휴대폰 카메라용 비구면 Glass렌즈 전사특성 분석

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Transcription Characteristics in the Molding of Aspheric Glass Lenses for Camera Phone Module

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Abstract

The transcription characteristics in the molding of aspheric glass lenses for camera phone modules have been investigated experimentally. The surface topographies of both the form and the roughness were compared between the mold and the molded lens. The molded lens showed a transcription ratio of 93.4%, which is obtained by comparing the form accuracy (PV) values of the mold and the molded lens. The transcription of the roughness topography was ascertained by bearing ratio analysis.

Key Words : Aspheric glass lens, Glass molding press (GMP), Bearing ratio analysis, Surface topography

1. Introduction

Aspheric glass lenses offer many optical advantages, including superior optical performance and reduced optical aberrations. The key process used for aspheric glass lens fabrication in conventional lens manufacturing is polishing. Magnetorheological finishing (MRF) and precision polishing are two automatic polishing methods that are commercially available. Due to the complexity of these processes and the long cycle times involved, the overall costs for medium- to high-volume productions of aspheric lenses are very high [1-3].

The use of a glass molding press (GMP) has recently become an attractive approach alternative to the traditional glass lens manufacturing process. This hot-forming compression method has many advantages. For instance, it is a simpler process than polishing and lenses can be pressed into shape without requiring the usual subsequent finishing operations. Finally, it allows the fabrication of aspheric glass lenses that cannot be created using traditional method – polishing.

The GMP method has resulted in the mass production of aspheric glass lenses being possible. Thus, in cases where the process parameters are properly designed, the GMP method is considered to be one of the most reliable methods for the fabrication of aspheric glass lenses.

However, due to the extremely high hardness (R_c>90) of popular mold materials such as tungsten carbide (WC) and silicon carbide (SiC), the grinding process used to fabricate such molds becomes expensive. In addition, it is sometimes difficult to control the many parameters of the molding process (e.g., the pressing force, cooling rate, and cooling range, etc.). To optimize the process parameters on GMP process, it is necessary to verify the transcription characteristics on a corresponding molding condition.

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we investigated how to transcribe the form and roughness of the mold surface onto the molded lens surface. In the case of the roughness transcription, the bearing ratio analysis was employed to obtain further surface details.

2. Experiments

The aim was to produce a plano-aspheric convex singlet lens with a diameter of 4.0 mm (clear aperture 3.0 mm), intended for a 3-megapixel, 2.5 magnification zoom camera phone module. The aspheric convex side of the lens was optically designed using the following aspheric equation:

$$z = \frac{C \cdot x^2}{1 + \sqrt{1 - (1+K) \cdot C^2 \cdot x^2}} + \sum_{i=1}^{n} A_i \cdot x^i \tag{1}$$

where K (= −0.298) is the conic constant, $C = 1/R$ (where R [= 2.934 mm] is the vertex radius of the aspheric surface), and A is the constant for the aspheric form.

Tungsten carbide (WC; 002K, Everloy Co., Japan) that contained 0.5 wt.% cobalt (Co) was used to build the mold. The mold surface was ground and polished using an ultra-precision aspheric processing machine (ASP01, Nachi-Fujikoshi Co., Japan) and an aspheric polishing machine (KRF-2200F, Kuroda Co., Japan), respectively. Diamond-like carbon (DLC), 80 nm in thickness, was coated onto the processing surface in order to protect the mold from the extreme working conditions during the molding process. The aspheric surface of the fabricated mold showed form accuracy (PV) of 0.199 μm.

A ball-type preform (L−BSL7, Ohara Co., Japan) was used as the glass material for the lens fabrication. The ten lenses were molded under the same condition using a precision glass molding machine (Nano Press-S, Sumitomo Co., Japan). The form accuracy (PV) and the surface roughness (Ra) of each aspheric surface were measured using an ultra-high accurate three-dimensional (3-D) profilometer (UA3P, Panasonic Co., Japan) and a white light interferometer (Newview5000, Zygo Co., USA) with a vertical resolution of 0.1 nm, respectively. Table 1 reveals the details of the molding condition in this study.

