THE ART of
μMANUFACTURING

READ THE ABSTRACT

Advanced Inkjet Technology Conference

LIVE TALK

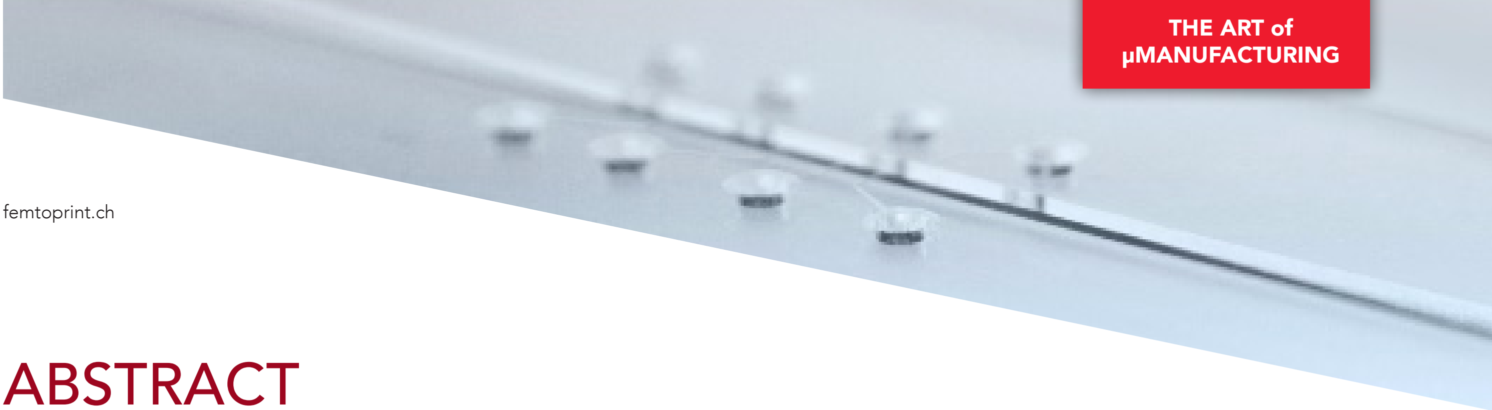
29-31 January, Fribourg, CH

Ultrafast, 3D laser micro manufacturing of novel glass based Microfluidics.

Advanced INKJET

TEN YEARS OF INNOVATION

FEMTOPRINT®



ABSTRACT

Ultrafast, 3D laser micro-manufacturing of novel glass based microfluidics.

REFERENCES

[1] M. Tovar, "3D-glass molds for facile production of complex droplet microfluidic chips", Biomicrofludics 12, 024115 (2018).

AUTHOR BIOGRAPHY

Davide Farina received his MSc in physics at Università degli Studi dell'Insubria in Como, Italy (2018).

After his Master thesis in the field of natural light colorimetry, Davide worked from 2018 to 2022 for CoeLux Srl, an innovative lighting company based in Lomazzo, Italy, as part of the R&D team with focus in optical design.

Davide joined the Engineering department of FEMTOprint SA in 2022 with the role of Application Engineer Optics.

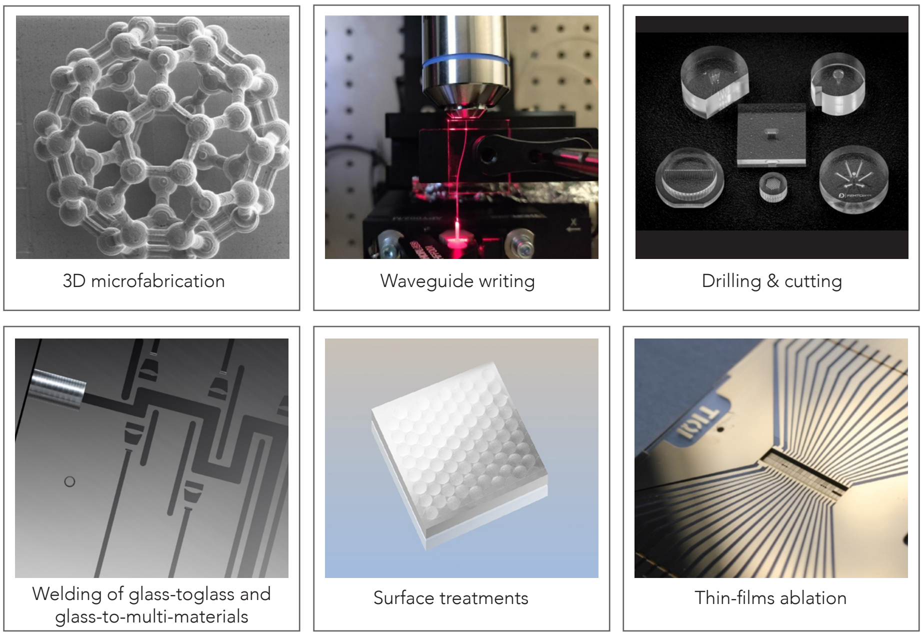


Figure 1: FEMTOPRINT® technology platform.

