2009년도 대한전기학회 하계학술대회 논문집 2009. 7. 14 - 17

CPD 방식을 통한 PDMS lens의 제작

이경건*, 장윤호*, 유병욱*, 진주영*, 하준근*, 박재형**, 김용권*
서울대학교 전기 컴퓨터 공학부*, 이화여자대학교 물리과**

A clindrical post dipping method to fabricate PDMS microlens array

Kyounggun Lee*, Yun-Ho Jang*, Byung-Wook Yoo*, Joo-Young Jin*, Joon-Geun Ha*, Jae-Hyoung Park** and Yong-Kweon Kim*
School of Electrical Engineering and Computer Science, Seoul National University*
Department of Physics, Ewha Womans University**

Abstract - A cylindrical post dipping (CPD) method to fabricate the PDMS microlens arrays is presented in this paper. The proposed CPD method is based on the surface tension effect. 2 mm gap and gapless lenses with 2 mm diameter are fabricated and characterized geometically. Both profiles of the fabricated microlens are well-fitted with ideal lens profile. The surface roughness average of the fabricated lens is measured to be 1.953 nm. The focal length of 2mm gap lenses and the gapless lenses is calculated to be 17.00 mm with 0.65 mm standard deviation and 29.88 mm with 2.58 mm standard deviation, respectively. The proposed CPD method can be applied to wafer level lens fabrication due to its simplicity and versatility.

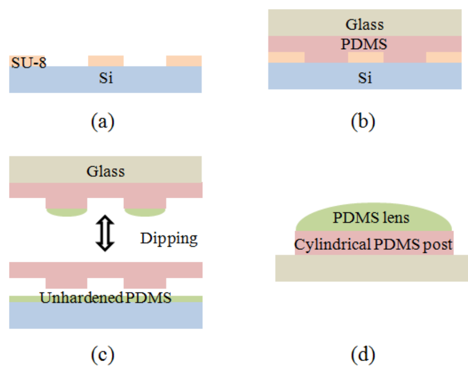
1. Introduction

Optical applications such as optical interconnections, adopted optics and imaging systems for three dimensional displays have lately adopted microlens arrays to present sharp images and enhance the light connection. Various technologies which approaches to fabricate microlens arrays have been reported. The thermal reflow technique is common method to fabricate a microlens array by melting cylindrical photoresist posts onto the substrate [1]. Melted photoresist posts form a spherical profile due to the surface tension effect. This thermal reflow method is easy and simple but a thermal instability of the photoresist causes a unpredictable microlens profile. Additionally, the reflowed spherical photoresist itself cannot be used as optical lenses due to low transparency of the photoresist. Another way to fabricate microlens is an isotropic etching technology. This technology forms a spherical mold and transfers patterns to a microlens material [2]. This molding method is easy to produce microlens at wafer level. However a surface of molded microlens is rougher than a surface of microlenses formed by the surface tension effect. The material dispensing is another widely used method to fabricate microlenses [3]. The dispensing method is able to control the volume of microlens easily but the material for dispensing is limited by viscosity and cannot provide wafer level production.

In this paper, we present a simple procedure to fabricate microlenses and microlens arrays by dipping polydimethylsiloane (PDMS) with cylindrical PDMS structure. The fabricated PDMS lenses are geometrically characterized to demonstrate the feasibility of CPD method for micro-opto-electro mechanical systems.

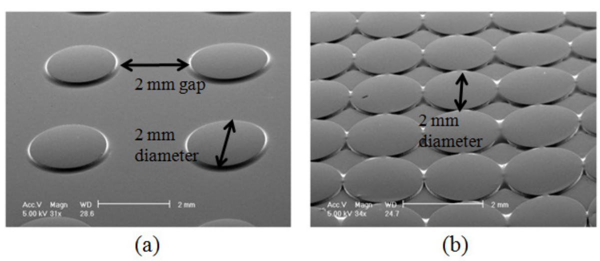
2. Fabrication process

An overall process view of the CPD method is illustrated in figure 1. The fabrication process starts with 4 inch, N(100) type, and 500 ㎛ silicon wafer. The SU-8 2075 photoresist (Microchem Corp.) is 100 ㎛ spin-coated to silicon wafer and patterned to be cylindrical post profile (figure 1 (a)). After self-assembled monolayer (SAM) coating on SU-8 cylindrical mold with 100 ㎛ height, PDMS(Daw corning SYLGARD 184 PDMS) is poured to the mold. A glass wafer is attached onto poured PDMS (figure 1 (b)). After the cylindrical PDMS posts are hardened at 70。C for 6 hours, the hardened PDMS posts are dipped into unhardened PDMS (figure 1 (c)). Then the dipped PDMS posts are lifted and hardenend. The adhered PDMS itself forms directly spherical shape due to the surface tension effect. The final step is curing PDMS lenses on the cylindrical post under vacuum condition. The curing process removes bubbles in unhardened microlens. The structure view of a fabricated lens is shown in figure 1 (d). The lens is formed on the cylindrical PDMS post. Young's modulus of PDMS is of the order of 1 MPa and coefficient of thermal expansion (CTE) is 3×10^{4}. Low young's modulus and high CTE allows thermal controllability of the lens focal length.



<figure 1> Fabrication process of CPD method.

