A monolithic micro-tensile tester for investigating silica micromechanics, fabricated and fully operated using a femtosecond laser

A monolithic micro-tensile tester for investigating silica micromechanics, fabricated *and* fully operated using a femtosecond laser

***Christos-Edward Athanasiou, Yves Bellouard**

Microsystems Group
Eindhoven University of Technology
**c.e.athanasiou@tue.nl*

The ***Galatea research project*** [1] is aiming at exploring the use of ultrafast lasers to locally tailor the physical properties of materials. Using a single process 3D objects with nanoscale features where optics, fluidics and micromechanical elements are integrated in a monolithic piece of glass.

Why study fused silica?

Fused silica- the amorphous phase of silica- is particular interesting for microsystems. Its unique thermal, optical and mechanical properties make it a very suitable substrate for multifunctional micro-devices.

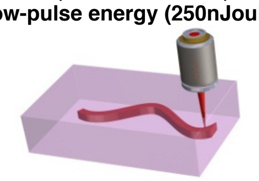
The yet (unknown) silica mechanics

Due to inherent difficulties the physical and mechanical properties of silica and silica's polymorphs still remain largely unexplored at the microscale & nanoscale.

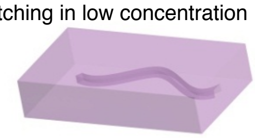
Femtosecond Laser Microfabrication

After femtosecond laser exposure of fused silica *below the ablation threshold*, the exposed zones of the material are more susceptible to chemical etching than the pristine material (ratio 70:1)[2]. We use this two-step process to fabricate the tensile tester.

~270fs pulses,800kHz rep-rate
low-pulse energy (250nJoule)

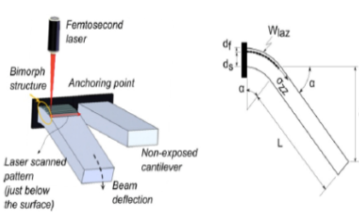


Etching in low concentration HF bath



Using a femtosecond laser as a Loading Tool

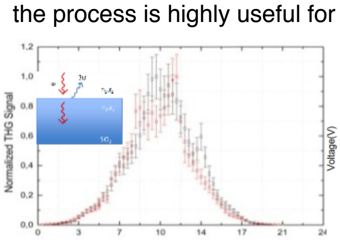
Femtosecond laser induced volume expansion in fused silica is reported from our group[3].

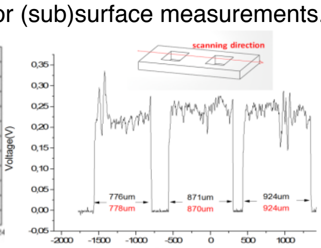


We induce controlled deformations to the device by writing adjacent planes in the bulk of the material. The stress of the tensile tester can be tuned at any desired level.

In-situ Characterization using *the same* femtosecond laser

Third harmonic generation is a weak process that occurs in all materials. When focused ultrashort pulses cross an interface the process is highly useful for (sub)surface measurements.



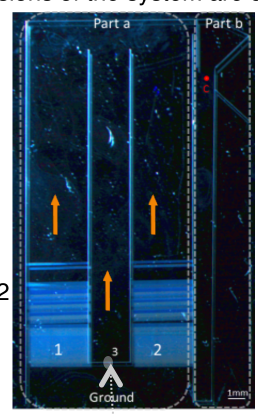


Using the same laser at lower pulse energy we measure the 3rd harmonic generation signal when femtosecond pulses cross a-SiO_2 interface [left figure] or a pattern made of predefined trenches [right figure].

How it works

The system consists of two parts: *the loading cell* (Part a) and the *displacement amplification sensor* (Part b). The overall dimensions of the system are 9mm×20mm.

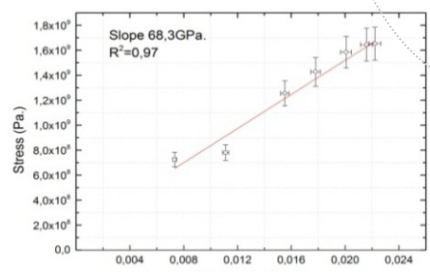
Loading Cell
The laser affected slabs (stressors) induce a volume variation. Since the loading cell is grounded on the bottom, the whole volume variation induced in bars 1 and 2 moves upwards. This way it loads the beam under test (bar 3).

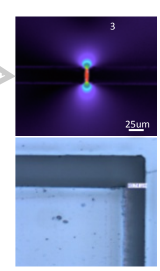


Displacement Amplification Sensor
The same volume variation comes as an input in the lever mechanism. Two thin flexures form a hinge with a remote point of rotation at point C. The strain of the under test beam is amplified 100 times.

Direct Elastic Modulus Measurements

By gradually increasing the induced volume expansion to the system, we measure the developed stress and the strain of the test beam. Stress is measured using polarized light microscopy [right top figure] and strain using the amplification sensor[4] [right bottom figure].





- As a proof of concept *fused silica's elastic modulus is measured 68,3GPa.* which is within the 7% error range that the tester provides.
- Future work will be focused on modifying the test beam's material so that silica polymorphs can be mechanically characterised.

References

[1] www.erc-galatea.eu
[2] *Y. Bellouard et al, Optics Express*, **12**, *2120-2129 (2004)*
[3] *A. Champion et al., Opt. Mat. Express* **2**, *165240 (2012)*
[4] http://dx.doi.org/10.1364/CLEO_AT.2014.AW1H.6

Technische Universiteit **Eindhoven** University of Technology

erc European Research Council