The present work aims to introduce the novel FEMTOPRINT® microfabrication technology, based on ultrafast laser and chemical wet etching processing, to create three-dimensional, high-precision patterns into transparent, glass materials for a wide range of applications and microdevices.

Thanks to the ability to generate 3D geometries with micrometric precision, to treat surfaces to achieve optical transparency on virtually any surface topography, and to laser weld hermetically microdevices without the need of glue or adhesive, new horizons for integrated microfluidics are yet to be explored.

More specifically in the inkjet industry, novel micronozzle arrays with a high degree of shape freedom and features dimensional repeatability over centimeter long substrates, within an exceptionally stable material as it is glass, can be now conceived at an industrial scale. Beyond that, the technology enables the integration of certain functional coatings to modify surface properties or the application of 3D electrodes, contributing to a new microfabrication approach suitable for a wide spectrum of microfluidic devices.

In recent years, tremendous progress in the field of ultrafast laser processing of glass has resulted in robust, industrial equipment to allow for scalable, high-throughput wafer-scale processing, competing with traditional photolithographic techniques and taking advantage of a much higher degree of geometrical freedom.

ABSTRACT

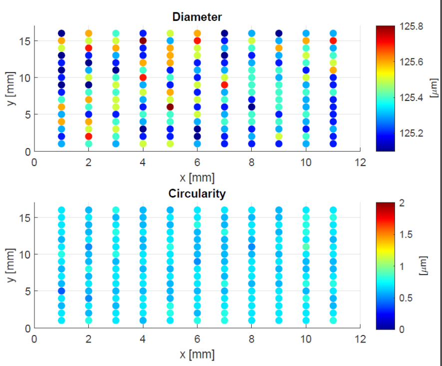
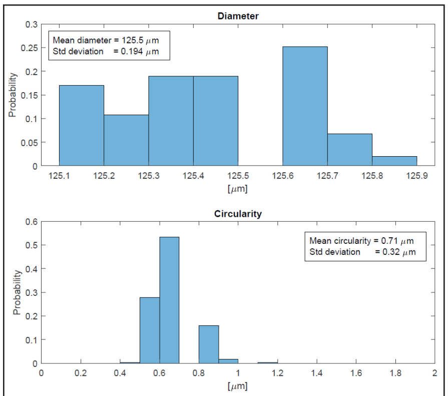


Figure 2: 2D holes array, diameter and circularity measurement over one complete device (upper) and average values over three devices (lower).



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Several sectors are looking at this potentially ground-breaking technology for the precision manufacturing of microfluidic devices and the industrial printing is of particular interest when looking at novel printhead and micronozzle array concepts.

The industrial printing landscape has expanded into various new domains, such as food printing, organic and biomaterials printing, and the well-known 3D printing. These domains have different printing needs, such as higher resolution, increased throughput, usage of robust and biocompatible materials, functional integration, miniaturized footprint, and precise liquid flows.

To address these challenges, a new design and manufacturing approach is required that can tailor the nozzle shape to the specific properties of the inks. The FEMTOPRINT® technology can achieve this by creating micron-level features with high accuracy and repeatability, and allowing free-form internal shapes to enable a wide range of microfluidics jetting applications across the different domains.

