Development of a lead-zirconium-titanate (PZT) actuator array using a CMOS-compatible solution process

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Piezoelectric actuator is a key component in every modern high tech field from semiconductor test to super-resolution microscopy, bio-nanotechnology and astronomy/aerospace. Among piezoelectric materials, lead-zirconium-titanate (PZT) appears as the most promising ones due to its excellent properties. For fabrication of high-density piezoelectric nanodevices and their integration with silicon-based CMOS circuits, low-temperature (≤ 450 ºC) processing of piezoelectric films is a must. Previously, we have reported a feasible approach for fabricating high-quality solgel-derived PZT films at a temperature below 450 ºC using a novel UV/ozone-assisted annealing method. Operation of a diaphragm-type piezoactuator was also demonstrated using the developed low-temperature PZT films [1]. However, the fabricated device had a low density, and factors that influence on actuator's performance such as diaphragm structure and thickness of PZT film have not been investigated. In this work, we report on fabrication and optimization of a high-density actuator array, which is designed for possible integration with an active-matrix thin-film transistor for electrical control.

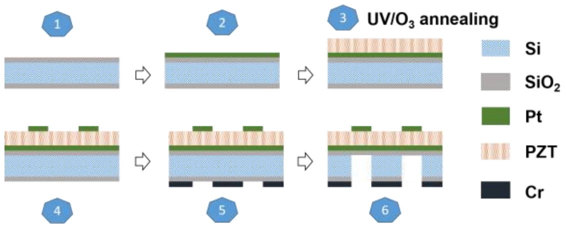

Fig. 1. Fabrication process of PZT actuator array. (1) Substrate cleaning; (2) Bottom-electrode deposition; (3) PZT formation via UV/O_3 annealing; (4) Top-electrode deposition; (5) Cr mask patterning; (6) BOSCH process for Si cavity.

Diaphragm-type structure was used for the fabrication of PZT actuator array, which consisted of 24×24 individual actuators with a pitch of 250 µm. The PZT film's thickness and actuator's cavity diameter were varied in between 450-750 nm and 30-100 µm, respectively, for structure optimization. Details of fabrication process is illustrated in Figure 1.

Figure 2 shows the dependence of the actuator's displacement on cavity diameter and PZT film thickness. Generally, the displacement increased as the cavity diameter increased. The displacement was also observed to get decreased when the PZT film thickness increased. These results indicated that proper ranges for the cavity diameter and PZT thickness are 50-70 µm and 450-600 nm, respectively. Moreover, it was confirmed that the fabricated actuator is able to generate ideal driving force for micropump/valve application. In conclusion, the proposed process and device are promising for various applications in microfluidics and micro/nanoelectronics.

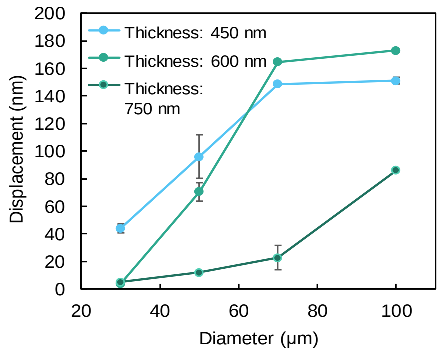

Fig. 2 Impact of cavity diameter and PZT thickness on displacement.

Reference: [1] R. Shimura, P. T. Tue, Y. Tagashira, T. Shimoda, and Y. Takamura, Sensors and Actuators A: Physical (2017), 267, 287-292.