Evaluation on Operation of a Lead-zirconium-titanate (PZT) Actuator Array for Highly Integrated Biochip Application

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Lead-zirconium-titanate (PZT) is one of the most promising materials for a piezoelectric actuator since its excellent piezoelectric characteristics. So far, fabrication and performance of piezoactuators based on thin and thick-PZT films have been confirmed. However, most of these actuators used either conventional vacuum-based or high-temperature (more than 600 °C) solution-based approaches for fabricating the PZT films which hindered them from practical applications. In particular, once the P r array is integrated with driving elements such as a thin-film transistor array, eratur PZT film is highly desired. Here, we report fabrication of an actuator array (pitch of 250 µm) using a low-temperature (450 °C) solution-processed PZT thick-film for a high-density biochip application. The low-temperature PZT film is advantageous in terms of less elemental interdiffusion and damages to the other device components, and possible use of a cheap glass substrate.

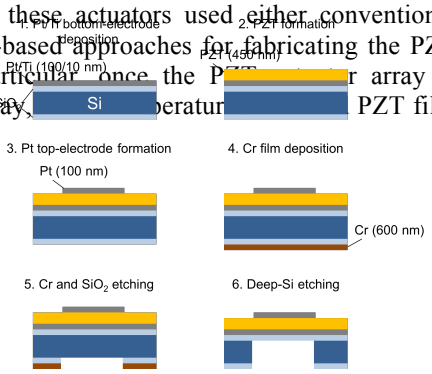

Figure 1. Schematic fabrication process of the PZT actuator array.

Firstly, the bottom-electrode Pt/Ti (100/10 nm) film was deposited on a SiO_2/Si/SiO_2 (1/300/1 µm) substrate using the rf-sputtering method. Next, a PZT film (Pb/Zr/Ti = 120/40/60, 25wt%, Mitsubishi Materials Corp., Japan) was formed by spin-coating followed by drying at 250° for 10 min on a hot-plate. After that the PZT gel film was treated with UV/O_3 exposure at 200 °C for 10 min. The PZT gel film was crystallized on a hot-plate at 450 °C in air ambient. Thickness of the single PZT layer was approximately 150 nm. These processes were repeated four times to get a desired thickness of 600 nm. In the next step, a top-electrode Pt film was deposited using the sputtering method. As for back-side Si cavity patterning, firstly a Cr film (600 nm) was deposited using the dc-sputtering method on the back-side of the wafer to play as a hard mask. The Cr film and SiO_2 layers at the back-side were patterned by conventional photolithography and wet-etching techniques. Finally, etching of Si using the BOSCH process was carried out to create the cavity. An array of PZT actuators (24×24) with a pitch of 250 µm was fabricated simultaneously. A schematic fabrication process of the PZT actuator array is shown in the Figure 1. The structure of the fabricated actuator was examined by the scanning electron microscope (SEM). Electrical characteristics of PZT films were characterized by the ferroelectric evaluation measurement system. Laser Doppler Vibrometer was used to visualize operation of the actuator.

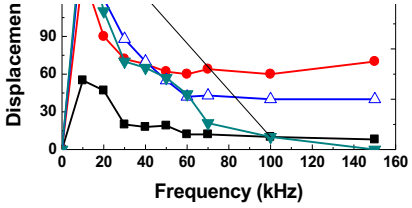

Figure 2. Displacement of a typical PZT actuator at different applied voltages with respect to frequency.

Cross-sectional SEM images of the fabricated actuator confirmed the completion of Si etching by the BOSCH process with an aspect ratio of 6:1. The X-ray diffraction pattern exhibiting a highly (111) oriented film was achieved. The 600-nm-thick PZT film showed a leakage current of approximately 0.75 nA at an applied voltage of 20 V and breakdown voltage of higher than 40 V, which is comparable to other reported works and suitable for our targeted application. Typical hysteresis characteristic of PZT film was observed with remnant polarization and coercive voltage of 27 µC/cm^2 and 3.8 V, respectively. Figure 2 shows the actuator displacement as a function of frequency at different applied voltages. We found that the displacement linearly increased as the applied voltage increased. Maximum displacement of 180 nm was able to be obtained at the applied voltage and frequency of 20 V and 10 kHz, respectively. By optimizing PZT film thickness and actuator structure, improvement of device performance would be expected.