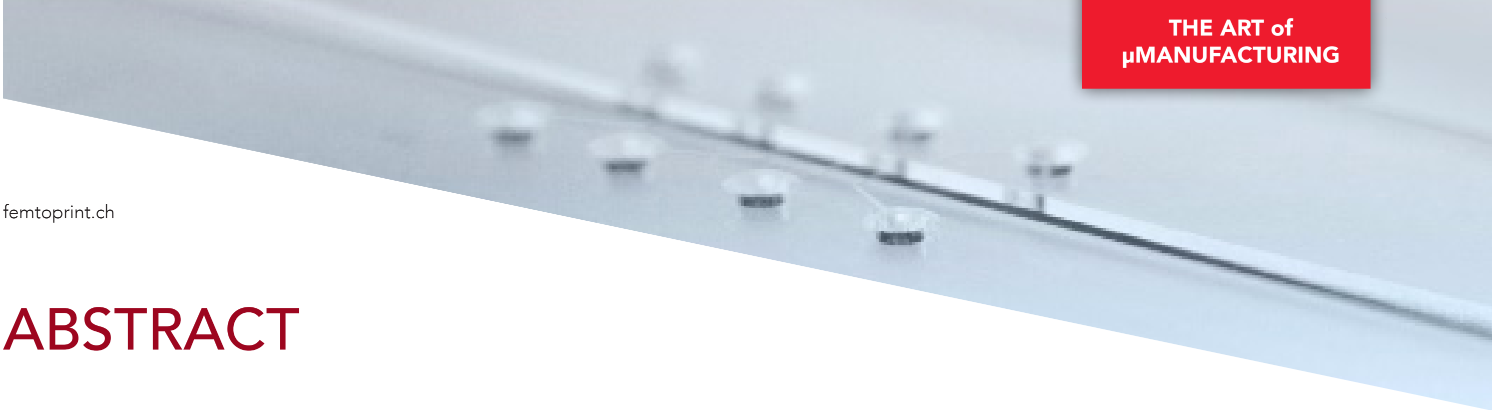
Most of the traditional microfabrication technologies offer limited freedom in geometry (binary structures) and are often associated with MEMS materials. The goal of the novel FEMTOPRINT® technology is to broaden up the opportunities in designing more sophisticated, yet miniaturized and monolithic, microfluidic systems, where the fabrication of undercuts, of precise slopes with any angle and an angle control within 0.05° and virtually no step effects (roughness average Sa << 0.5 µm) is possible.

Sub-micron accuracy on holes diameter and positioning, in addition to a laser welding process made at room temperature, without the need of glues or adhesive, enabling tight and hermetic sealing even on miniaturized elements (contact surfaces can be as small as 75 µm in width and 200 µm in depth), takes the freedom in design thinking to a new level.

Finally, glass is an exceptional material of choice thanks to its multiple properties. It's an amorphous material, insulating, biocompatible and sterilizable, inert to chemicals and mechanically and thermally stable, with outstanding optical transparency. Some specific glass families such as the borosilicate are also well known for their similar CTE with silicon materials, making them the perfect choice when laser welding needs to be applied for sealing the two materials together (often in combination with sending and MEMS-based applications).

The FEMTOPRINT® micro-manufacturing technique belongs to the so-called selective laser-induced methods that rely on a combination of ultrafast laser exposition and chemical material processing. In a first step, the desired 3D shape is patterned within the glass substrate by a focused ultrafast laser which locally modifies the material structure and refractive index, significantly increasing the etching rate in comparison with the pristine material.
In the subsequent wet etching step, all the exposed material is removed. The combination of the laser writing and the etching step in relation to the overall dimensions will eventually define the minimum feature size and the shape accuracy of the resulting microdevice, which are typically of the order of a few microns or below.

Surface quality of patterned surface can reach Sa values below 100 nm, and such quality can be further enhanced via an additional surface processing down to Sa ≤ 10 nm, depending on the geometrical shape under evaluation. Feature aspect ratio can be higher than 1:500 and sidewall deviation below 0.05°; minimum hole diameter can be as low as 2 µm; transparent materials can be processed up to 30 mm in bulk height, and the maximum working area is 300 mm in diameter. The FEMTOPRINT® technology is compatible with a broad range of glass materials, i.e., fused silica, borosilicate, boro-aluminosilicate, and others.



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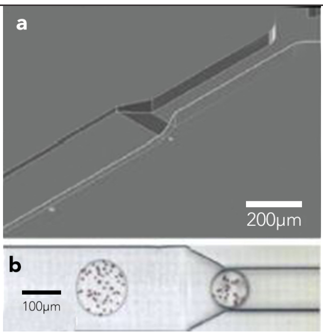

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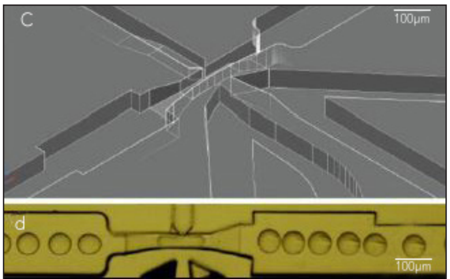

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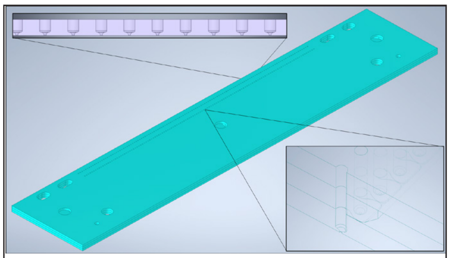


Figure 4: Fused silica printhead nozzle plate (Source: Courtesy of iPrint).

