Precision Glass molding for diffractive optics

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Abstract: We proposed a comprehensive technical scheme addressing the fabrication limitation of diamond turning, coating stability and adhesion problem during molding process,to realize high performance of diffractive optics.
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Diffractive optics have already drawn attention of scientists in space telescope field due to its excellent advantages, such as thin size, ultra-light weight, and capability to eliminate chromatic aberration [1,2]. Glass materials have superiorities over polymers concerning optical performance, mechanical strength, thermal expansion, as well as chemical resistance [3]. However, to fabricate diffractive glass optics with high quality in micrometer size is still challenging [4]. In this presentation, we propose a comprehensive fabrication scheme including mold fabrication, mold coating, precision glass molding, and molding simulation to obtain molded diffractive glass optics with high performance.

Considering the fabrication challenges, the proposed technical scheme aims to address the fabrication limitation of single point diamond turning (SPDT), mold coating stability and adhesion problem during molding process. Firstly, CuNi is selected as mold substrate, since CuNi is a non-ferrous alloy, diamond machining can be used to directly cut this material. Secondly, NiP is chosen as the coating layer since it has excellent cutting property and potential superior anti-sticking ability. Since CuNi has similar thermal expansion coefficient with NiP, the thermal stability of the coating could be guaranteed. Besides, compared with coating deposited on accurate mold routine, where a coating with a thickness between 10 nm and 200 nm would cause a noticeable deviation on mold features [5], another advantage for direct SPDT on NiP coating is that exact accurate diffractive profile can be further achieved. This is more suitable to obtain high resolution, high aspect ratio (depth/width) or complex microstructures. More importantly, glass molding simulation is implemented to predict the molding process, in order to find the most appropriate process parameters and solve the potential molding problems prior to real molding.

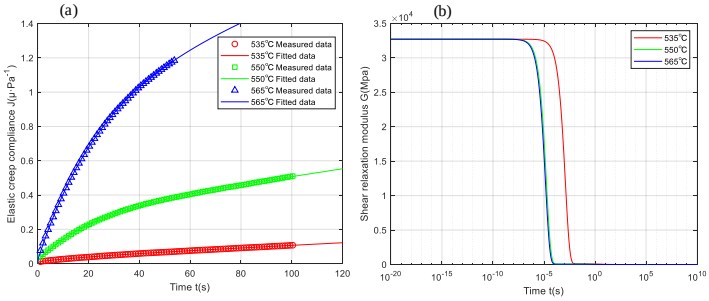

Figure 1. a) Creep compliance fitting and b) calculated shear relaxation modulus curve at different temperature.

Before simulation, L-BSL7 glass cylinder with 10mm in height and 14mm in diameter is used to perform the uniaxial creep compression experiments at temperature 535℃, 550℃, and 565℃ to have glass viscoelasticity and thermal-simplicity data [6,7], as shown in Fig. 1(a) and (b). With the acquired viscoelastic data, the simulation of molding process is implemented in Abaqus or MSC.Marc, as presented in Fig. 2(a), to validate the feasibility of mold surface compensation and determine the best molding parameters. According to the simulation results, a set of appropriate process parameters with 550℃ molding temperature and 500N compressive force is selected for real molding. Meanwhile, other molding parameters during the annealing process such as cooling rate are optimized with help of simulation.

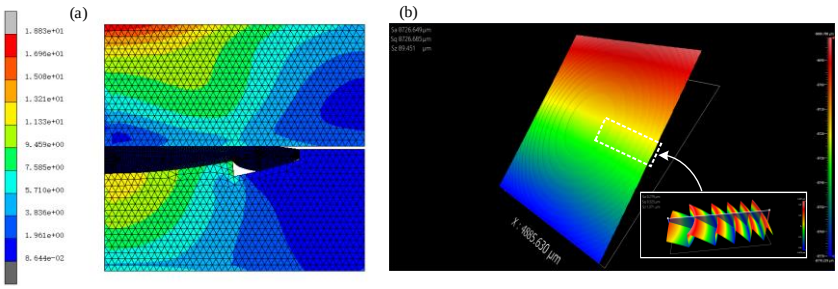

Figure 2. a) Precision glass molding simulation and b) molded diffractive structure on optical glass L-BSL7.

With the appropriate molding process parameters, the precision glass molding is performed. As expected, the diffractive optics molding is successful, and the molded glass surface are scanned with a large area by interferometer as shown in Fig. 2(b). In order to have detailed information of the molded diffractive surface, a segment with 800umx400um in size is taken out for surface finish and profile accuracy study, as illustrated in the left bottom side of Fig. 2(b). According to the testing result, diffactive optics with high quality of 2nm in rms and about 50 nm peak-to-valley surface variation is acquired by the proposed method.

Besides, in order to know the chemical stability of NiP coating, EDS are used to do the chemical component analysis of the coating and molded glass. According to EDS testing result, there is not chemical diffusion between L-BSL7glass and NiP coating after molding. This indicates the chemical property of NiP in our application is quite stable, which could also explain the high surface quality of molded glass due to no adhesion occurring (no chemical component diffusion).

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