50μm GAP 8×8 PIXELS DEFORMABLE MIRROR FABRICATED BY MEMBRANE TRANSFER PROCESS

T. Wu[1], T. Sasaki[1], M. Akiyama[2], and K. Hane[1]
[1]Department of Nanomechanics, Tohoku University, Sendai 980-8579, Japan
[2]Astronomical Institute, Tohoku University, Sendai 980-8578, Japan
E-mail: wu@hane.mech.tohoku.ac.jp

ABSTRACT

We propose, design and fabricate here an electrostatically actuated continuous single-crystal-silicon membrane deformable mirror (DM) for astronomical observation. A 50μm air gap is generated a large between the mirror membrane and the electrode to get a large stroke. A DM with a 4mm×4mm mirror membrane and 8×8 underlying electrode array a is fabricated by combining Au-Si eutectic wafer bonding and the subsequent all-dry release process.

INTRODUCTION

Deformable mirrors (DMs) have been successfully used in adaptive optics (AO) to correct the optical aberrations[1-3]. Especially in the next-generation astronomical observation, a DM with a large stroke (>20μm) and a continuous high-quality optical surface is required. As the stroke of a DM is always limited by the air gap between the electrode and the mirror, several researches has been carried out to enlarge the air gap[3, 4]. In our previous study[5], we present a continuous membrane DM with a stroke of ~7μm. A bimorph spring array was used to enlarge the air gap to ~20μm. In this study, a new DM structure with a gap of ~50μm is proposed and fabricated.

DESIGN AND FABRICATION

Figure 1 shows the structure of the proposed DM. A single-crystal-silicon(SCS) mirror membrane is connected to a micro post array. The other end of the micro post is bonded at the center of a bridge spring, the two ends of which are fixed on the Si substrate. The electrode array is laid on the silicon substrate to locally actuate the mirror. The height of the micro post is about 50μm. The length and the width of the bridge spring are 250μm and 40μm, respectively. The influence function of the designed structure can be calculated by a approximated model in our previous study[6].The calculated IF of this structure is 4.18%.
To transfer a large(4mm square) and thin(~2μm) SCS membrane to a micro post array, we used a process comprised of a reliable Au-Si eutectic bonding process and a stable all-dry release process which is introduced in our previous study[5]. The fabrication flow is illustrated in Fig. 2. The device was fabricated from two silicon on insulator(SOI) wafers. The wafers are first diced into 2cm square chips before processing. The chip used to fabricate the electrode and bimorph spring array is called actuator chip and the other one used for fabricate the mirror membrane is called mirror chip. The fabrication process of mirror chip is shown in Fig.2 (a). The fabrication process of actuator chip is shown in Fig.2 (b). Figure 2 (c) illustrates the bonding and release process of the device. Au-Si eutectic bonding is adopted to achieve a reliable bonding quality within a small bonding area(35μm in diameter). After bonding, the device is released using an all-dry process using HfO_2 mask.

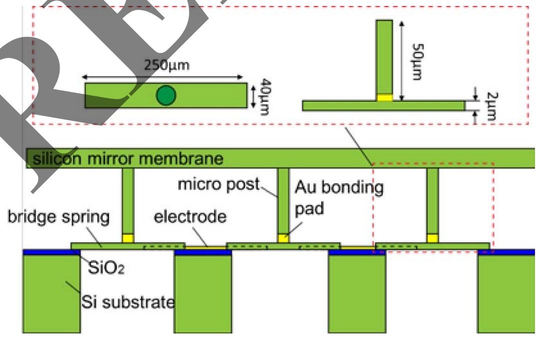

Figure 1. schematic diagram of the structure of the proposed DM.

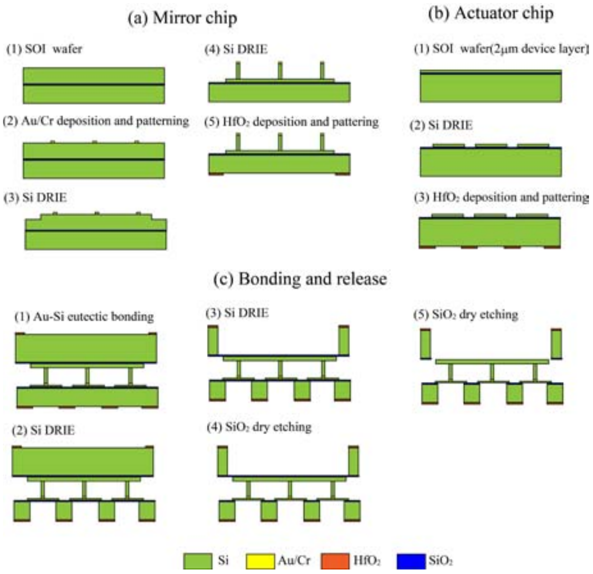

Figure 2. fabrication process of the (a) mirror chip, (b) actuator chip and (c)bonding and release.

RESULTS AND DISCUSSION

A DM with an underlying 8×8 electrode array is fabricated. Figure 3 shows the fabricated mirror chip. A mirror membrane with a micro post array is fabricated. The thickness of the membrane is about 1.3μm as shown in Fig. 3(b).

