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Design and Development of Glass Array Aspherical Lens Using Glass Molding Press

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Abstract: - The glass molding press (G-M-P) process was applied in manufacturing the glass array aspherical lens. Instead of lithography process that required high production cost and that is capable of forming aspherical shape but incapable of forming high order aspherical shape. To obtain high order aspherical shape, mold core manufactured by using ultra-precision machine. As to the machined mold core and glass array lens was measured by Form TalySurf PGI 2+ contact stylus profilometer. The measurement data of mold core were suitable for below 0.15 um which was the design criterion. In addition, glass array lens were suitable for below 0.8 um. Also, by achieving the high order aspherical shape, the coupling efficiency could be further increased than the existing array lens and high productivity and low cost could be achieved through the molding process.

Keywords: *Glass, Array lens, Aspherical, Glass molding, Ultra-precision machining*

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I. INTRODUCTION

Recently, an increase in multimedia content such as UCC(User Created Contents) and Twitter, as well as in applications such as utility computers that demand high bandwidth, and the advent of the virtual data center, have increased bandwidth demands from next-generation broadband service. The 40G/100G Ethernet technique has been suggested as a long-term solution. Meanwhile, the network evolution to 40G/100G Ethernet is has started all around the world. The development of technologies and parts for light-weight integration and high- speed transfer of large amounts of data is ongoing, and the demand and market potential is tremendous. While array lenses made of plastic are widely available, those made of highly refractive glass are still rare. Plastic array lens are cheap to manufacture; however, plastic is not resistant to high temperature and moisture. Optical glass represents a better solution but is a more expensive alternative. Glass array lens can be produced using lithography or precision molding techniques. The lithography process is commonly used, for instance, in the semiconductor industry. However, the manufacturing costs are high, the processing time is quite long, and spherical aberration is a problem [1-2]. This limits the technique to the production of small quantities. Mass production calls for a different approach. Precision glass molding process is adopted for mass production of aspheric lens, glass array lens and diffractive optical elements which are difficult to be manufactured by conventional methods. Figure 1.1 shows the schematic diagram of the proposed glass molding process. In this paper, we fabricated glass array aspherical lens using the process of glass molding press with precision pin core type mold. The manufactured glass array aspherical lens was analyzed using Form TalySurf PGI 2+ contact stylus profilometer.

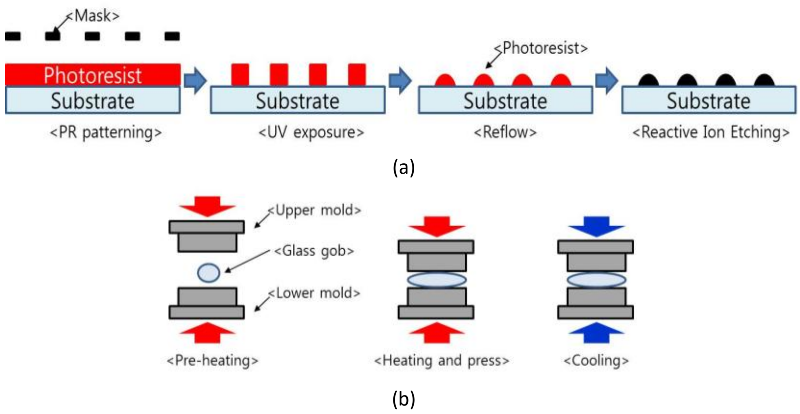


Fig. 1.1 Schematic diagram of the proposed glass molding process. (a) Photo-lithography (b) Glass molding press

II. EXPERIMENT METHOD (MANUFACTURING MOLD CORE AND FORMING THE MOLD)

The glass molding press (G-M-P) process is a high temperature/high pressure process in which the mold and mold core are made of binder-less tungsten carbide, which shows high strength at high temperature and has Co content below 0.5%. To obtain high order aspherical shape, mold core manufacturing is conducted through ultra-precision grinding machining. In this paper, a pin core type mold core was manufactured using an ultra-precision machine for 4X1 glass array lens molding. The ultra-precision machine is consist of a V-V roller guide, linear motor drive(X, Z axis) and aerostatic bearing spins for fixing a structure. Two guide surfaces are driven to the orthogonal shape of the X axis and Z axis. The wheel was actuated by the linear scale feedback system with 1 nm positioning resolution in the X, Y and Z-axis. The wheel air spindle and the workpiece air spindle were an air-bearing spindle.

