

SILICON-ON-GLASS FABRICATION PROCESS FOR OUT-OF-PLANE COMB CAPACITORS

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Vertical comb capacitors have been widely used for out-of-plane electrostatic actuators and sensing elements [1-3]. The self-aligned multi-step deep reactive ion etching (DRIE) process is a popular approach to fabricate the vertical silicon comb capacitors. In our previous work, a 5-mask silicon-on-glass process has been developed to fabricate the vertical sensing comb capacitors. As that depicted in Fig.1, a time-controlled final DRIE is required to reduce the height of partial comb fingers to realize the vertical combs. During this etching step, the comb structures have already been released, hence the heat conduction of the suspended structures will become poor, which will cause the temperature raising of these structures. The elevated temperature will degrade the passivation layers on the sidewall of the comb fingers, thereafter cause severe lateral etching to damage the suspended comb fingers. As the large height difference requires more etching time, the lateral etching problem will become more serious, as that shown in Fig.2. It is clear to see that all the suspended comb fingers are severely damaged by the lateral etching, while the fixed comb fingers are almost intact. Although the heat conduction problem can be partially solved by a series of short time etching to reduce the temperature, it is quite time consuming and cannot work well when the etching power is high.

In this work, an improved silicon-on-glass process that can solve the heat conduction problem mentioned above is proposed. An out-of-plane electrostatic actuator has been successfully fabricated to demonstrate the feasibility of the new process. The new process is based on the 5-mask silicon-on-glass process shown in Fig.1. The key steps of the modified process are shown in Fig.3. After the comb structures are released and before the height reducing etching, the whole structures are filled and covered with photoresist (Fig.3a). A flood exposure is often needed here to remove the photoresist on top of the comb fingers. Then the final height reducing etching step is carried out to form the asymmetrical comb structures (Fig.3b). Because all the comb fingers are connected with the photoresist, the problem of poor heat conduction for the suspended structures can be avoided. After that, the photoresist can be removed by either acetone or oxygen plasma. The comb structures fabricated with the improved process is shown in Fig.4.

Based on the modified process, an out-of-plane electrostatic actuator for micro-lens control was fabricated and shown in Fig.5. The total range of the open-loop static actuation is measured to be 13 μm with the maximum actuation voltage of 32 volts. With the in-situ position sensing and closed-loop control, the maximum displacement error of closed-loop controlled actuation is evaluated to be 0.01 μm for static actuation and 0.06 μm for dynamic actuation.

Word Count: 447

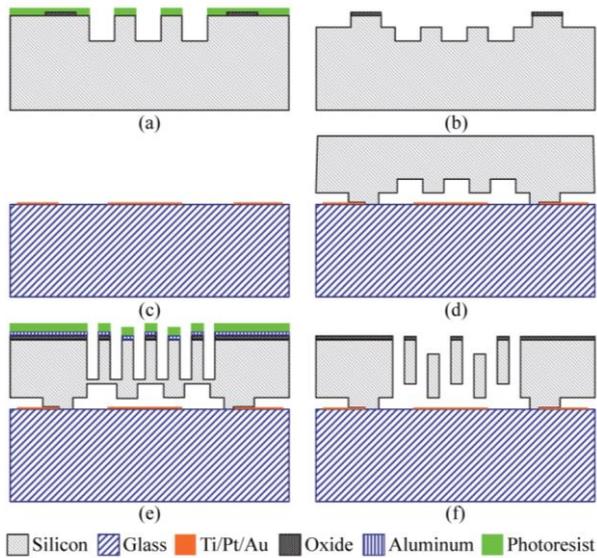


Fig.1 Schematic of the fabrication process.

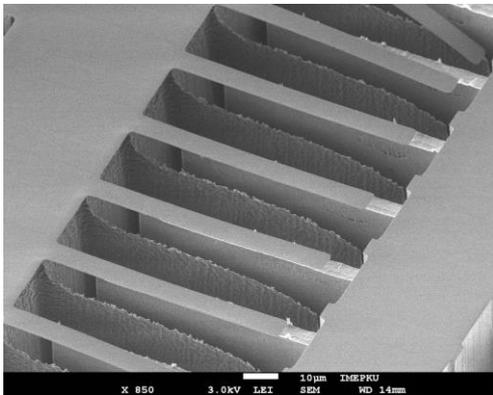
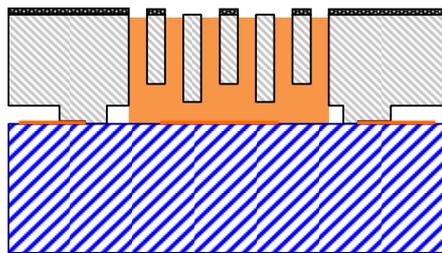
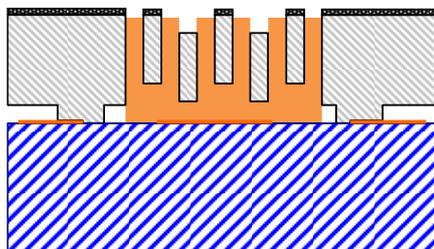


Fig. 2 SEM picture of the damaged combs.



(a) Photoresist refilling and flood exposure.



(b) Second DRIE to reduce the finger height

Fig. 3 Improved fabrication process for the vertical combs.

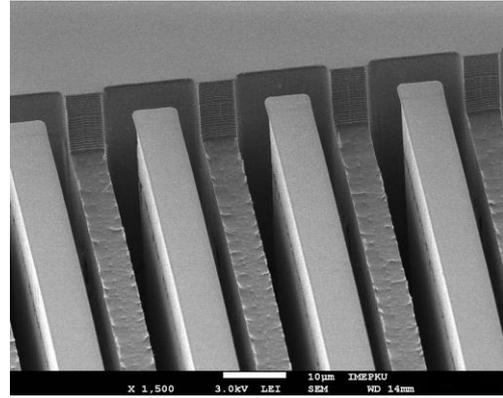


Fig. 4 Vertical combs fabricated with the improved process..

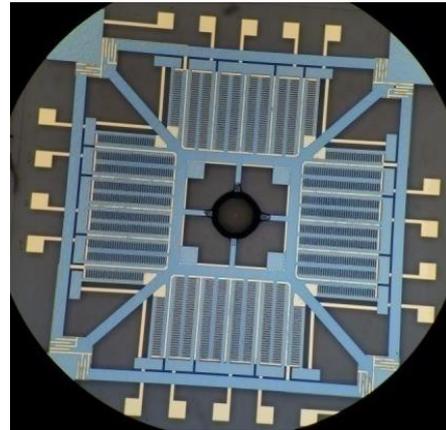


Fig. 5 Photo of the fabricated out-of-plane actuator.

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