A High Efficiency 3D Planar Microlens for Monolithic Optical Interconnection System

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Abstract: A new 3D planar microlens for efficient monolithic optical interconnection system was developed. The fabricated 3D planar microlens showed excellent focusing characteristics and fiber-to-fiber coupling efficiency compared with a conventional 2D planar microlens.

Recent researches on optoelectronics are mainly concentrated on the monolithic integration of various optical devices for low-cost fabrication and parallel signal processing. To achieve highly efficient monolithic optical interconnection systems, several types of microlenses have been developed. Surface-relief microlenses had excellent light coupling efficiency, but they had problems in monolithic integration and precise alignment between microlenses and fibers [1-2]. Lensed fibers and ball lenses are not suitable for a monolithic integration into optoelectronics system due to their specific fabrication process such as droplet formation on a fiber-end and thermal reflow process, respectively [3-4]. On the other hand, planar microlenses are easy to integrate monolithically with other optoelectronic devices. However, abrupt sidewalls of the conventional planar microlenses prevent focusing incoming light in a vertical direction and degrade coupling efficiency [5-6]. In this paper, we developed a new 3D planar microlens which could focus incident light vertically as well as horizontally and characterized the optical interconnection system with the 3D planar microlens.

Fig. 1 shows a schematic view of the monolithic optical interconnection system with the proposed 3D planar microlens. The rounded sidewall of the microlens enables the vertical focusing of the light from an optical fiber or a laser diode and it is exaggerated to see the curvature clearly as shown in the inset of Fig. 1. We used 3D diffuser lithography and polydimethylsiloxane (PDMS) replication method to fabricate the 3D planar microlenses [7]. Because PDMS is transparent (transmittance > 90 % for visible and infrared light), it has been widely used as a lens material [8]. The 3D diffuser lithography system is briefly introduced in Fig. 2(a). The diffuser on a photomask changes the direction of the collimated UV light randomly and the UV-exposed regions with rounded sidewalls are formed in the photoresist (Clariant AZ9260). Fig. 2(b) shows a photoresist mold with a concave sidewall after development process. Its height is 70 μm and radius of curvature is 108 μm. The SEM picture of the replicated 3D planar microlens is provided in Fig. 3. The layout for the planar microlens was designed to have the same radius of curvature with that of the sidewall. The microlens was 208 μm in width and 70 μm in height.

Focal spots of the 3D and conventional 2D planar microlenses having the same focal length of 300 μm were compared in Fig. 4. While the 2D planar microlens showed a 3.5 μm-wide focal line, the proposed 3D planar microlens focused the incident light into a focal point with 7.9 μm in height and 4.0 μm in width. Such an excellent focusing characteristics of the 3D planar microlens enhanced fiber-to-fiber coupling efficiency more than twice as indicated in Fig. 5. Single mode fibers whose core diameter was 10 μm were used and the coupling efficiency was measured along the y-direction displacement of the input fiber. Intensive optimization in design of the microlens sidewall would result in better focal point with negligible aberrations and higher coupling efficiency over 90 % in consideration of signal loss in air and PDMS.

The developed 3D planar microlens can be a good solution for a monolithic integration as well as excellent light coupling in various optical interconnection systems.

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References

[1] M. Oikawa, et. al., Applied Optics, vol. 29, pp. 4077-4080, 1990.
[2] M. Kufner, et. al., Optics Letters, vol. 20, pp. 276-278, 1995.
[3] K. Kim, et. al., IEEE Photonics Technology Letters, vol. 15, pp. 1100-1102, 2003.
[4] C. Pan, et. al., Applied Optics, vol. 43, pp. 5939-5946, 2004.
[5] J. Shimada, et. al., Journal of Lightwave Technology, vol. 9, pp. 571-576, 1991.
[6] A. Glebov, et. al., IEEE Photonics Technology Letters, vol. 16, pp. 1107-1109, 2004.
[7] S.-I Chang, et. al., Optics Express, vol. 12, pp. 6366-6371, 2004.
[8] N. Chronis, et. al., Optics Express, vol. 11, pp. 2370-2378, 2003.