Among the aspherical grinding types, cross-grinding is usually used because of its superior ground surface. However, some aspherical shape such as a small concave mold core or a small radius mold core must be used for slanted grinding [3-4]. In this paper, slanted grinding was applied to the small concave type mold core process. As with other machining processes, it is possible theoretically to predict an 'ideal' surface roughness for grinding by modeling how the abrasive cutting points on the rotating wheel kinematically interact with the workpiece. For this purpose, the surface texture is assumed to be generated by clean cutting, whereby the cutting edges remove all material that they encounter in their paths, leaving behind the resulting cutting grooves. For machining processes with well-defined cutting-tool geometry, including turning and milling, the analysis is straightforward. The 'ideal' roughness is usually found to be less than the actual roughness due to such factors as material sideflow, build-up-edge phenomena, and vibrations. The ideal longitudinal surface profile generated by straight surface grinding with such a wheel, as illustrated in figure 2.1, consists of successive identical scallops each with a radius of curvature corresponding to that of the cutting path. For practical grinding situations with the workpiece velocity Vw much less than the wheel velocity Vs that the radius of the trochoidal path for straight surface grinding can be approximated by the wheel radius (Dw/2). Analogous to plain horizontal milling which would give the same profile geometry, the spacing between successive scallops along the workpiece is the feed per cutting point Sc which is given by [5]

$$S_c = \frac{V_w L}{V_s}, \qquad (1)$$

For the profile in figure 3.4, the peak-to-valley roughness is

$$R_t = \frac{S_c^{\,2}}{4 \cdot D_w}, \qquad (2)$$

Which combined with Eq. (1) leads to

$$R_t = \frac{1}{4} \cdot \left(\frac{V_w \cdot L}{V_s \cdot D_w^{1/2}} \right)^2, \qquad (3)$$

The arithmetic average roughness for this profile is

$$R_a = \frac{1}{9\sqrt{3}} \cdot \left(\frac{V_w \cdot L}{V_s \cdot D_w^{1/2}} \right)^2, \qquad (4)$$

Optimization of machining parameters improves not only the efficiency of machining, but also the product quality. In addition, we should estimate the surface roughness and surface damage using experimental data.

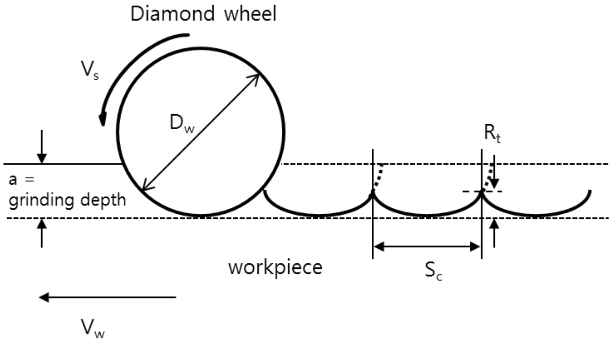


Fig. 2.1 Ideal longitudinal surface profile.

In this study, we investigated experimental parameters for process optimization in order to improve product quality and increase productivity for reducing machining cost. The optimal process conditions are specified in Table 2.1.

Table 2.1 The optimal grinding condition

Item	Cutting condition
Grinding method	Slanted grinding
Wheel mesh	#400, #2500
Wheel diameter (㎜)	Ø 1
Turbine speed (rpm)	70,000 / 65,000
Feed rate (㎜/min)	2, 0.5
Depth of cut (㎛)	1, 0.2
Grinding fluid	Water 95%, Rust preventive oil 5%

III. RESULTS AND OBSERVATIONS (GLASS ARRAY LENS MOLDING)

If the existing optical mold structure is applied to glass array lens molding, effective lens molding is not possible. Thus, as shown in Figure 3.1, a lower holder was manufactured to insert multiple pin cores at the same time, and a groove in a spherical shape was created at the mold core center to stably place the glass gob.

