Piezoelectric MEMS Actuators Fabricated by Chemical Solution Deposition and Surface Micromachining Technologies

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Micro electromechanical systems (MEMS) based on the piezoelectric effect allow a significant reduction of the device supply voltage compared to conventional change based actuator devices. Ceramic thin films of lead-zirconate-titanate (PZT) are of great interest, since they exhibit a huge piezoelectric effect. To reduce the fabrication costs it is desirable to use established technologies such as silicon bulk micromachining or surface micromachining in combination with chemical solution deposition (CSD) of the piezoelectric film to make such devices.

This work presents the development and fabrication of actuated cantilevers on silicon substrates with lengths up to 1000 µm and thicknesses down to 700 nm with a variation of the PZT layer between 125 nm and 255 nm.

First, a detailed characterization of PZT films on Pt/TiO_2/SiO_2/Si (100) substrates is necessary to find the most suitable composition. Electromechanical measurements using a double beam laser interferometer with a resolution in the pico meter range yield a maximum piezoelectric coefficient d_{33} = 101 pm/V for (111) oriented PZT with a ratio of 45 % Zr and 55 % Ti, which is several times higher than for other known materials. Furthermore the material exhibits a remnant polarization of around 25 µC/cm².

The cantilevers consist mainly of a sandwich structure with PZT between two Pt electrodes and SiO_2 as substrate (Fig. 1). An electric field, applied to the electrodes, leads to a contraction of the PZT due to the d_{31} effect. The different mechanical compliances of the involved materials then induce a bending of the structure. The layers are structured in multiple steps by dry etching technology. To release the cantilevers from the silicon either reactive ion etching or wet etching in TMAH is used. Figure 2 shows a couple of freestanding cantilevers with lengths up to 1000 µm. The cantilevers reach tip-displacements up to 14 µm at 5 V (Fig. 3) and resonant frequencies up to several kHz, which is enough to design e.g. a micro relay.

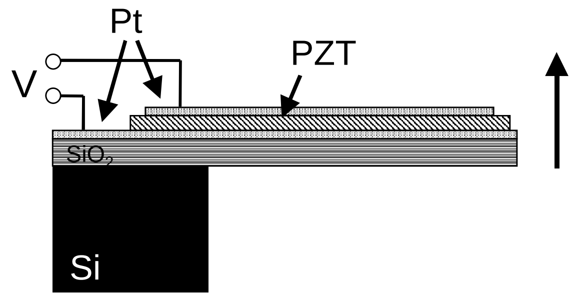

Fig. 1. Schematic concept of a PZT actuated cantilever.

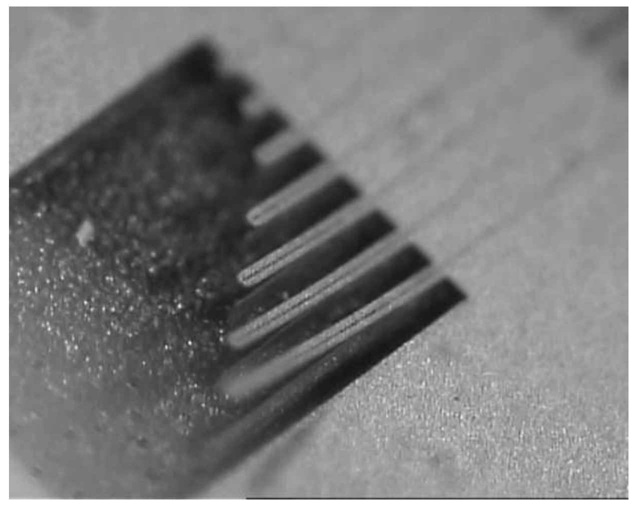

Fig. 2. Set of Cantilever beams with length from 50 µm to 1000 µm and 50 µm in width.

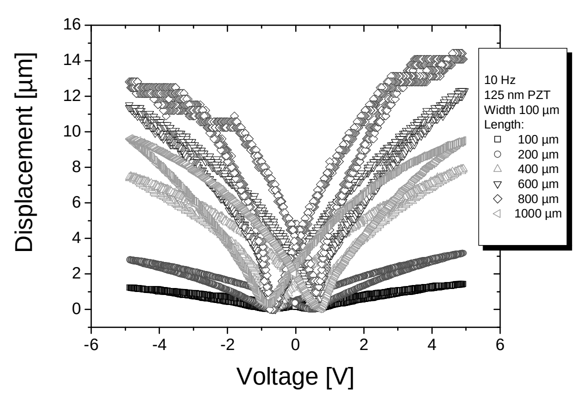

Fig. 3. Displacement of 100 µm width cantilevers with length up to 1000 µm actuated by a 125 nm thin PZT film.