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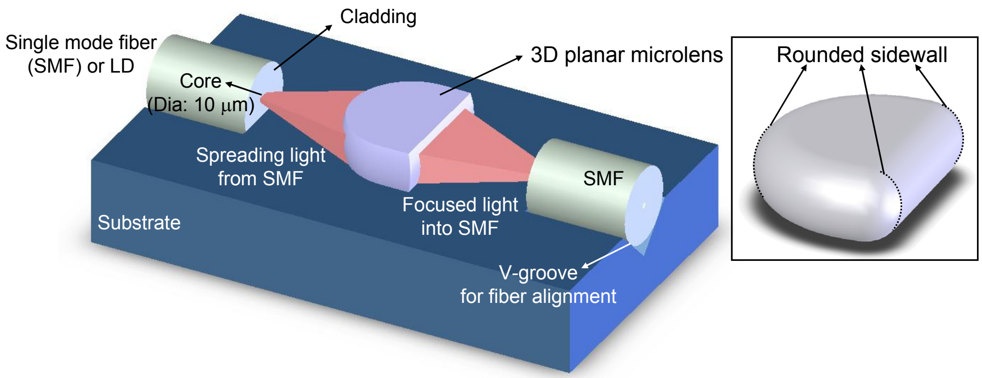
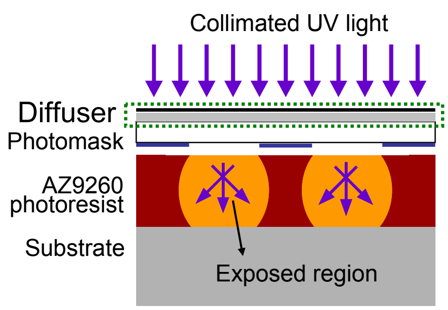
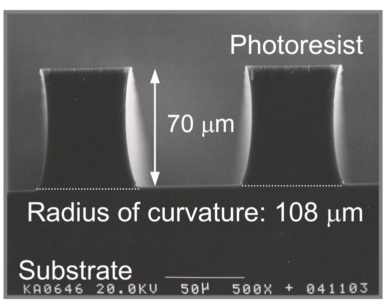


Fig. 1. Schematic view of the proposed 3D planar microlens used for optical interconnection system



(a)



(b)

Fig. 2. (a) Schematic view of the 3D diffuser lithography (b) SEM photographs of the photoresist mold cross-section having rounded sidewalls (radius of curvature: 108 μm)

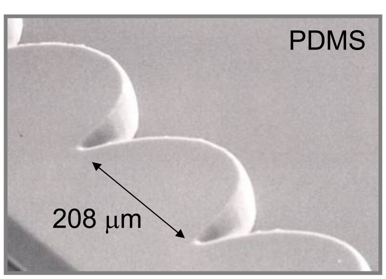
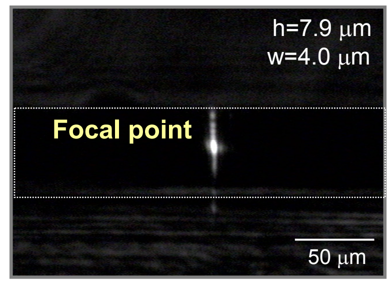
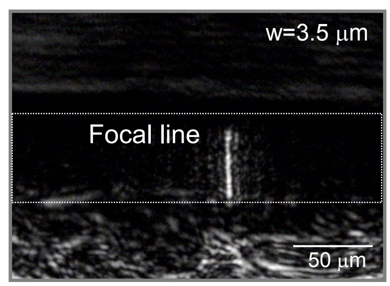


Fig. 3. SEM photographs of the fabricated PDMS 3D planar microlenses



(a)



(b)

Fig. 4. (a) Focal spot of the 3D planar microlens (height: 7.9 μm, width: 4.0 μm) (b) Focal line of the 2D planar microlens (height: 50 μm, width: 3.5 μm)

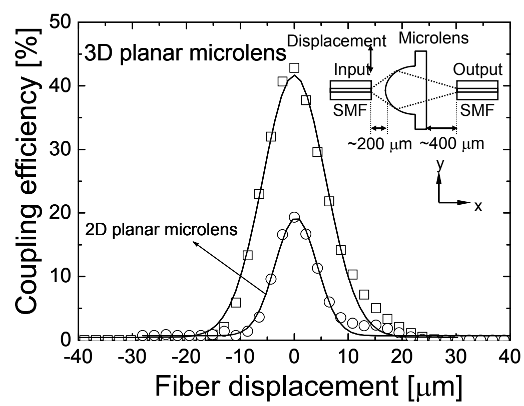


Fig. 5. Single mode fiber coupling efficiency along the input fiber displacement