

High temperature micro forming of inorganic glass - an effective replication method

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Abstract

Glass is a commonly used material in the MEMS technology. Applications range from usage in the optical data transmission, MOEMS, applications in the micro-fluid analysis and bioengineering, packaging for housing and as insulating substrate for bonding. Functional structures are mostly applied in array arrangements on the glass wafer following other wafer level processes of the micro system technology. Beneath the numerous possibilities to structure glass at the surface, high temperature micro forming is one of the economically most favourable processes [1] [2], in particular for the manufacturing of higher quantities with high surface quality.

With this technology it is possible to mould functional structures directly into bondable borosilicate glass. Former research results from within this research group on structuring of fluoride glasses [3] had shown the possibility of micro-structuring the material glass by moulding. After improving the equipment technology with respect to achievable forming temperatures up to 800 °C, isothermal tempering and accurate controlling of the load transmission, the possibility to microstructure glass wafers of Pyrex®7740 and other borosilicate glasses is proven within a suitable process window.

1 Experimental equipment

A process chamber, integrated into a precision press equipment, is used for high-temperature micro-forming at the Fraunhofer IWU. For accurate moulding of microstructures on a flat substrate the press is equipped with four spindles and four synchronized servo-drives which realize positioning and load transmission. With this

system a precise, isothermal tempering can be ensured at forming temperatures up to 1000°C, separately adjustable for upper and lower die with a deviation of 1 Kelvin. At the same time, embossing forces up to 50kN on a pressing area of 50mm in diameter can be applied with the test equipment. To avoid oxidation as well as to assure a complete form filling of the microstructures, it is possible to work either within the fine vacuum range or under an inert gas atmosphere.

Accompanying the process development at the Fraunhofer IWU a industrial scale plant for the high temperature micro forming in a production environment was developed together with partner companies. This hot embossing equipment distributed under the label "MicroShape 100" also comprises a complete handling system [4] and therefore is suitable for an automated production (Figure 1).

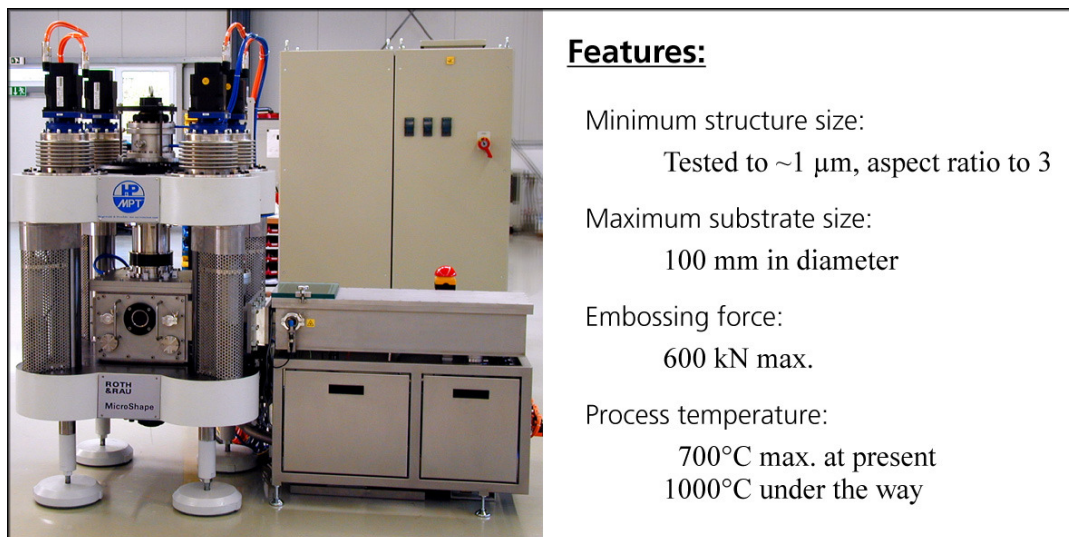


Figure 1: High temperature micro forming equipment “MicroShape 100”

2 Forming dies

The research group has investigated in different high temperature-forming metals (nickel-base alloys, molybdenum alloys), ceramic tool materials (silicon carbide, aluminum nitride) as well as silicon as tool materials for the micro-structuring of inorganic glasses. The metallic high-temperature alloys are characterized by a good thermal diffusivity and toughness and can be structured by means of high precision chipping or by eroding at Fraunhofer IWU. However there still exists a need for optimization in order to realize very small structures below 50μm. So far no surface qualities for

optical applications were reached. Nevertheless, for applications in electronic packaging and micro fluidics these processes offer an optimal solution.

