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Ultrafast laser processing of glass for MEMS and micro-fluidic applications

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Microsystems perform sophisticated tasks in miniaturized volumes. Shaping or analyzing light signals, mixing ultra-small volumes of chemicals, sensing mechanical signals, manipulating micro-objects, sequencing bio-molecules are common operations that can be done by these tiny machines. To further advance the field, there is a growing interest for integrated manufacturing platform where optics, fluid handling capabilities or micro-mechanical elements can be combined.

In that context, the use of ultrafast laser to process fused silica (the amorphous form of SiO_2) is of particular interest. Femtosecond laser beam can locally increase the refractive index [1], enhance the etching rate [2], introduce sub-wavelength patterns [3], create voids [4] or change the thermal properties [5] of fused silica. By scanning the laser through the specimen volume, one can distribute, combine and organize these material modifications to form complex patterns to be used for instance as waveguides or fluidic channels. With this technique, instead of building up a device by combining layers of materials as common practice, the microdevice structure and function are directly “printed” into a single piece material. Note that thanks to the non-linear nature of the laser-matter interaction, laser-induced material modifications can be introduced not only at the material surface but anywhere in the bulk where the laser is focused.

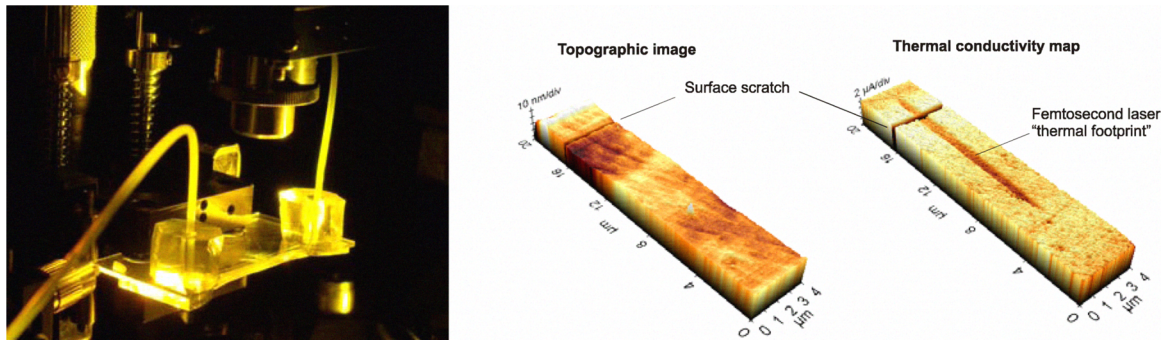


Fig. 1 Left: an illustration of a biochip device for algae analysis made by femtosecond lasers. The biochip contains a curved waveguide that is used to guide the light emitted by a laser toward a fluidic channel and doing so, to illuminate algae specimens passing in the channel / Right: Thermal conductivity changes observed in a fused silica exposed to femtosecond laser. While no changes are noticeable on the topographic images, the thermal conductive map reveals the laser affected zone corresponding to structural changes in the material.

To form microdevices like the one shown in Fig.1 (left), we focus low-energy pulses (a few tens of nanojoules with an average power below 250 mW) to write in the bulk the microdevice contour [6,7] along with optical functions (consisting in waveguides). At this level of energy, no ablation occurs but a subtle change of material properties. The material is just “exposed” to the laser radiation. After exposure, the device contour is revealed by etching the substrate in a low-concentration hydrofluoric (HF) acid bath.

The nature of the structural changes like for instance thermal conductivity changes (Fig. 2, right) is still debated and will be discussed in this paper from the view-point of laser processing of microdevices. We will also review new developments toward the integration of additional functionalities using ultra-fast laser exposure.

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