MEMS Amplification of Piezoelectric Strain for In-Plane Actuation

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Concepts and Key Idea

Though MEMS piezoelectric actuators can provide very high force output at low driving voltages, they have a very small strain, typically only a couple of tenths of one percent, leading to very limited applications in real world. A new method of amplifying the small strain of in-plane piezoelectric actuators has been developed. Very compact in-plane piezoelectric actuators with a few percent of strain will enable very compact MEMS devices replacing the existing bulky electrostatic actuators. The entire device is designed and fabricated using batch micro-fabrication techniques, averting the need for costly micro-assembly of the actuator with a piezoelectric element.

Design and Fabrication

The strain amplification is achieved through the fabrication of a compliant mechanism. A piezoelectric membrane, made of PZT, is situated in the middle of four parallel guiding linkages comprise the actuation mechanism. The pivot points are small length flexural pivots, or living hinges designed to approximate an ideal pivot, but without any backlash associated with a real pivot. Because the angles the pivots subtend are small, the pivots behave close to ideal. By amplifying the membrane displacement, the compliant structure sacrifices some piezoelectric force, however, the PZT membrane provides sufficient force that the output force is still desirable (order of 100 µN). Each actuator has a form factor of 500 µm X 500µm X 30µm, and the expected output displacement is 6 µm. The actuator can easily be arrayed in n-parallel to gain an n-times force advantage or in series to gain an n-times displacement advantage, with the drawback of increased form factor.

In-plane piezoelectric micro-actuators have been fabricated. Bending of the PZT member (not the end effector) limits the blocked force output. The hybrid actuator demonstrated an amplification ratio estimated to be in excess of 10:1 per cell. Also demonstrated was the ability of the actuator to be fabricated in arrays of micro-actuators, in series, or in parallel, by means of a flexible electrode bus. New fabrication techniques for PZT were developed, including the patterning of the sol-gel film prior to annealing, and the release of a piezoelectric actuator using XeF_2. A foundation has now been established for the development of devices which use this actuator, and compliant devices using SU-8, but more tests including the device fatigue need to be made. After the conservative finitial design, it is expected to be able to shrink the design to as small as 300x500 μm^2 with the same performance. Leveraging the arrayability, large stroke, and force of the micro-actuator, novel lateral MEMS RF relays are being developed by the authors.

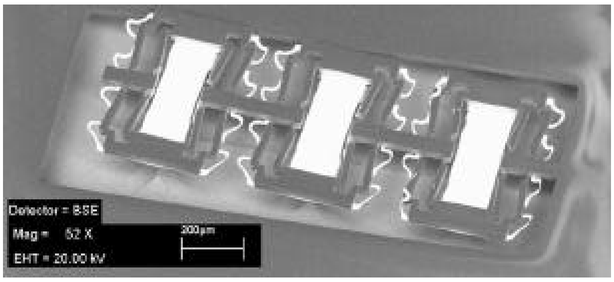

Fig. 7 A 3-cell Bow Actuator for Strain Amplification