Development of sub-wavelength structure optics by injection molding process

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The utilization of nanostructures in surface engineering holds great potential for enabling additional functionalities in optical devices, such as anti-reflection and a wire grid polarizers, wetting control of hydrophilic and hydrophobic and structure bonding. To incorporate the nanostructure into the manufactured part, the technology development for precision fabrication process is very important in plastics replication process.

In the case of nanostructure transfer by injection molding, the mold temperature needs to exceed melting point of the polymer. Consequently, achieving precise shape accuracy becomes a challenging specification. Addressing these limitations is essential to enable industrial applications, particularly for optical lens elements. To resolve these requirements, we have developed a specially designed mold with thermal insulation layer to allow the nanostructure transfer process as shown in Fig.1[1]. By utilizing a mold with a thermal insulation layer during the nanostructure transfer process, the temperature of the mould was evaluated to be 20 ˚C lower than that of a conventional mould as shown in fig.2. In addition, as the mold temperature was lower than glass transition temperature (Tg), the both properties with very precise shape and high filling rates within the nanostructure are obtained. The precise shape accuracy was 6 times higher than that of a conventional mold as shown in fig.3.

In the part of the nanostructure formation on the mold, we have developed structure fabrication process using self-organization of metallic nanoparticles. This process allows the nanostructure formation on the freeform surface such as lens shape, flow path shape and so on. Using the mold with nanostructure by self-organization method, we successfully developed subwavelength antireflection structures on lens surfaces as shown in fig.4. By combining with self-organization of metallic nanoparticles and mold with thermal insulation layer, an optical lens with a transferred nanostructure exhibited low antireflection of less than 0.5 % and precise shape accuracy of 0.5 μm at a diameter of 5 mm. Additionally, the hydrophilic structure coating enabled anti-fogging properties for long-term usage. We believe that these specifications are sufficient for an optical imaging lens. We suggest that these characteristics are expected to be applied to automotive panels that require high visibility and anti-fogging properties.

In another approach to fabricating nanostructure on the mold, we have developed nanoimprinting lithography specifically for the injection molding process. We have fabricated mold with nano scale line & space pattern for injection molding for wire grid type polarizers(WGP)[2]. The WGP can be produced by injection molding process. In this presentation, we will present a nanoimprinting process with specially designed mold with thermal insulation layer. Additionally, we will discuss optical device such as anti-reflection and WGP.

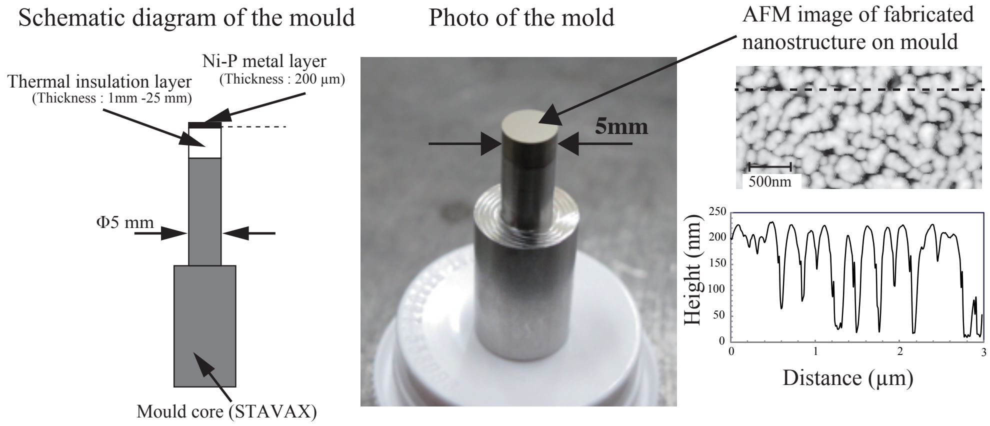

Figure 1 Schematic diagram and photo of the mold with thermal insulation layer.

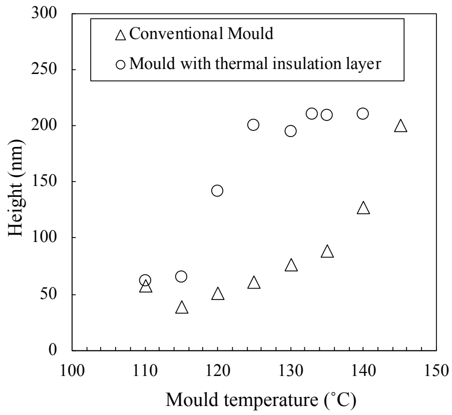

Figure 2 Variation in nanostructure height with change in mould temperature.

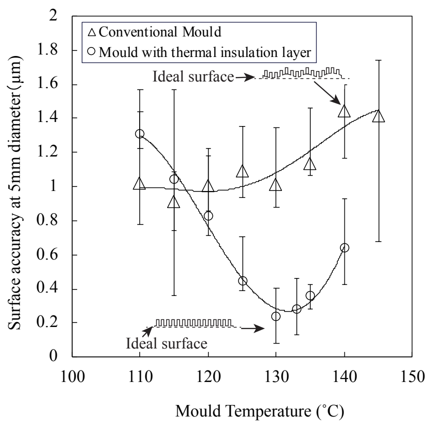

Figure 3 Variations of surface profile accuracy with change in mould temperature.

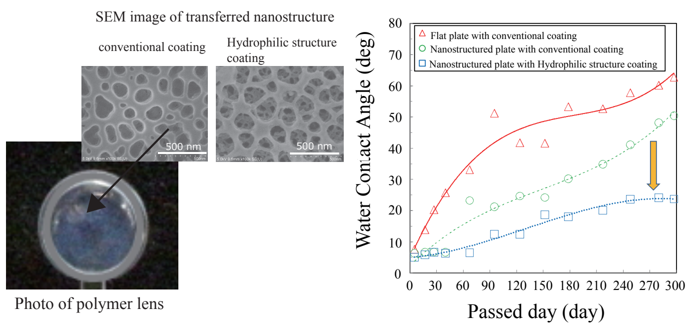

Figure 4 photo of the subwavelength antireflection structure with anti-fogging properties

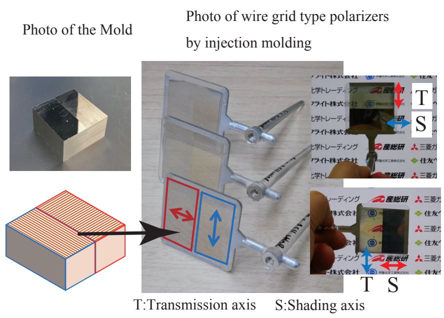

Figure 5 photo of the wire grid type polarizers by injection molding process.

References

[1] Kurihara and K. Hokari, et al "Precise Shape Nano-Replication for an Antireflective Imaging Lens Using a T Mould With a Thermal Insulation Layer". Microelectron. Eng. 217 (2019).

[2] Hokari R, Kuwano G and Kazuma Kurihara et al, "Wire-grid polarizer sheet with low reflectance in the visible and near-infrared regions fabricated by a nanoimprinting and electroless plating process," Opt. Express **30**, 45583-45591 (2022)