

Laser-based Manufacturing of an Acoustic Chamber for an optical microphone

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Microphones are widely used for applications in voice and sound recognition. However, the dynamic range of current microphones is inferior to that of the human ear. The PionEar project aims to enhance this dynamic range by developing a VECSEL-based optical microphone.

1 Introduction

This study introduces a concept for a laser-based manufacturing process to manufacture a miniaturized acoustic chamber from glass. These acoustic chambers will serve as a base platform for the integration of customized vertical emitting laser gain chips (VECSELs) and membranes. The substrates with the acoustic chambers are fabricated using selective laser induced etching (SLE) and standard metallization techniques. The microphone design incorporates several essential functions, including pillars for mounting the gain chip, an optical entry for sensor readout, electrical circuits for gain chip operation and thermal conductors for effective heat management. The SLE technique allows the development of complex structures for mechanical, fluidic or optical applications [1, 2]. In this work the SLE process is used to design structures for optimal placement and alignment of the gain chip, membranes and optical measurement channels.

2 Microphone structure and requirements

The microphone features a glass-based acoustic chamber, a silicon membrane, and a laser gain chip, as illustrated in Fig. 1. The gain chip is mounted on a glass pillar, creating a laser cavity in conjunction with the membrane. The dimensions of the completed microphone are $5 \times 5 \times 1.5 \text{ mm}^3$.

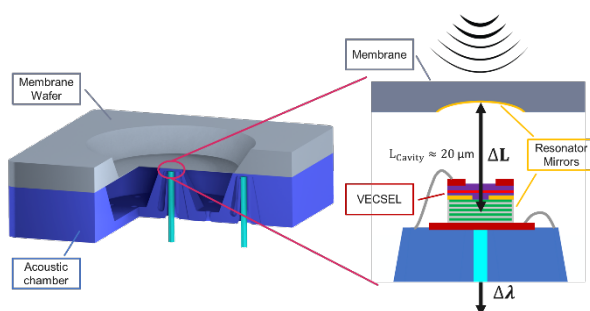


Fig. 1 Microphone structure and assembly

To operate and read out the microphone, the gain chip requires electrical, thermal, and optical interfaces. The electrical interface supplies the current necessary for laser pumping and serves as a

metallized pathway for thermal management. Effective thermal management is crucial to prevent the laser from overheating and to ensure stable operation.

When an acoustic signal deflects the membrane, it causes a shift in the central wavelength of the laser. This detuning is measured externally by detecting the wavelength shift of the optical signal, necessitating an optical interface. To minimize optical coupling losses, this interface must be positioned very close to the gain chip and is implemented using an optical single-mode fiber connection.

3 Acoustic chamber

To enhance the signal-to-noise ratio, the acoustic chamber requires a substantial back volume. Therefore, a 1 mm thick fused silica substrate is employed, which is precisely machined using selective laser induced etching (SLE).

The SLE process uses ultrashort laser pulses that are precisely focused onto a small volume within the micrometer range. The laser treatment alters the glass material, enabling subsequent removal of the modified regions through wet chemical etching with high selectivity. In the case of fused silica, the etching selectivity between unmodified and modified material is approximately 1000 [3]. By moving or scanning the laser's focal point, known as a voxel, three-dimensional objects can be created. In this study, various structures such as cavities with a depth of 0.8 mm, through-glass holes (TGHs) and pillars equipped with integrated fiber clamps and alignment markers are needed, as illustrated in Figure 2.

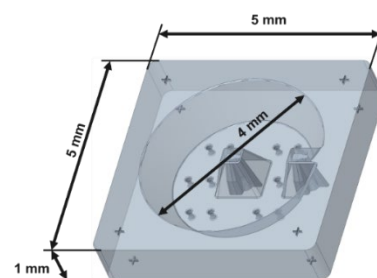


Fig. 2 Design of the acoustic chamber

A structured metallization layer is applied to the acoustic chamber, serving as electrical and thermal interface for the gain chip (see Fig. 3). The metallized through-glass vias enable current flow into the acoustic chamber and function as a heat sink.