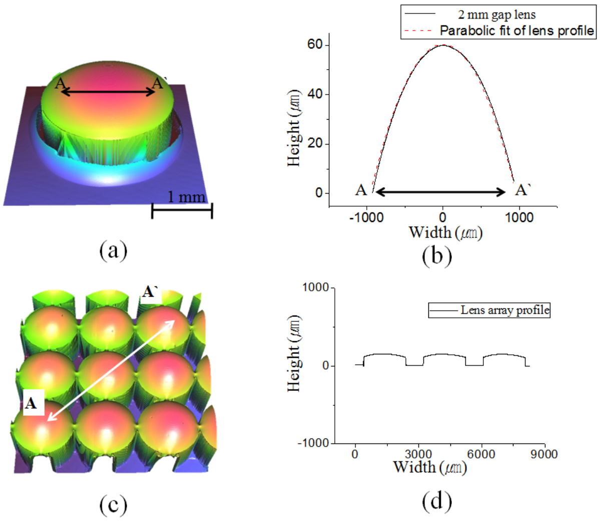
Figure 2 shows the fabrication results. figure 2 (a) and (b) shows 2 mm gap lens and gapless lenses with cylindrical PDMS post, respectively. The diameter of both types of lenses are designed to be 2 mm. The height of the cylindrical PDMS post is measured to be 100 ± 2 ㎛.



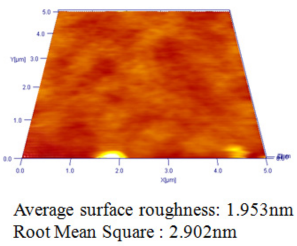
<figure 2> SEM images of (a) 2 mm gap lenses and (b) gapless lenses with 2 mm diameter

3. Characterization

Due to the surface tension effect of the PDMS dipping method, the fabricated lenses have ideal profile for optical lens and low surface roughness. In figure 3, 3D images of the fabricated 2 mm gap lenses and gapless lenses are shown with a 2D profile and a parabolic fit. The R square of parabolic fit to 2D profile of two types is calculated to be 0.996 and 0.995, respectively, which means each type have ideal lens profile. The microlens surface roughness is determined using an atomic force microscope (AFM). The measurement result is shown in figure 4. The average surface roughness of the fabricated microlens is measured to be 1.953 nm which is much smaller than interest wave length (several hundred nanometers). The measured area is 5 x 5 ㎛ on the top of the fabricated lens.

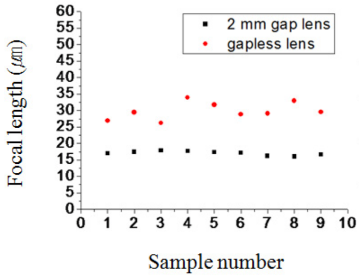


<figure 3> 3D images and 2D profiles of (a,b) 2 mm gap lenses and (c,d) gapless lenses with 2 mm diameter



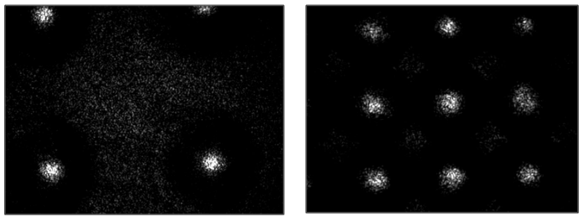
<figure 4> 3D topology images of the fabricated lens. Measured area is 5 × 5 ㎛ on the center of the lens

In figure 5, the focal length uniformity of the fabricated microlens arrays is analyzed. The nine of each 2 mm gap lenses and gapless lenses are sampled for analysis. As shown at table in figure 5, the focal length of the 2mm gap lenses and the gapless lenses is calculated to be 17.00 mm with 0.65 mm standard deviation and 29.88 mm with 2.58 mm standard deviation, respectively. Because the PDMS post of the 2 mm gap lenses are isolated, the 2 mm gap lens shows lower standard deviation than the gapless lens. The focal length is calculated by Lensmaker's equation with measured geometry parameters. Figure 6 shows a focusing performance of the fabricated lenses.



	Average	Standard deviation
2 mm gap lens	17.00 mm	0.65 mm
Gapless lens	29.88 mm	2.58 mm

<figure 5> Focal length plot of the 2 mm gap lens.



(a) (b)

<figure 6> CCD images showing the focused beam of (a) the 2 mm gap lenses and (b) the gapless lenses

4. Conclusion

In this paper, the CPD method to fabricate microlens has been demonstrated. It provides the simple mechanism to fabricate lenses. Also it can be adopted to wafer-level fabrication. The 2 mm gap lens and gapless lens with 2 mm diameter are fabricated. The profile of fabricated lenses is perfectly fitted with ideal lens profile. The average surface roughness 1.953 nm of the fabricated lens is sufficiently low for optical applications. The uniformity of the focal length of the fabricated lens is analyzed to demonstrate the feasibility of a mass production. Presently, the concept of the dipping method to fabricate microlenses is qualitatively verified. More experiments are progressing to provide quantitative descriptions.

[Reference]

[1] Hsiharng Yang, Ching-Kong Chao, Mau-Kuo Wei and Che-Ping Lin, "High fill-factor microlens array mold insert fabrication using a thermal flow process", Jounal of micromechanical microengineering, 14, 1197-1204, 2004

[2] P. Zhang, G. Londe, J. Sung, E. Johnson, M. Lee and H. J. Cho "Microlens fabrication using an etched glass master", Microsyst Technol, 13, 339-342, 2007

[3] V. Bardinal, E. Daran, T. Leichle, C. Vergnenegre, C. Levallois, T. Camps, V. Conedera, J. B. Doucet and F. Carcenac, "Fabrication and characterization of microlens array using cantilever-based spotter", Optics express, 15, 6900-6907, 2007