

# Short-pulse laser processing of Silicon: towards all laser-made devices

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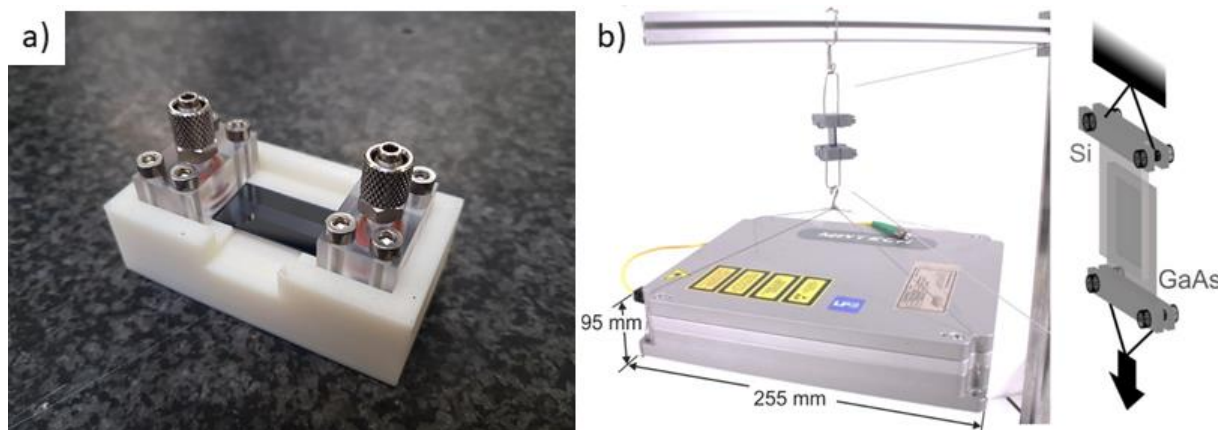
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Silicon is among the most important technological materials with extensive uses in the fields of microelectronics, microfluidics and micromechanics. Fabrication of the different silicon-based micro-parts relies on lithography-based processing techniques that mainly use clean room environment and/or consume hazardous chemicals. Such examples are dry (deep reactive-ion) and wet (KOH) etching for engraving/drilling and fusion or anodic bonding when encapsulation is necessary. However, the above-mentioned techniques suffer from tedious cycles inherent to the fabrication process that result in limited flexibility and increased failure probability. These issues need to be addressed in order to allow widespread access to research and development, and provide an appropriate solution for prototyping silicon-based devices.

In this work, we first demonstrate the relevance of maskless laser writing to advantageously replace lithographic steps in the fabrication of a Si-SiO<sub>2</sub> microcooling device (see Fig. 1 a) [1]. We use a 20-Watt infrared laser with a pulse duration of 50 ps to engrave and drill a 525 μm-thick silicon wafer. Anodic bonding to a SiO<sub>2</sub> wafer is used to encapsulate the patterned surface. Mechanically clamped inlet/outlet connectors complete the fully operational microcooling device. The functionality of the cooling device has been validated using a thermal measurement setup confirming an operational micro-chip dissipating a few W/cm<sup>2</sup>. This approach constitutes a modular microfabrication solution that should facilitate prototyping studies of new concepts for co-designed electronics and microfluidics [2].

In an effort to extend the palette of advanced laser-based silicon processing techniques we demonstrate transmission laser welding of similar and dissimilar semiconductor materials (see Fig.1 b) for the first time as an alternative to classical bonding techniques [3]. By employing a modest milliwatt nanosecond laser emitting at a wavelength of 1.55 μm, we show that it is possible to circumvent the optical limits on the deliverable energy density at interfaces between semiconductor materials and achieve welds with shear joining strength of 32 ± 10 MPa comparing favorably to complex alternatives.

We will present in detail the experimental configurations and technical aspects used in the above-mentioned developments. Then, we will discuss the most important current limitations and finally different possibilities for improvement in perspective. We anticipate that laser-based manufacturing will rapidly hold an even more important place among typical microfabrication techniques in the semiconductor sector.



**Fig. 1** a) Microcooling device b) Image of the laser source used in the experiments (~3 kg) hanging from a Si wafer welded on GaAs.

## References

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