A New Wafer-Level Membrane Transfer Technique for MEMS deformable mirrors

Category: (3) Fabrication Technology
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Novelty: This abstract describes a new technique for transferring an entire wafer level silicon membrane onto dissimilar substrates. A 1 μm thick silicon membrane of 100 mm in diameter has been successfully transferred onto a dissimilar wafer without involving adhesives or polymers (i.e. wax, epoxy, photoresist). Smaller or larger diameters can also be transferred using this technique.

Background: A surface micromachined polysilicon deformable mirror [1] has been demonstrated. The polysilicon mirror has a marginal surface quality, which limits its applicability. Therefore, a continuous single crystal silicon membrane deformable mirror concept [2] has been proposed for astronomical applications (Fig. 1). In order to realize this concept, a sheet of optical quality single crystal silicon membrane (> $1cm^2$) should be transferred onto deformable membrane actuators. Batch transfer of localized microstructures have been demonstrated [3-6]. Wafer level transfer techniques have been developed [7,8], which involved photoresist, wax or epoxy as adhesives and/or molding materials. These techniques are not suitable for wafer level multi-layer transfer. A new fabrication method has been developed for the fabrication of a deformable mirror.

Membrane Transfer Process: A 1 μm thick corrugated polysilicon membrane has been transferred onto an electrode wafer to show the feasibility of the proposed technique. The transferred membrane with underlying electrodes constitutes an electrostatic actuator array. An SOI wafer and a silicon wafer are used as the carrier and electrode wafers, respectively. After thermal oxidation, both wafers are patterned and etched to define a corrugation profile and electrode array, respectively. The 1 μm thick polysilicon layer is deposited on the SOI wafer (Fig. 2 (a)). The carrier wafer is bonded to the electrode wafer by using evaporated Indium bumps. The piston pressure of 4 KPa is applied at 156 °C in a vacuum chamber to provide hermetic sealing (Fig. 2 (b,c)). After bonding of two wafers, the substrate of SOI wafer is etched in 25 % TMAH bath at 80 °C (Fig. 2 (d)). The Teflon fixture provides selective etching of the substrate. The etched wafer pair is cleaned by using an oxygen plasma. The exposed buried oxide is then removed by using 49 % HF droplets (Fig. 2 (e)). The SOI top silicon layer is etched away by using an SF_6 plasma to define the corrugation profile, followed by the HF droplet etching of the remaining oxide. The wafer level silicon membrane transfer is completed at this stage (Fig. 2 (f)). The SF_6 plasma with a shadow mask selectively etches the polysilicon membrane if the transferred membrane structure needs to be patterned (Fig. 2 (g)). Electrostatic actuators with various electrode gaps have been fabricated and characterized to prove the feasibility of the proposed membrane transfer technique. Fig. 3 shows the SEM photographs of a 1 μm thick polysilicon membrane, which has been successfully transferred onto the electrode wafer. The gap between the transferred membrane and electrode substrate is very uniform (+- 0.1 μm across a wafer diameter of 100 mm, provided by optimizing the bonding control). A WYKO RST Plus optical profiler has been used to accurately measure the surface topography and static deflection of the membranes. The fabricated actuator membrane with an electrode gap of 1.5 μm shows a vertical deflection of 0.37 μm at 55 V (Fig. 4).

Summary: A new wafer level silicon membrane transfer technique has been demonstrated by fabricating and testing an electrostatic actuator array. The complete characterization of the single crystal silicon membrane transfer over existing deformable membrane actuator arrays (Fig. 2 (h)) will be included in the final paper. The proposed technique has the following benefits over those previously reported: 1) no post-assembly release process (e.g. using HF) involved and no wax, photoresist, epoxy as used for the transfer purpose; The bonded interface is completely isolated from any acid, etchant and solvent, which ensures a clean and flat surface of the membrane. 2) capable of transferring wafer-level membranes over deformable actuators.

References

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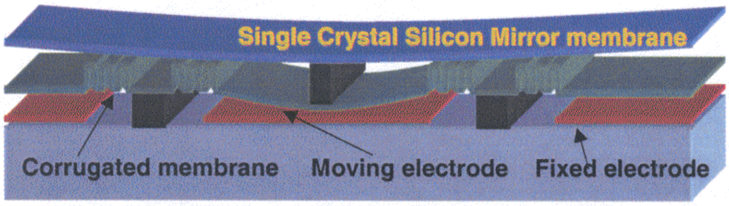


Fig. 1 The concept of the double layered MEMS deformable mirror with a single crystal silicon mirror membrane.