The wide breadth of capabilities of the FEMTOPRINT® platform ranges from 3D micromanufacturing (microfluidics, micromechanics, and micro-optics) to glass encapsulation and packaging via laser welding, surface ablation and polishing, optical patterning, and waveguide writing, drilling & cutting (pass-through holes), and laser ablation of thin films. Additionally, surface functionalization can be achieved with metallic and dielectric coatings.

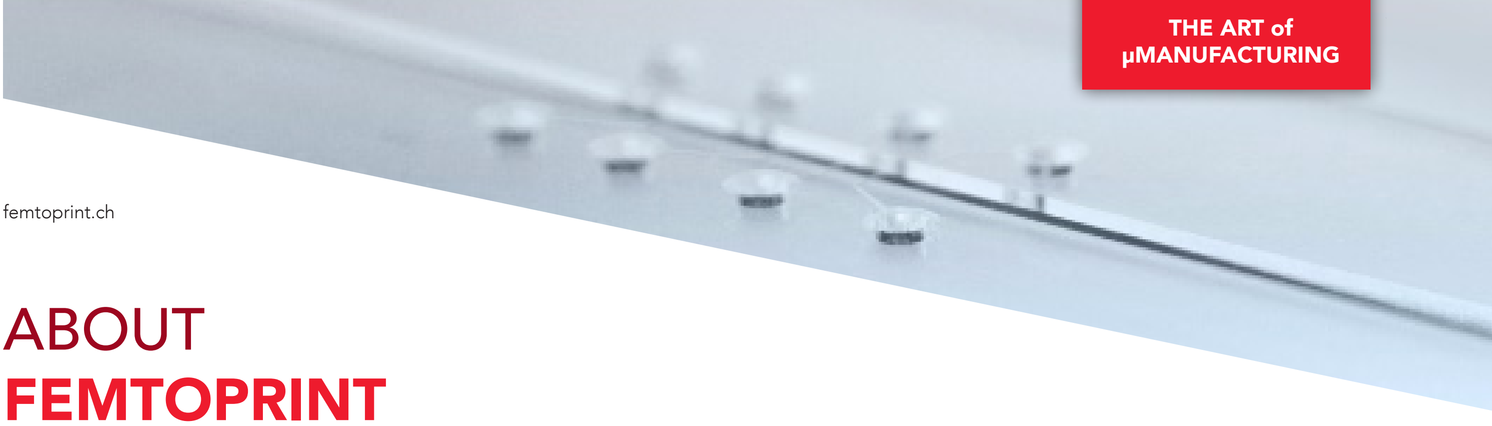
As an example of the homogeneity and repeatability of the FEMTOPRINT® technology, Figure 2 shows measurements relative to fused silica 2D arrays of pass-through holes; target hole diameter is 125.5 µm and the inter-hole nominal distance is 1 mm. Measured diameters are narrowly distributed around the target value (standard deviation < 0.2 µm), with circularity lower than instrument resolution (± 2 µm). Moreover, holes positioning is highly precise, with errors within a single array lower than instrument resolution (± 2 µm) and a micron-level relative positioning error over multiple arrays (average 0.7 µm, standard deviation < 0.4 µm). Holes are homogenously reproduced over each complete array, and results are repeatable over multiple arrays.
The device in Figure 3 consists of a microfluidic fused silica droplet-trapping chip for prolonged observation and imaging [1].

The design features differently shaped chambers of variable depth, with ramps to observe droplet contents in flow under different channel heights, as well as to improve picoinjection. Channels overall length is 15 cm, with multi-level sloped transitions, while the over 100'000 filtering elements consist in holes with diameters below 10 µm, whereby the smallest featured diameter is 3 µm. The device presents 192 nozzles packed in a structure 25 mm in length and 4 mm in width, including all inlets and outlets, generating monodisperse droplets 70 µm in diameter. The structure can be easily scaled to contain 1'000 nozzles in a 6.5 cm long structure.

