Demonstration of Biconic Micro-Mirror Fabrication for Co-Packaged Optics by Imprint Technology

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The exponential expansion of Artificial Intelligence (AI) has significantly increased the demand for high-capacity connection in datacenters[1]. Co-packaged optics (CPO) is an expected solution, since it provides low-power consumptive and high-capacity optical link by integrating optical components on electrical package substrate. Figure 1 shows one of CPO configuration called Active Optical packaged (AOP) substrate, where a pair of micro-mirrors achieved highly efficient optical re-distribution from embedded photonics IC[2]. We have demonstrated fabrication of top-side angled mirror for AOP by photo nanoimprint technology, which is suit to scalable formations of 3D structure[3]. In this study, fabrication of biconic lens mirror in the bottom side was demonstrated by imprint process, which has two distinct radii of curvature along orthogonal axes for high-precision beam shaping.

The schematic of process flow for biconic mirror is shown in Figure 2. At first, a master mold with 4.6-µm-height mirrors were prepared by high-accurate two-photon polymerization 3D printing using *Nanoscribe Quantum X*. Then Aluminum was sputter, and a release agent was deposited via vapor deposition onto the sample. OrmoStamp® (micro resist technology) droplets were dispensed onto the master mold, followed by UV exposure and demolding to form a replica mold on a glass film. In imprint process, UV curable resin PAK-01 (Toyo Gosei) was applied by spin-coating on a 4-inch silicon wafer. Herein the measured thickness of the cured resin was 3.8 µm on average across the wafer. The replica mold was pressed with mold load of 62.4 kPa. Finally, the mold was released after curing the resin. Condensable gas (CTFP/TFP)[4] was introduced during mold descent to suppress the occurrence of bubble defects.

The result of mirror fabrication measured by laser micro-scope was shown in Fig.3. Fig.3. (a) shows 3D view of the biconic mirrors fabricated by imprint process, and Fig. 3. (b) shows surface profiles of molds and an imprinted mirror. the average height variation of 0.42 µm was observed in five mirrors from the master mold to the imprint mirror. The average thickness of residual resist was 95.9 nm. Although some shape shrinkage occurred, biconic micro-mirrors were successfully obtained using imprint technology suitable for 3D fabrication. The causes of the shape variation in each process will be discussed.

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[2] A. Noriki, *et. al*., European Conference on Optical Communications, Tu2C-5, 2020.

[3] F. Nakamura, *et. al*., Electronic Components and Technology Conference, pp. 1404-1408, 2024

[4] K. Suzuki, et. al., Journal of Photopolymer Science and Technology, Vol. 32, 2019.

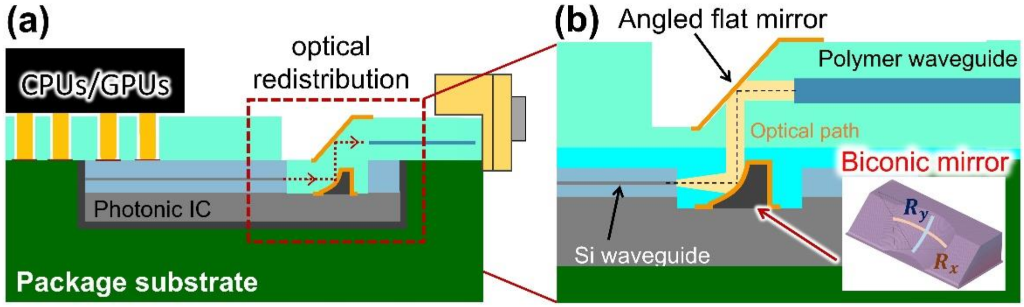

Figure 1: Schematic of the co-packaged optics using AOP substrate: (a) Cross-sectional view, (b) Enlarged view of a micro-mirror-based optical redistribution

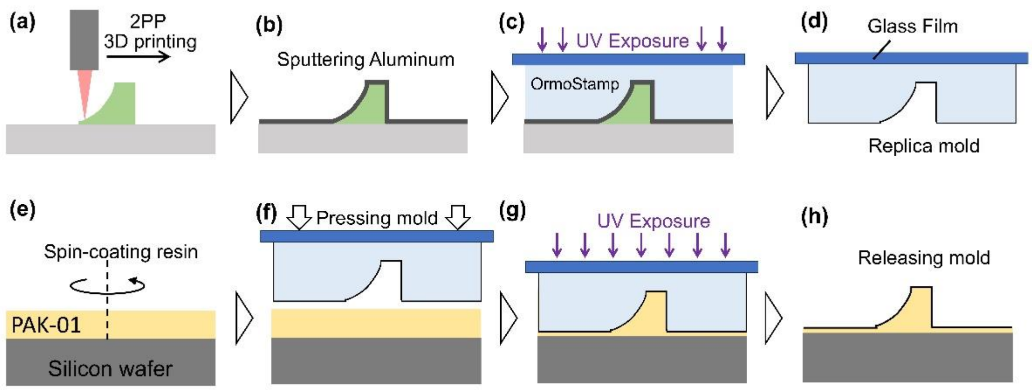

Figure 2: Process flow of biconic micro-mirror using photo nanoimprint technology: (a) forming mirror by 2PP 3D printing, (b) sputtering aluminum, (c) dispensing and curing OrmoStamp®, (d) releasing, (e) spin-coating resin, (f) pressing the replica mold, (g) curing imprint resin, (h) releasing the mold.

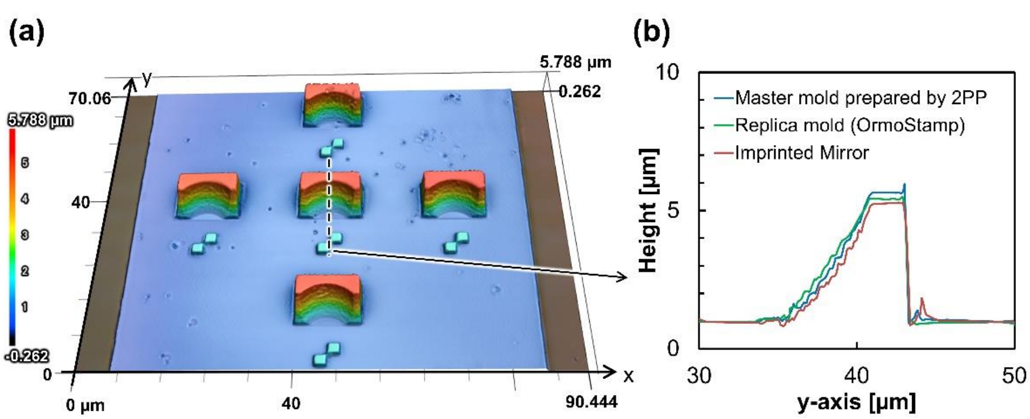

Figure 3: Result of biconic mirror fabrication measured by a laser microscope: (a) 3D view of mirrors fabricated by imprint process, (b) surface profiles of a master mold, replica mold and imprinted mirror