IPD-Glas (Into Surface Embedded Antenna)

Abstract

The IPD-GLAS project focuses on the further development of 3D glass structuring with SLE of 200 mm glass wafers, in particular in the application of Schott AF32eco and quartz glass wafers. To this end, the ILT has expanded the laser processing range and developed hatching and slicing approaches for complex-shaped channel structures. In addition to processes for processing very thin wafers and adapted beam parameters, the etching process for aluminum silicate glasses has also been improved. ISIT has further developed its aluminum melt filling process for long 3D channel structures. Demonstrators for 5G/6G front-end IPD are being realized with Fraunhofer IAF.

1. Introduction

Various competing technologies are known for the production of vertically aligned electrically conductive vias through wafer substrates, which are based either on the use of solders or electroplated copper for filling the vias. These processes require an additional bonding layer to achieve a bond between the substrate and the metallic feedthrough. This not only makes the manufacturing process significantly more complex and restricts their possibilities to purely vertical vias, but also leads to poorer high-frequency properties due to the skin effect, as the current concentrates in the surface, i.e. the less conductive bonding agent, as the frequency increases. Alternative manufacturing processes use glass-embedded pin vias made of highly conductive silicon or tungsten, both of which are less suitable for high-frequency and quantum technology applications.

The pressure filling of through-holes in dielectric substrates with an aluminum melt is a completely new technology. Channel structures with different geometries in terms of hole diameter, flank angle, channel inclination and channel length can be filled.

IPD-Glas has investigated the production of 3D structures in glass substrates by means of SLE laser processing and subsequent wet chemical etching as well as their aluminum melt filling for the production of passive electrical components at chip level.

The participating partner institutes have concentrated on important sub-aspects:

ISIT: Process development aluminum melt filling in fused silica chips
ILT: Process development SLE process for 3D structures and parameter study Eagle XG glass

IAF: Design of high-frequency filter structures to avoid cavity resonances in high-frequency split-block structures

2. Methodology

ILT Laser processing

The SLE process is a two-stage process for processing transparent dielectrics. First, the material is modified with ultrashort pulsed (USP) laser radiation. The modified material has an increased etching rate compared to the unmodified material and is removed by wet chemical etching in a second process step. This is followed by further processing steps if necessary, such as cleaning the component in an ultrasonic tank or post-processing using laser polishing.

Important laser parameters are the pulse energy, the repetition rate of the pulses, the pulse duration, the pulse overlap and the polarization of the laser radiation.

For the SLE process, 3D CAD models are converted into vectors. These vectors lie in planes perpendicular to the beam direction of the laser and are structured into the sample material. So-called slice vectors form the contour of the model and are generated at various positions in the z-direction of the model. Hatch vectors generate the so-called filling. The filling forms channels through which the etching fluid can flow during the etching process, thus exposing the component.

ISIT Melt filling

An induction coil with a diameter of 160mm was used in the setup, which made it possible to inductively heat a thick graphite heat spreader plate with a diameter of 200mm to up to 800°C. The graphite plate is thermally insulated and aligned horizontally with the press ram. The graphite plate is thermally insulated and aligned horizontally to the press plunger. The press plunger is closed to a certain pressure and the molten aluminum is pressed into the channels. The filling process takes place in <1 sec. and the wafer can be removed from the pressing device after a short cooling phase. A high-temperature foil ensures a seal between the wafer and the aluminum foil so that no melt can escape from the side. Depending on the structure being filled, the pressure and temperature holding time must be adjusted.

The process can currently be applied to fused silica, silicon and Schott AF32 glass. Due to the lower melting temperature of Schott BF33 glass, an aluminum-copper alloy has been developed that can be incorporated into hole structures using the same process.

3. Results

Aluminum melt filling

The quality assessment of the aluminum filling was carried out at ISIT using a 3D X-ray tomograph. Metallographic sections were also produced and the grain structure was visualized using a Baker etch.