Figure 4 illustrates a printhead nozzle plate with miniaturized curved channels connected to 256 individual nozzles. The nozzles have an entry diameter of 200 µm changing via curved shapes to an exit diameter of 40 µm; nozzles inlets feature channels 5 µm deep and 10 µm wide. Measured geometries of produced nozzle plates give highly accurate results, with maximum absolute errors of 1 µm for both entry and exit diameters of all nozzles, as well as for the dimensions of the nozzle inlets.

The excellent geometrical accuracy and surface quality, combined with a monolithic fabrication process at µm-scale resolution, grant FEMTOPRINT® technology several benefits for many different applications. For example, it allows multifunctional integration of components in a monolithic design, simplifying assembly and alignment challenges on the µm-scale level. Moreover, components can be assembled hermetically and without the need of adhesives via robust laser welding, either for glass-to-glass or for glass-to-multi-materials assemblies (e.g., SOI wafers, ceramics, and metals).

Thanks to such 3D free-form manufacturing capabilities, microfluidics, micromechanics and micro-optics can be seamlessly combined. Also, the technology can leverage thermal properties of glass materials to achieve optimal thermal stability of integrated parts. FEMTOPRINT® process is maskless and doesn't require a cleanroom environment, allowing for fast turnaround cycles during prototyping; thanks to its unique know-how and capabilities in glass microprocessing, FEMTOprint gives full support to its customers along different phases of development, from proof-of-concept to product development and wafer-scale manufacturing, delivering from single units up to high-throughput volumes.



ABOUT **FEMTOPRINT**

TECHNOLOGIES
MEDICAL
LIFE SCIENCES
INTEGRATED PHOTONICS
ENERGY MICROMECHANICS
AEROSPACE
WATCHMAKING

SOLUTIONS
Together with the customer, the chip has been engineered to be monolithically produced using the FEMTOPRINT® glass microfabrication platform. Requested key functionalities included optical access to the chip, high precision microfabrication, three dimensional and micrometer-size features inside the glass bulk.

CREATIVITY
Creativity is defined as the tendency to generate or recognize ideas, alternatives, or possibilities that may be useful in solving problems, communicating with others, and entertaining ourselves and others.

FEMTOprint is a Swiss high-tech Contract Development and Manufacturing Organization (CDMO) specialized in high-precision 3D microfabrication in glass.
With the ground-breaking FEMTOPRINT® microfabrication platform we serve leading industrial Customers with feasibility, rapid prototyping, and pilot- and industrial series manufacturing at the wafer-level.

APPLICATIONS
Microfluidics | Micro-optics | Photonics | Microelectronics | Micromechanics | MEMS | Packaging | Mastering

INDUSTRIES
Life Sciences & Diagnostics | Medical | Watchmaking I Aerospace | Automotive | Industrial Machinery | VR & AR | Photonics | Energy | Quantum

The FEMTOPRINT® micro-fabrication platform relies on ultrafast, laser-based manufacturing processes, creating novel glass microdevices in 3D, with integrated waveguides, welded and laser diced. The company is certified ISO 13485:2016.
Different glass types can be used as raw materials to structure components, such as, but not limited to, fused silica, borosilicate, or alkali-free glass.
The minimum feature size range is a few microns, while the maximum working area is currently 300mm in diameter and 30mm in thickness.

BENEFITS
- Free-form microfabrication with sub-micron accuracy
- High surface quality and outstanding glass properties
- Integration of optical, fluidic, and mechanical functionalities
- Wafer-scale production for series volumes
- Engineering expertise to support product development
- Full control over proprietary processes and systems
- Demonstrated residence time of 2.1± 0.3 ms and theoretical minimum mixing time of 0.91 ms.
- Determination of electronic structure of conventionally inaccessible reaction intermediates.

We want to be part of your success, contact us:

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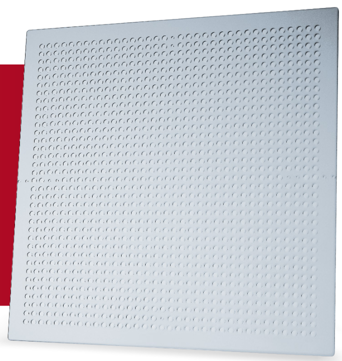

FEMTOPRINT®
3D PRINTING FOR GLASS MICRODEVICES