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Ultra-short pulse laser-based fabrication process for lightweight structures in quartz glass applied for mirrors

David Bischof[1*], *Michael* Kahl[1], and *Markus* Michler[1]

[1]OST Eastern Switzerland University of Applied Sciences, 9471 Buchs, Switzerland

Abstract. In the following work a manufacturing process for light weight structures in Fused Silica is presented. Such structures can potentially be used for mirrors to decrease the mass by simultaneously ensuring high stiffness. This talk should give the audience the possibility to assess the selective laser etching technology for mechanical structures in the field of optical mirrors.

1 Introduction

Classical manufacturing of glass-based lightweight structures is based on grinding or molding, for example, for large mirrors. In this work we will present a laser-based manufacturing process for lightweight structures (section 1.2). The advantage of the selective laser-induced etching process (SLE) used is that any 3D shape can be inscribed. The disadvantage on the other hand is that the manufacturing time increases linearly with the size of the device. Nevertheless, there are many interesting features that can only be realized with this concept.

The SLE fabrication process is based on two main steps. At first, the glass morphology is modified by the laser treatment and in a second step the glass substrate is shaped by wet chemical etching (Fig. 1).

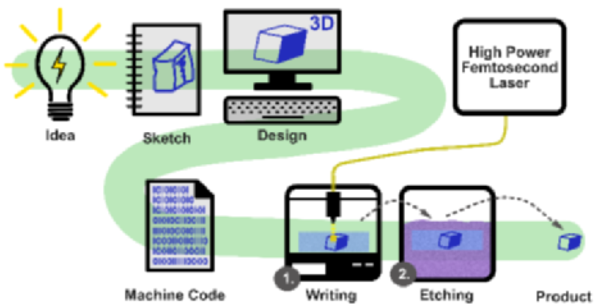

Fig. 1. Illustration of selective laser etching process

For the modification of the synthetic quartz glass a laser with a pulse repetition rate of 750 kHz, a pulse duration of 1 ps, a wavelength of 1030 nm, circular polarization, a pulse energy of about 350 nJ and a focusing objective (20x, NA0.4, -1.1 mm cover glass correction) is used [1]. The focus has a voxel size of about 3 µm, this focus has to be routed with a controlled multi-axis system to form a 3D object. Consequently, the 3D CAD design must be translated into lines and arcs. These curves are finally written into the glass and etched with hot potassium hydroxide (8mol/l, 80°C).

The advantage of this technology is, on the one hand, the design freedom to realize undercuts and freely movable parts, and on the other hand, subtractive manufacturing means that the material quality is defined by the glass and not by the machining process. As a result, of the etching there is an RMS roughness of about 1 to 2 µm observable, but there are no sharp cracks. Compression tests on small etched cylindrical pillars with a size of Ø17 µm and height of 28 µm showed that these structures can withstand a compressive stress up to 8 GPa [2].

The aim of lightweight structures is the reduction of the mass by simultaneously ensuring high stiffness. The stiffness against deflection of a part is inversely proportional to the moment of inertia of the part cross-section. The moment of inertia is defined by the equation $I_y = \int_A z^2 dA$. As a result, the material further away from the center contributes more to the stiffness of the part. For this reason, the material in the center is removed in lightweight structures. [3]

2 SLE applied to generate light weight structures

In this work, SLE technology was applied to create lightweight structures in a fused silica mirror. Two designs with additional features were realized to demonstrate on the one hand the possibility to realize rotating elements (Fig. 2) and on the other hand a linear translation system with flexures (Fig. 4).

The mass of the moveable part of both designs is decreased by a lightweight structure on the backside of the mirror. This structure consists of honeycombs and pillars connected to the front of the sample (Fig. 3). The web width of the honeycomb in Fig. 5 is 250 µm and the structure depth is 5 mm. This corresponds to an aspect ratio of 20.

* Corresponding author: david.bischof@ost.ch

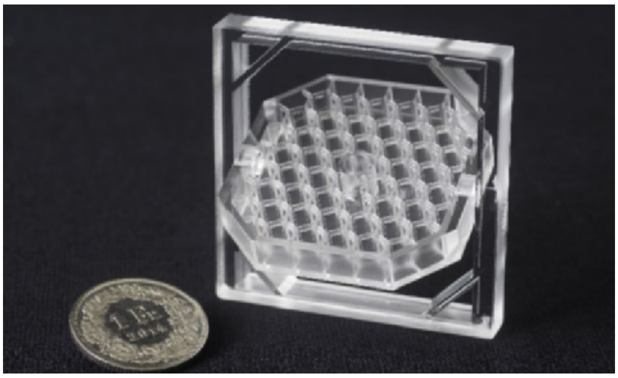

Fig. 2. Lightweight structure combined with a rotation axis

The rotary axis of the design shown in Fig. 2 and 3 is realized with a plain bearing. Its disadvantage is the clearance fit, which is always greater than about 20 µm due to the etching process. Nevertheless, it can be shown that simple rotary bearings can be integrated with this technology platform.