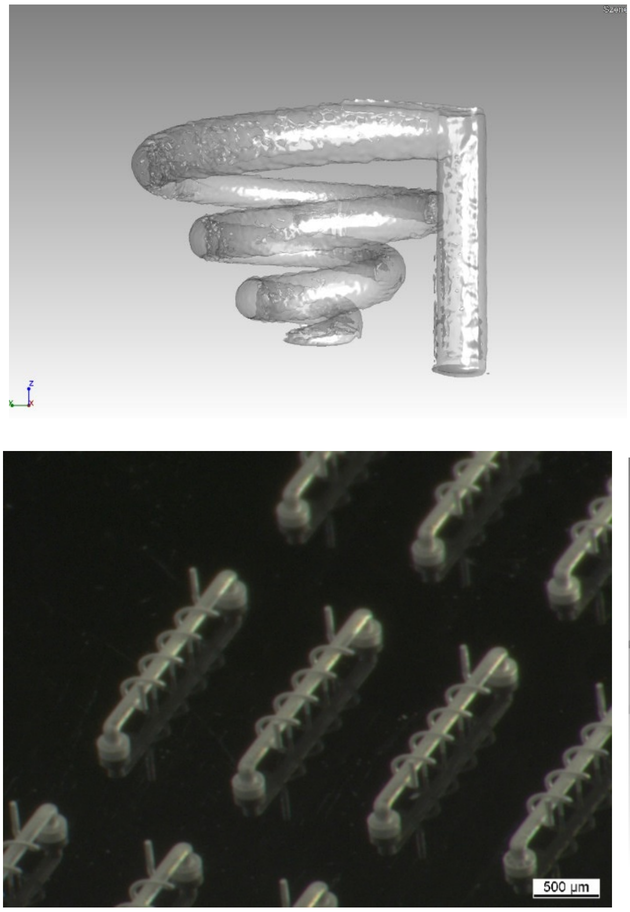

Figure 1: CT images of spiral and coil sample with unfilled fluid channel

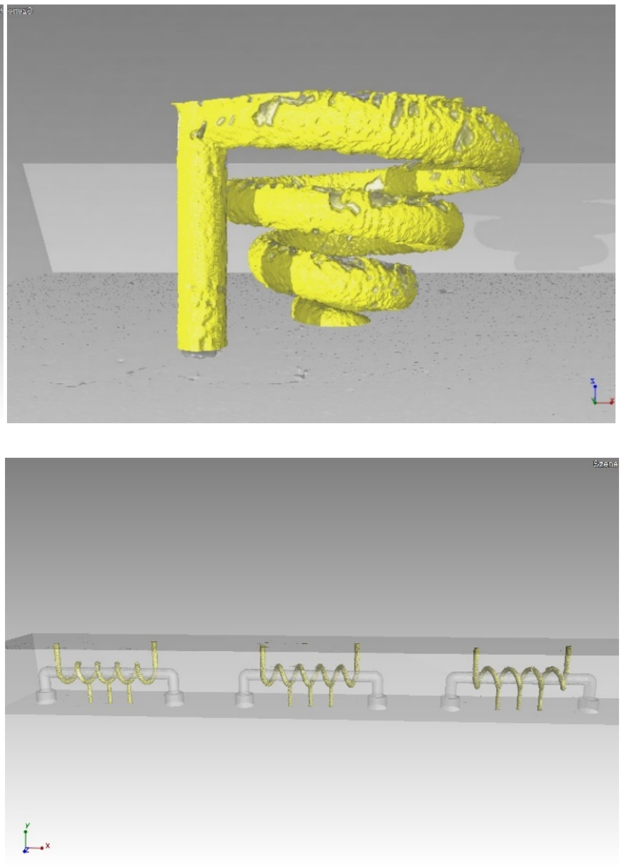

Figure 2: CT images of spiral and coil sample filled with AL. The fluid channel has openings to the opposite substrate side

The spiral with tap and the coil could be manufactured by Fraunhofer ILT and completely filled with aluminum by Fraunhofer ISIT. The filling was carried out on one side and the aluminum on the filling side was removed by grinding. The samples consisted of quartz glass with a thickness of 1.6 mm.

The yellow colored channels show the area that was filled with aluminum. It is noticeable that the channel walls are very rough after wet chemical etching, but this did not prevent the molten metal from being introduced. Air inclusions, which lead to interruption of a channel, could not be detected. For filling very long channels (60µm Ø) of 6mm, as in the coil sample, 30µm taps were provided, which made it possible for air to escape.

In addition to filling 3D structures in glass, work also continued on filling through-holes from the previous CAPS Insurf project.

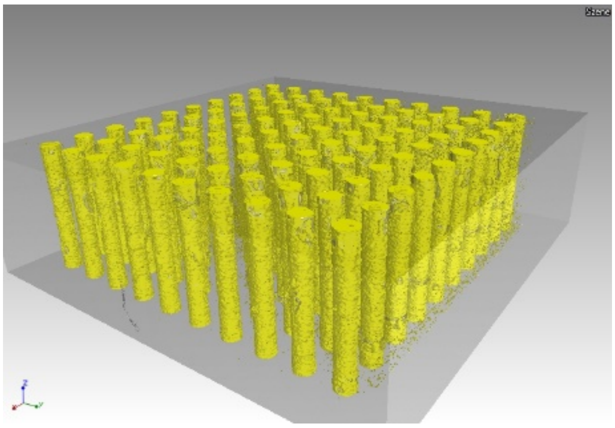

Figure 3: CT image of filled test coupon with 60µm vias at a pitch of 120µm

4. Applications

- Quantum technologies
- High frequency applications
- 2.5D technology
- MEMS

5. Conclusion

In the IPD-Glass project, it was successfully demonstrated that it is possible to produce complex 3D structures in quartz glass using the SLE process and to fill them completely with aluminum. The ILT was able to successfully develop parameters for laser processing and etching the samples. Only the high roughness of the channel walls and the cleaning of the long channels after etching need to be investigated further in order to enable more homogeneous filling.

The melt filling developed by Fraunhofer ISIT was also successfully demonstrated. Homogeneous fillings of channel lengths up to 6mm with a diameter of 60µm were achieved. In the future, further work must be done on the surface conditioning of the filled wafers to enable further processing in the clean room.

6. List of references

Ahmed, O., Okoro, C., Pollard, S. and Jiang, T. (2021), "The effect of materials and design on the reliability of through-glass vias for 2.5 D integrated circuits: a numerical study", Multidiscipline Modeling in Materials and Structures, Vol. 17 No. 2, pp. 451-464. https://doi.org/10.1108/MMMS-05-2020-0125

Dow, Wei-Ping. "Microvia and through-Hole Filling By Electroplating for Electronic Circuit Fabrication." Electrochemical Society Meeting Abstracts 227. No. 15. The Electrochemical Society, Inc., 2015.