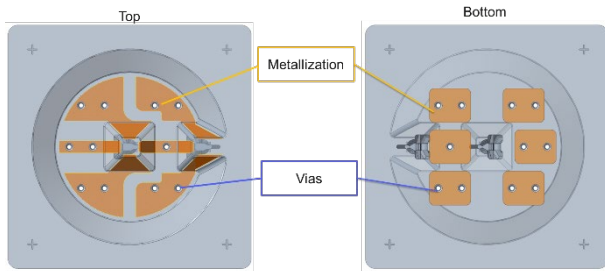


Fig. 3 Metallization of acoustic chamber

Electroplating is employed to metallize the selectively laser-etched structures. An example of a metallized test structure is presented in Figure 4.

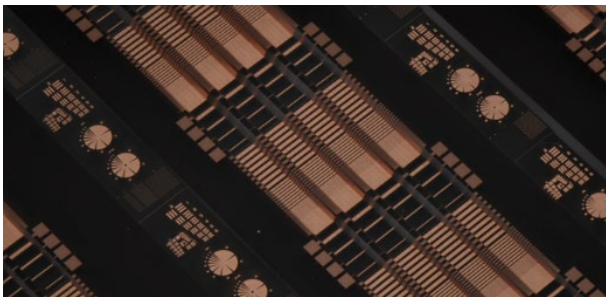


Fig. 4 Metallized SLE structures

In the optical interface design, a fiber is inserted from the backside of the glass substrate into the pillar (Fig. 5). To enhance the positioning accuracy of the fiber, a spring mechanism is employed to push the fiber into a V-groove. This approach allows for a precise alignment, achieving a separation of approximately 50 μm between the fiber facet and the gain chip. By minimizing this distance, optical coupling losses between these components are reduced.

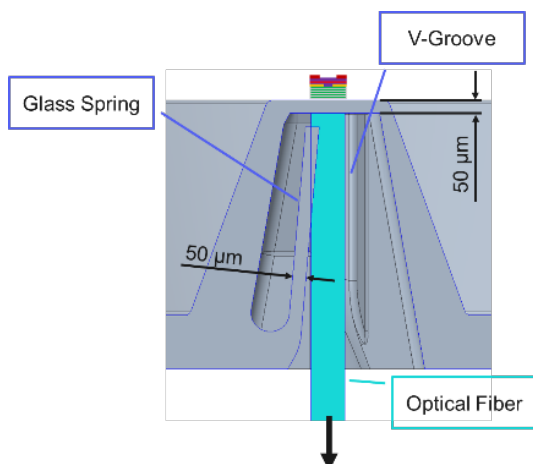


Fig. 5 Mechanical fiber interface with clamping spring inside the pillar

Figure 6 displays the manufactured acoustic chamber with the optical interface. An optical single-mode fiber is inserted at the back of the central pillar as shown in the cross-section on the right side of the figure. Due to the roughness of the etched glass surfaces, UV adhesive is applied to ensure index matching between the fiber facet and the glass surface.

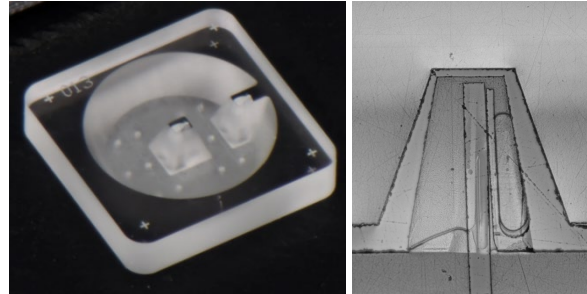


Fig. 6 Manufactured fused silica body of the acoustic chamber with its fiber clamp

4 Conclusions

In this study, we successfully fabricated an acoustic glass body for a miniaturized microphone using selective laser induced etching. Additionally, we integrated and tested a fiber clamp with promising results. The next steps involve applying metallization to the acoustic chamber and optimizing the mechanical fiber interface to prevent fiber tilting.

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