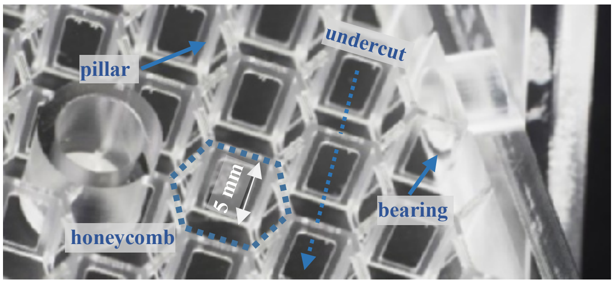

Fig. 3. Detailed view into the lightweight structure. A honeycomb structure is visible at the top and undercuts can be seen in the center, which further reduce the weight

By using two parallel bending beams as shown in Fig. 4 a translation system with two degrees of freedom can be integrated into the quartz glass. In this example the inner lightweight structure can be deflected by ±250 µm in two directions. The advantage of this system is that due to the low thermal expansion coefficient (CTE) of 1 ppm such systems are potentially very stable compared to metal-based solid flexures with a CTE of about 10 ppm.

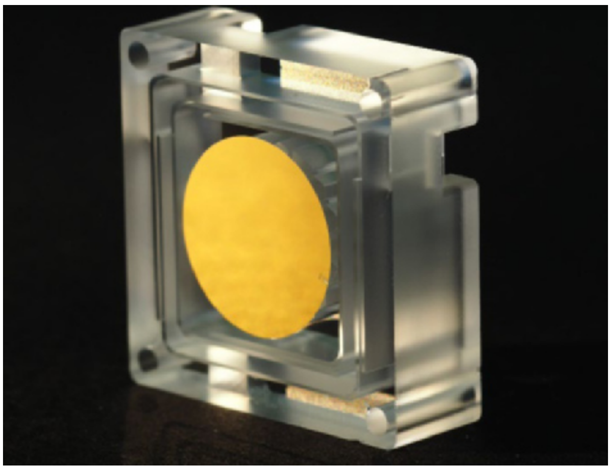

Fig. 4. Plan Mirror with a lightweight structure on the backside combined with solid flexures. The flexures provide a translation range of ±250 µm in two directions.

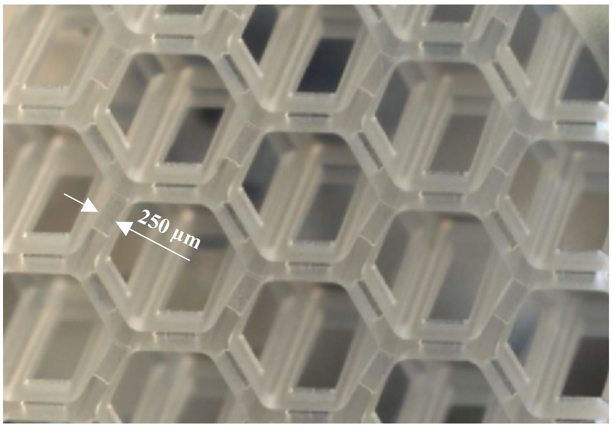

Fig. 5. Detail view of the lightweight structure of the mirror with the solid flexure design. On the foreground there is the honeycomb structure with a web width of 250 µm visible

3 Conclusion

Lightweight structures with very small feature sizes and undercuts can be fabricated by using selective laser induced etching. In addition, it was demonstrated that additional features like rotation axes and solid flexures can be integrated into devices using the SLE technology platform.

Acknowledgement

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References

[1] J. Gottmann, M. Hermans, N. Repiev, and J. Ortmann, “Selective Laser-Induced Etching of 3D Precision Quartz Glass Components for Microfluidic Applications—Up-Scaling of Complexity and Speed,” *Micromachines*, vol. 8, no. 4, p. 110, 2017, doi: 10.3390/mi8040110.

[2] R. N. Widmer, D. Bischof, J. Jurczyk, M. Michler, J. Schwiedrzik, and J. Michler, “Smooth or not: Robust fused silica micro-components by femtosecond-laser-assisted etching,” *Materials & Design*, vol. 204, p. 109670, 2021, doi: 10.1016/j.matdes.2021.109670.

[3] A. Ahmad, *Handbook of optomechanical engineering*. Boca Raton [Floride]: CRC Press, 1999.