FABRICATION OF BIMORPH PZT MICRO-ACTUATORS WITH PASSIVE POLYSILICON STRUCTURE

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In Lead Zirconium Titanate $Pb[Zr_{1-x}Ti_x]O_3$ based piezoelectric transducers, silicon film has been used as a passive structural layer to enhance the mechanical stability and reliability of the system due to its excellent mechanical properties. Previously reported piezoelectric unimorph transducers consisting of silicon (single crystalline or polycrystalline) structures are formed with SOI wafers or deposited silicon film. To date, PZT thin film bimorph or multimorph configurations consists of PZT/ZnO/PZT [1] or PZT/PZT stacks with Pt as the elastic shim [2]. Brittleness of the PZT thin film poses limitations in its use as bimorph micro-actuators. Bimorph actuators with PZT thin films alone are insufficient to provide reasonable structural strength required to move loads such as micro-lens and micro-mirrors. With thicker PZT films to form a bimorph actuator, it is more susceptible to form large cracks and pores which poses reliability issue. Bimorph actuators consisting of just two active layers (PZT/PZT) without a passive structure are not practical for micro-lens or micro-mirror actuation. This kind of configuration are usually seen in energy harvesting devices instead. Formation of bimorph or multimorph arrangements with low stress silicon as the passive structural layer(s) in-between the piezoelectric active layers could potentially enhance the mechanical performance and reliability of such transducers. However, typical LPCVD and Epi-poly depositions require processing temperatures that are not suitable for PZT films to sustain its quality. Therefore, bimorph arrangements consisting of PZT/Poly-Si/PZT layers have never been reported before. For the first time, a bimorph thin film PZT micro-cantilever actuator with low thermal budget Ultra-High Vacuum E-beam Evaporated Polysilicon (UHVEEPoly) as a passive structural layer is fabricated.

The micro-actuator is 1000 µm long and 250 µm wide. Fig. 1 shows a simplified fabrication process flow for the bimorph actuator. The actuator consists of Ti(15nm)/Pt(100nm)/PZT(1.2µm)/Ti(15nm)/Pt(100nm)/Ti(15nm)/SiO_2(0.75µm)/Poly-Si(4µm)/SiO_2 (0.75µm)/Ti(15nm)/Pt(100nm)/Ti(15nm)/PZT(1.2µm)/Ti(15nm)/Pt(100nm) layers to form approximately 8.3µm thick structure. The released bimorph structure is shown in Fig. 2a. It can be seen that the residual stress is well balanced on the top and bottom actuator to achieve a near flat curvature as oppose to an unimorph structure reported from our previous work [3]. From a cross-section view of a focused ion beam (FIB) milling in Fig. 2b, it can also be verified that the top and bottom active layers have equivalent thickness which result in the small initial deflection. The bimorph actuator has a measured resonance frequency of 6.3 kHz by exciting the top or the bottom actuator with a chrip signal (Fig. 4a and b). The bi-directional movement of the actuator can be confirmed by 180º phase difference between the top actuation and bottom actuation phase response plots (Fig. 4c and d), demonstrating an unique suitability for micro-actuation mechanisms or micro energy harvesters where a passive structural layer is required to enhance the mechanical performance and reliability of the system.

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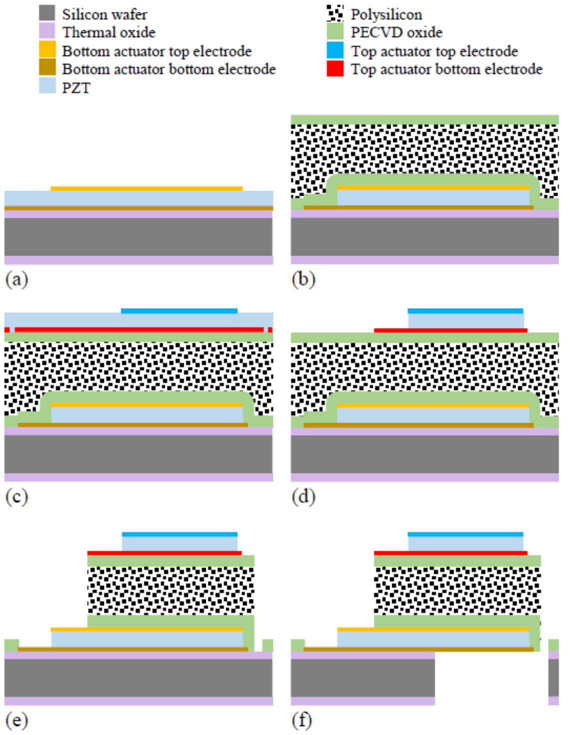

Fig.1 Fabrication process steps of the bimorph PZT micro-cantilever actuator

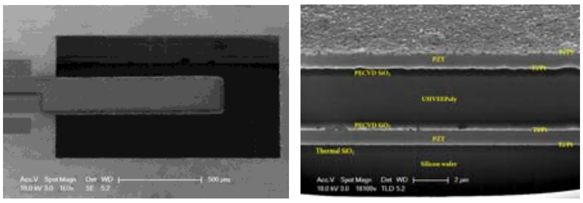

Fig. 2 (a) SEM image of the released bimorph structure at 30° angle (b) SEM image of the bimorph actuator cross-section from FIB milling at 45° angle.

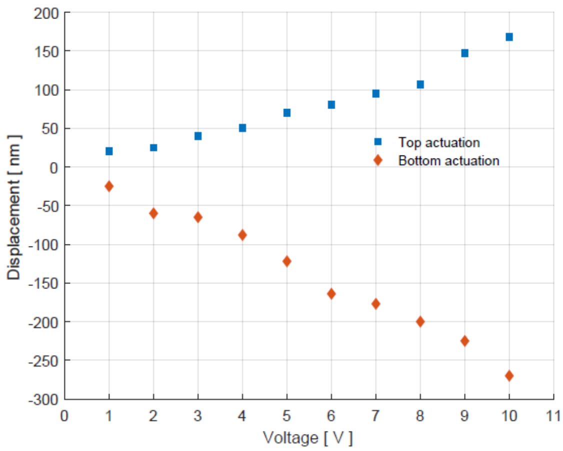

Fig. 3 Static deflection measured by Polytec MAS-500

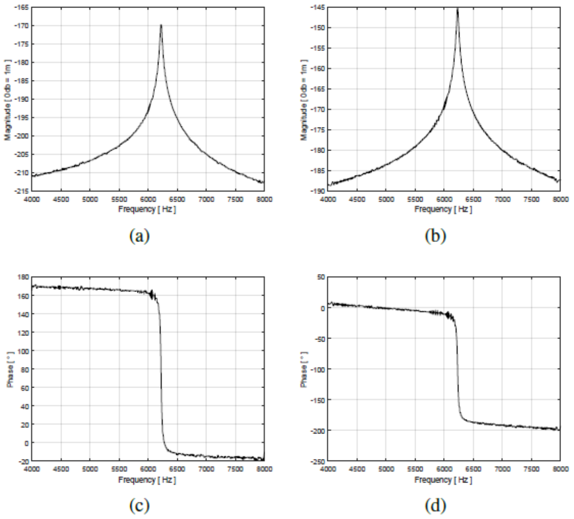

Fig. 4 (a) Frequency response of top actuator (b) Frequency response of bottom actuator (c) Phase response of top actuator (d) Phase response of bottom actuator

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