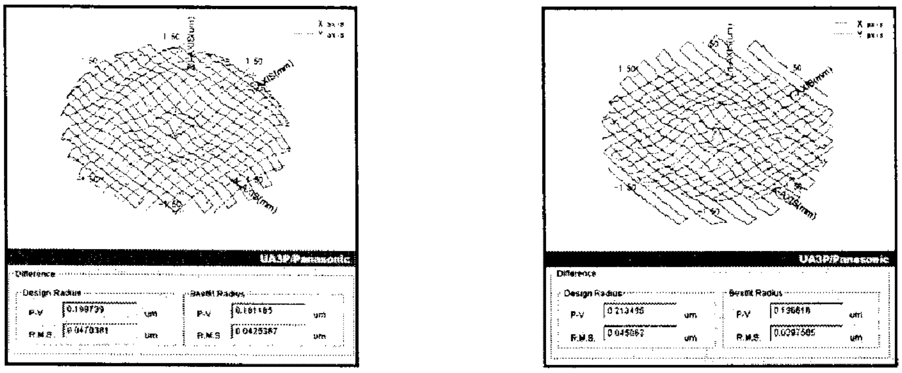
Table 1. Parameters of the GMP process in this study.

Parameter	Delay time	Pressing process		SC* process
		Step 1	Step 2	
Force (N)	–	100 N	300	200 N
Time (sec)	30	10	10	–
Temperature	Molding	Rapid cooling point	Release	Rate (°C/sec)
(°C)	555	460	200	0.4

*SC : Slow Cooling

3. Results

The measured form accuracy (PV) values for the aspheric surfaces of the mold and the lens molded under the optimum molding conditions are depicted in Fig. 1 (a) and (b), respectively. The form accuracy (PV) values are found to be 0.199 and 0.213 μm against the design radius (2.934 mm), respectively. The percentage transcription ratio is calculated as the ratio of the form accuracy (PV) against the design radius between the mold and the molded lens. It is calculated to be around 93.4% for the optimum molding condition.



(a) (b)

Fig. 1 Form accuracy (PV) of the aspheric surfaces of: (a) the mold and (b) the lens molded.

The surface roughness (Ra) of 3-D topography was measured using a microscopic interferometer, which captures and measures the microstructure and topography of surfaces in three dimensions. To obtain the surface roughness (Ra), the noise in the raw data is removed by the λ_s cutoff and the roughness topography is maintained by the λ_c cutoff. The cutoff length chosen were 2.67 μm (λ_s) and 80 μm (λ_c) based on the ISO 3274 standard. The measured surface roughness (Ra) of the mold and the molded lens was 3.97 nm and 4.20 nm, respectively.

Table 2 shows the bearing ratio curves of the mold and the molded lens and the related parameters, respectively. A comparison of the bearing ratio parameters of the mold and the molded lens in the Table 7 reveals more detailed transcription properties of the roughness topography.

The values of the absolute area parameters (*A1 and A2*) for the molded lens are higher than those for the mold. This shows that the increased surface roughness (Ra) of the molded lens was caused by both the peak and valley sections. By comparing the parameters between the mold and the molded lens, the following three results were obtained:

(1) For the mold, the peak area ($A1_{mold}$) was less than the valley area ($A2_{mold}$). Therefore, for the molded lens, the peak area ($A1_{lens}$) was expected to be greater than the valley area ($A2_{lens}$). However, the peak area is less than the valley area on the molded lens.

Table 2. Bearing ratio parameters of the mold and the molded lens.

Bearing ratio parameter	Mold	Molded lens	Unit
R_k	12.36	13.09	nm
R_{pk}	5.53	5.09	nm
R_{vk}	6.99	5.25	nm
Mr1	9.66	9.82	%
Mr2	89.74	89.62	%
Mr2-Mr1	80.08	79.8	%
100-Mr2	10.26	10.38	%
A1	0.09	0.69	μm^2
A2	0.13	0.75	μm^2

(2) For the molded lens, the material ratio of both the core ($(Mr2-Mr1)_{lens}$) and the peak ($Mr1_{lens}$) sections were decreased, but that of the valley section ($100-Mr2_{lens}$) was increased compared to the corresponding parameters of the mold.

(3) The R parameter value of the valley section in the mold ($R_{vk\text{-}mold}$) is comparatively higher than that of the peak section in the molded lens ($R_{pk\text{-}lens}$); other R parameters are relatively similar. This observation indicates that the depth of the peak section on the molded lens is more uniform than that of the valley section on the mold.

4. Conclusions

- The lens molded under the optimum molding condition showed a transcription ratio of 93.4%. This value is obtained by comparing the form accuracy (PV) values of the mold and the molded lens. This value is sufficient for fabricating the precision optical component for our system.

- The molded lens has a rougher surface (Ra 4.20 nm) than the mold (Ra 3.97 nm). This phenomenon is understood by comparing the absolute area parameters ($A1$ *and* $A2$) between the mold and the molded lens; the values of both $A1$ and $A2$ for the molded lens were higher than those for the mold.

- The peak section of the mold surface was more finely transcribed on the glass surface than the other sections (the core and the valley sections).

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