields:

- Microfluidics: Entirely new 3D systems for lab-on-chip devices and microreactors
- Optofluidics and optical integration: optical detection of biomarkers and cells inside the microfluidic cell; integration of fiber optics
- Optics: Optical grade aspheres and freeform surfaces
- Micromechanics: Integrated valves, flaps, and nozzles in the fluidic cell; micromixers