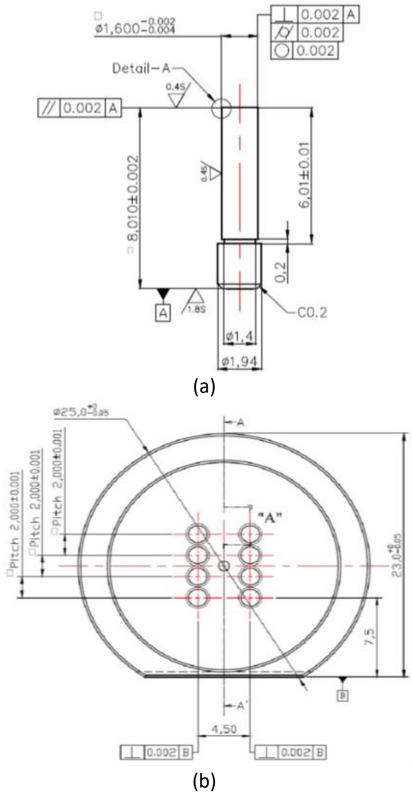


Fig. 3.1 Pin core type mold core and lower holder. (a) Pin core type mold core (b) Lower holder

Figure 3.2 is the final mold assembly diagram. The glass array lens molding consists of a stop ring for adjusting the height of glass array lens, an upper mold, eight pin cores in a high order aspherical shape, and a lower mold that enables assembling the pin cores in a regular pitch interval. In order to solve the problem of overflow due to a large volume of glass material or mis-molding due to small volume during high temperature/high pressure molding, the glass material of a calculated volume was inserted between the upper/lower mold, and mold designing was conducted in the structure considering the precision of the upper and lower mold cores in order to ease the taking-out after molding [6-7].

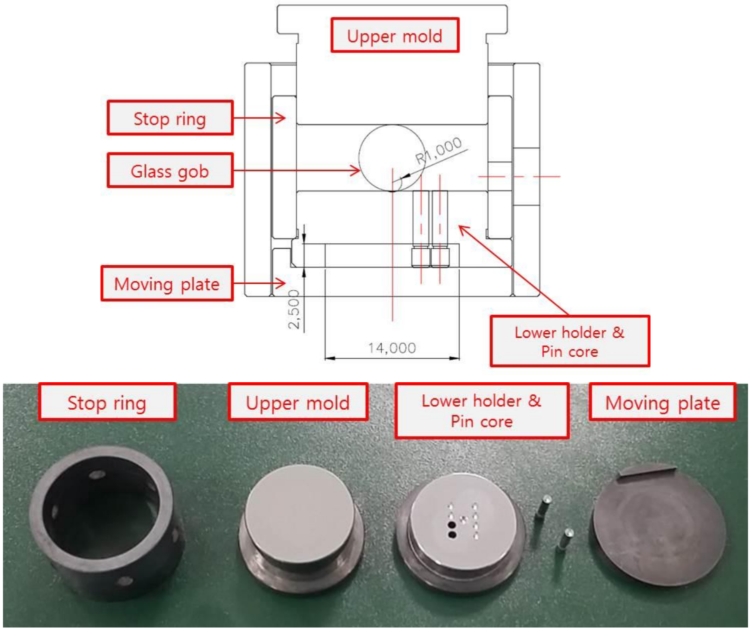
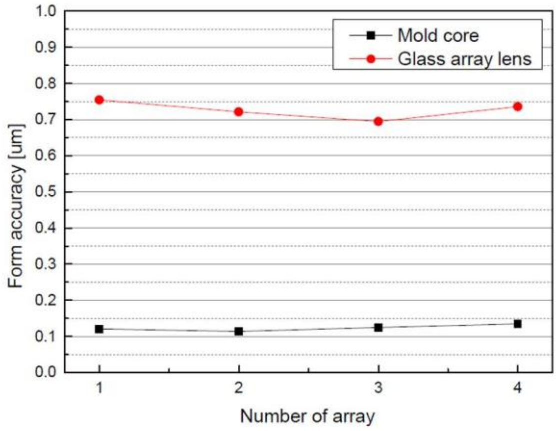


Fig. 3.2 Mold assembly for glass array lens molding press process.

