Precision Glass Molding of Wafer Lens Optics

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Abstract

Nowadays, micro optical components and systems are frequently used in consumer electronics, laser, life science or biotechnology applications, such as mobile phone camera modules, sensor systems and endoscopes. Due to the demands of ongoing miniaturization as well as the continuously growing quantities in the optics manufacturing, precision molding of such optics in wafer scale is an optimal solution, which can keep the production costs and handling efforts of these optics as low as possible. Although there is already a wide range of applications of polymer micro optics on wafer scale, advantages of using such ultra precise optical components made of glass instead of polymer are un-ignorable – such as their resistance against environmental impact and reflow soldering processes, their biocompatibility and their capability of being used in high power applications. However, engineers encounter several difficulties during the technology development of a suitable and reliable molding process, mainly due to the lack of understanding about the molding process of such complex wafer optics.

In this work, further discussions on development of mould design and molding phase of the process are mentioned based on previous work.

1 Molding process simulation

1.1 Systematic simulation procedure

In precision glass molding (PGM) process, the glass raw material is initially heated to a temperature between its transition- and softening point temperature and subsequently pressed into a lens shape; Then, this lens shaped glass is cooled in two steps with different controlled cooling rates; And finally, the lens is taken out from the molds and cooled naturally to the room temperature.

It has been proved in the previous work[1] that FEM process simulation can help the mould- and process design by predicting the global pitch error and local form error of each single lens cavity on the wafer, as well as the thickness of the glass disc preform. However, such 3D simulation itself is very time consuming due to manual preparation of its FE model, unstable calculation because of its large model size, and complex result analysis of pitch-/shape-/tilt-/decenter error. Therefore, it is highly demanded that the input information of such 3D simulation, such as mould design, molding process parameter, glass perform geometry should be as optimized as possible. Based on such requirement, a systematic design procedure for this type of process simulation has been developed in this work (see Figure 1). Following such procedure, a wide range of mould- und process design varieties can be evaluated, such as the arrangement of upper- and lower moulds, the avoidance of undesired glass material flow, the shape of the “glass flow reservoirs” which can assist glass material flow during molding and the enhancement of the process stability, so that only few iterations of the 3D wafer simulations for those error compensations mentioned above are required, which can largely increase the whole process simulation efficiency.

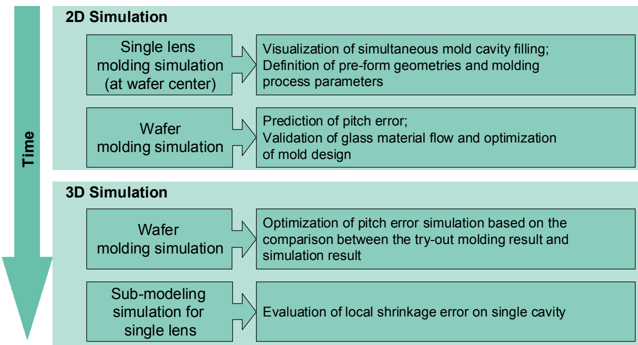

Figure 1: Procedure of the process simulations for molding of glass wafer optics

Besides the benefit of gaining simulation efficiency by implementing the above procedure, problems such as undesired glass material flow can also be discovered in an early design stage, such as shown in **Error! Reference source not found.**, where the middle thickness of glass disc preform is optimized and suitable glass flow reservoirs on moulds are built up in order to avoid the unexpected material self-overlapping and incomplete filling problems.

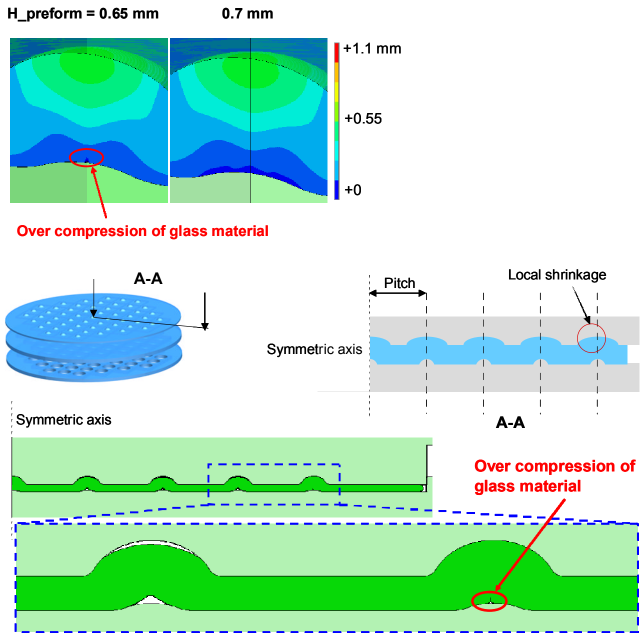

Figure 2: 2D simplified single lens- and wafer molding simulation for validation of glass material flow

1.2 Simulation accuracy

In this work, a validation of the predicted pitch error is carried out with another wafer provided by industrial partner. A molding process of a Ø100 mm glass wafer is simulated and the pitch errors are compared with the experimental result. Figure 3 shows that the predicted accuracy of the pitch errors from simulation are above 80%.

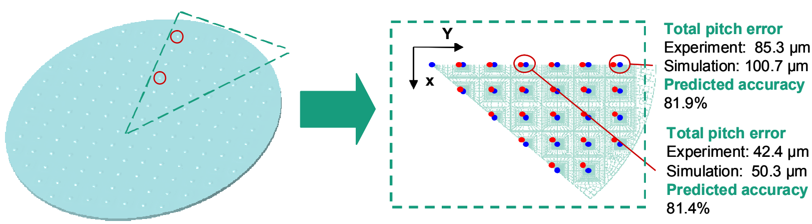

Figure 3: Accuracy of simulation predicted pitch errors in comparison with the ones from experiment

2 Molding of glass wafer

Apart from the molding of single optic lens, one of the major challenges in molding of glass wafer optics is the alignment of the upper and lower mould die in order to guarantee the centricity of the optical surfaces. And this is very important for the stacking and dizing of integrated optical system. Another important issue is the scale effects that affect the tooling layout and process setup. The high amount of shrinkage can only be tolerated to a certain amount. This points out the need for an adapted molding process and the development of mold materials with thermal expansion properties matching those of optical glasses. Furthermore, when the lens cavities on the wafer are filled and the thickness of the wafer has to be reduced further, shear flow towards the outer edges over the entire mold surface is required. Due to the greater lateral dimensions of wafer molds, in order to achieve the same deformation rate compared to a single lens, much higher molding force and lower viscosity of molded glass are required. As the suitable process window is limited, the key to accurate center thickness, short process times and an overall robust process is an intelligent design of moulds and glass preform, with the help of reliable process simulation results.

3 Conclusion

The newly established process simulation procedure for molding of wafer scaled optics can largely increase the efficiency and capability of mould- and process design. The simulation based pitch correction is verified on the experimental results.

There are still many issues remained in the molding process development which prevents the wafer molding process from introduced into mass production. The challenges of overcome these issues can be addressed at a reliable process simulation system based on continuously gained experience of the process technology and accurate material models.

References:

[1] F. Klocke, Y. Wang, F. Wang, G. Liu, D. Hollstegge, O. Dambon and A. Y. Yi, “3D Process Simulation for Precision Glass Molding of Freeform and Wafer Optics”, Proceedings of the 11th Euspen International Conference, Italy, Vol 2, pp 132-135, 2011.