Structured silicon as tool material appears promising due to its very good micro-structuring possibility and high hardness. A further advantage is the excellent surface quality and small surface roughness. In order to avoid an adhering of the tool to the substrate during demolding, however a coating of the tool is inevitable.

3 Embossing results

Following preliminary tests to confine the process window, experiments using a wet-etched silicon tool for structuring were accomplished. The moulding results show an accurate replication of the microstructure in the bottom of the embossed pattern. Both formation of the mould as well as the quality of the surface and work piece edges correspond to the requirements of functional structures of the micro system technology. A blurred transition from the structure to the ground level of the wafer requires still further process optimization, but with optimal moulding parameters a isogonal replication should be possible. There could not be determined any impediment to moulding of significant smaller structures in principle. This is revealed by the exact replication of smallest structures of the tool with a height of below one Micron.

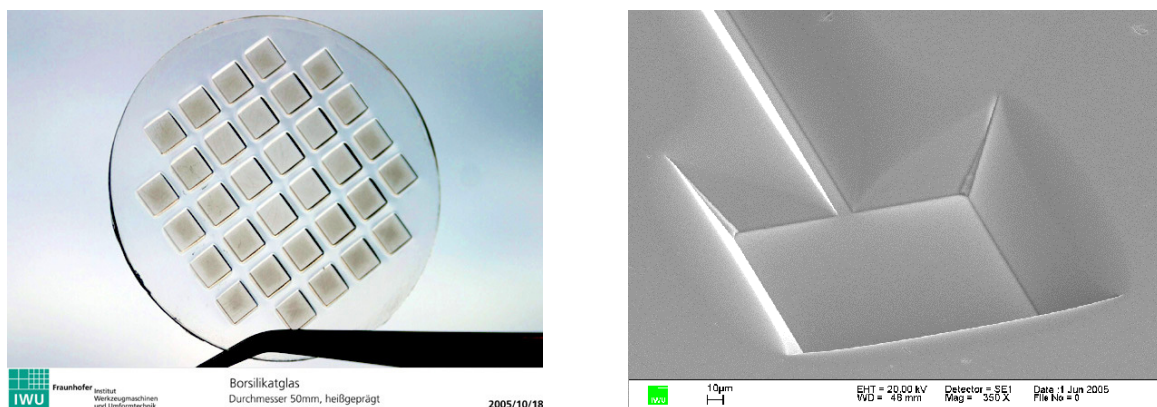


Figure 2: High temperature formed borosilicate glass wafer with an array pattern and detail of a fluidic micro structure moulded with a silicon tool into the same glass material (SEM picture).

During repeatability experiments problems with adhesion of the silicon tool to the glass arose at corners and edges of the microstructure. Due to this phenomena

breakouts of the tool structure could be determined. This is attributed to an insufficient covering of the structure with coating material in the region of atomically sharp edges and undercuts originating in the etching process of the tool. An improved manufacturing process and coating of the tool should eliminate these problems.

4 Conclusions

With the technology of the high-temperature micro-forming it is possible to mold functional structures of the micro system technology directly into inorganic glasses. After improving the equipment technology of hot embossing with respect to achievable forming temperatures, isothermal tempering and accurate controlling of the load transmission, the possibility to micro-structure glass wafers of Pyrex®7740 could be proven within a suitable process window.

Concerning the form filling of the structures a further optimization of the process parameters is necessary. The sharpness of edges of the molded structures permits the conclusion that highest accuracies can be achieved comparable to optical quality. For this purpose, however, also the molding tools must achieve optical quality regarding surface roughness. Also an improvement of the coating is necessary, in order to minimize the wear of the tools. The experiments nevertheless show the high potential of the technology.

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