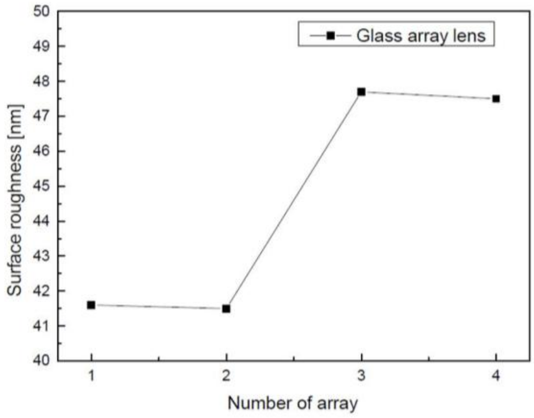
For accurate positioning, stable coupling, and homogeneous molding and cooling temperatures, the molding process was conducted by considering the influence of several governing factors including the mold structure, self-weight, positioning, and lens precision resulting from mold core transformation [8]. In array lens molding, the degree of mold deformation was analyzed using FEM (finite element method) analysis on the deformation of the mold core to be molded, and the analysis result was reflected in the design. Because the physical property of the mold core is that it returns to the original position through deformation, the lens shapes precision according to the molding pressure. The glass array lens molded using the optimal molding condition is shown in Figure 3.3. Precision molding allows for cost-efficient mass production of optical components. In this, a special glass is heated to a temperature at which it reaches a certain viscosity that makes it deformable.

Fig. 3.3 4×1 Glass array lens.

At this point, the glass is pressed into the final shape and gradually allowed to cool down. Correction thermal management of the cooling step is essential for ensuring the accuracy of the optical element. Furthermore, anti-reflective or filter coatings are often applied to these optical components.



(a)



(b)

Fig. 3.4 Measurement results of mold core and glass array lens. (a) Form accuracy (b) Surface roughness

As to the machined mold core, the shape precision of the aspherical shape was measured using Form Talysurf PGI 2+, a contact stylus profilometer. The measurement result is shown in Figure 3.4, which indicates a shape precision of P-V < 0.15 um. The manufactured mold for glass array lens molding was molded by using low melting optical glass and glass molding press (G-M-P). The shape precision of glass array lens measured using a contact stylus profilometer was P-V < 0.8 um. In addition the surface roughness of glass array lens was Rmax below 50 nm. The precision of the glass array lens pitch measured using a measuring microscope was 2.0 ± 0.001 ㎜. Measurement results of 5 glass array lens pitch accuracy are in Table 3.1.

Table 3.1 Measurement results of 5 glass array lens pitch accuracy

# of sample	Pitch 1[㎜]	Pitch 2[㎜]	Pitch 3[㎜]
1	1.9996	1.9995	2.0007
2	2.0009	2.001	1.9997
3	1.9992	1.999	1.9995
4	2.0004	1.9994	2.0002
5	2.0008	2.0005	1.9990

IV. CONCLUSION

In this study, a glass array lens applicable in mass optical information transmission for 40G/100G Ethernet was manufactured. Instead of lithography that entails high production costs and is capable of forming aspherical shape but incapable of forming high order aspherical shape, a molding method with low production cost and short process time was developed to manufacture the glass array lens. To achieve high temperature/high pressure glass molding press (G-M-P) molding and high order aspherical shape, a tungsten carbide mold and mold core which show high strength and less deformation at high temperature/high pressure were designed and manufactured. It was possible to manufacture a glass array lens by using an ultra-precision machine that can control spherical aberration through high order aspherical shape mold core manufacturing. Also, by achieving the high order aspherical shape, the coupling efficiency was further increased than of existing array lens and high productivity and low costs could be achieved through the proposed molding process. Finally, the shape precision and surface roughness characteristics of the molded glass array lens were analyzed to evaluate the possibility of employing the present molding processes in manufacturing glass array lenses.

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