The fabricated 8×8 pixel DM is shown in Fig. 4(a). As shown in Fig. 4(b), the mirror membrane is successfully transferred to the electrode substrate.

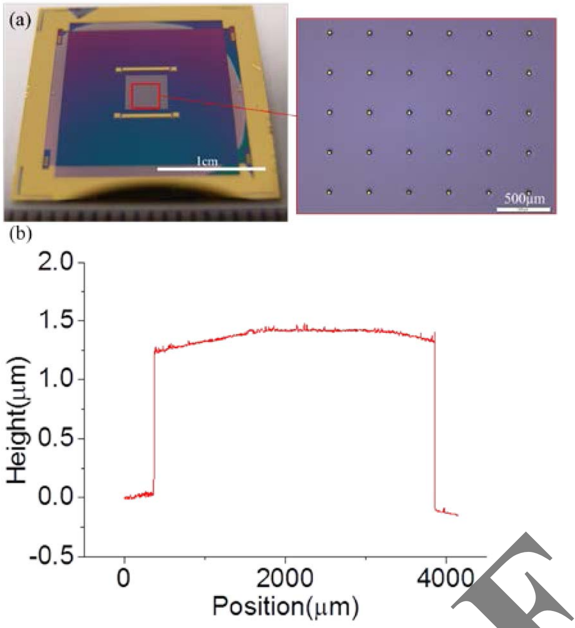

Figure 3. (a)the fabricated mirror chip; (b)surface profile across the mirror membrane on the mirror chip

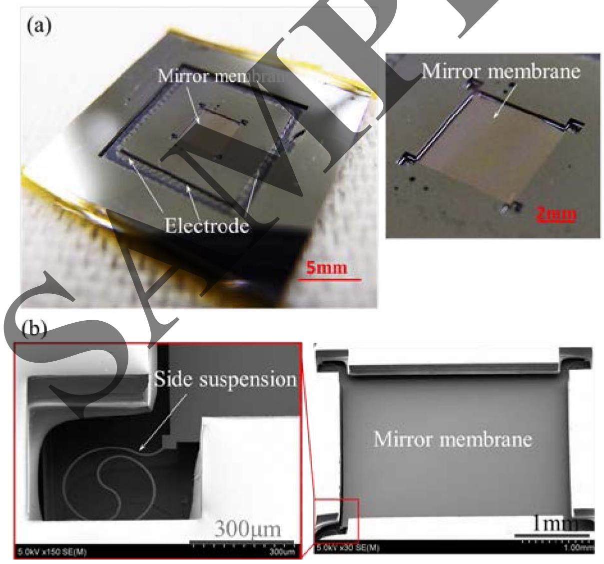

Figure 4. (a)picture of the fabricated 8×8 pixels DM; (b) SEM image of the fabricated 8×8 pixels DM

CONCLUSION

A continuous membrane DM with a large air gap is proposed and fabricated. A 1.3μm-thick membrane is transferred to a micro post array by combining bulk micromachining, Au-Si eutectic bonding technology and the subsequent all-dry release process. This process allows transferring an edge-free SCS membrane to a substrate with a large air gap. The applications of this transfer process extend to the fabrication of many other MEMS devices such as large stroke actuators, wavelength selective switches and biosensors in additions to deformable mirrors. The deformable mirror described in this paper is developed for the applications of the next-generation astronomical observation.

REFERENCES

[1] M. Sato, S. Tsuda, I. Kanno, H. Kotera, and O. Tabata, "Development of piezoelectric MEMS deformable mirror," *Microsystem Technologies-Micro-and Nanosystems-Information Storage and Processing Systems,* vol. 17, pp. 931-935, Jun 2011.

[2] I. Kanno, T. Kunisawa, T. Suzuki, and H. Kotera, "Development of deformable mirror composed of piezoelectric thin films for adaptive optics," *Ieee Journal of Selected Topics in Quantum Electronics,* vol. 13, pp. 155-161, Mar-Apr 2007.

[3] M. A. Helmbrecht, T. Juneau, M. Hart, and N. Doble, "Performance of a high-stroke segmented MEMS deformable-mirror technology," in *MOEMS-MEMS 2006 Micro and Nanofabrication*, 2006, pp. 61130L-61130L-10.

[4] T. G. Bifano, R. K. Mali, J. K. Dorton, J. Perreault, N. Vandelli, M. N. Horenstein, *et al.*, "Continuous-membrane surface-micromachined silicon deformable mirror," *Optical Engineering,* vol. 36, pp. 1354-1360, 1997.

[5] T. Wu, T. Sasaki, M. Akiyama, and K. Hane, "Large-scale membrane transfer process: its application to single-crystal-silicon continuous membrane deformable mirror," *Journal of Micromechanics and Microengineering,* vol. 23, p. 125003, 2013.

[6] T. Wu, T. Sasaki, M. Akiyama, and K. Hane, "15μM air gap 8× 8/4× 4 pixels single crystal silicon continuous membrane deformable mirror," in *Solid-State Sensors, Actuators and Microsystems (TRANSDUCERS & EUROSENSORS XXVII), 2013 Transducers & Eurosensors XXVII: The 17th International Conference on*, 2013, pp. 2501-2504.