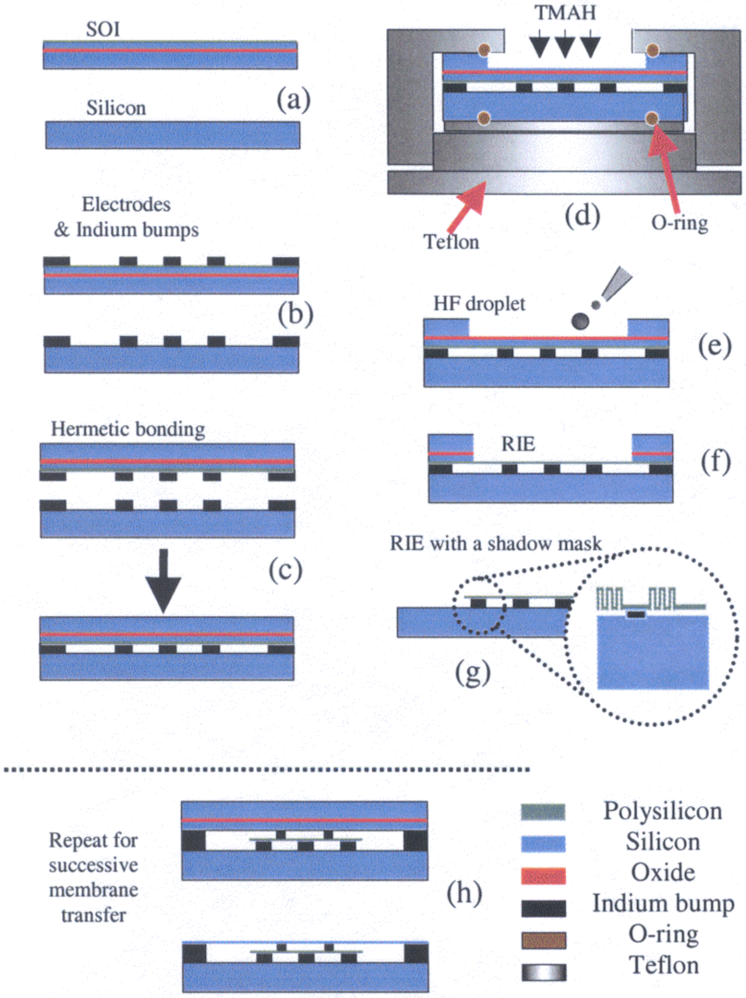
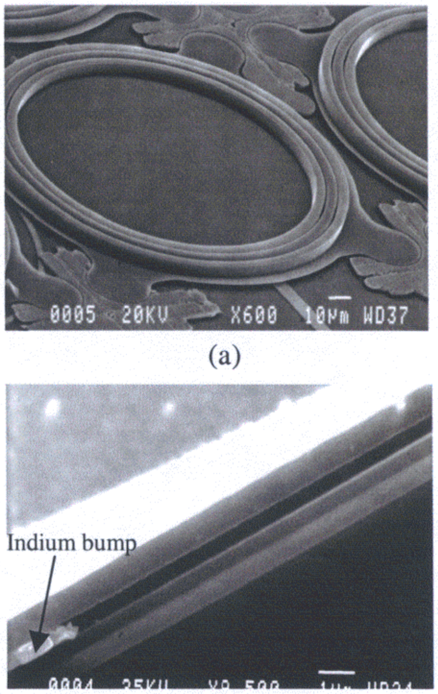


Fig. 2 The membrane transfer process.



(b)

Fig. 3 The SEM micrographs of the transferred polysilicon membrane actuator.
(a) The corrugated deformable actuator
(b) The cross sectional view of an actuator. The transferred membrane shows a flat and uniform profile.

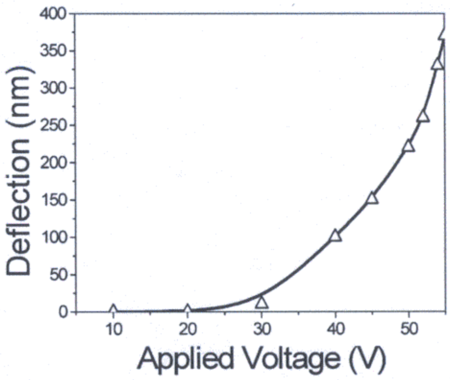


Fig. 4 The deflection characteristic of a transferred membrane actuator.