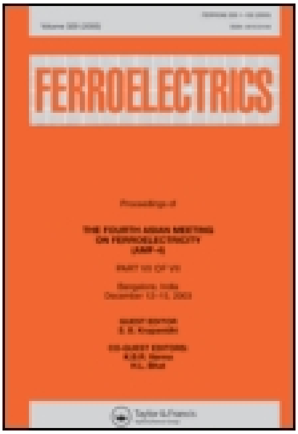

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Fabrication and properties of microcantilever using piezoelectric PZT thin films

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FABRICATION AND PROPERTIES OF MICROCANTILEVER USING PIEZOELECTRIC PZT THIN FILMS

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Piezoelectrically driven micro-cantilevers using $Pb(Zr_{0.52},Ti_{0.48})O_3$ (PZT) films have been successfully fabricated. We have fabricated the micro-cantilever for the nano-storage or AFM. The cantilever structures consist of piezoelectric PZT capacitors fabricated on a low stress SiN_x supporting layer. Flat micro-cantilevers have been obtained by controlling the stress in Pt electrode and PZT layer. The dielectric constant and loss of the PZT thin films in the cantilever structure were 700 and 2 % at 100 kHz, respectively. The remanent polarization was 16 $\mu m/cm^2$. The micro-cantilever had a dc response of 0.5 μm/V. The micro-cantilever had a resonant frequency of 17.3 kHz and the corresponding displacement of 2.36 μm at the applied bias of 1 V. The piezoelectric coefficient d_{31} of the PZT cantilever is –56.4 pm/V.

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Keywords: PIEZOELECTRIC; MICRO-CANTILEVER; PZT

INTRODUCTION

Micro-electro-mechanical systems (MEMS) have many promising applications. Such applications include tools for micro-fabrication and nano-fabrication, micro-surgery, and nano-probing analysis systems. Especially, micro-devices employing a piezoelectric PZT film have been studied for micro-sensor and actuator applications[1-3]. Most piezoelectrically driven MEMS devices have been fabricated in the form of a micro-cantilever, in which the vertical displacement was actuated by a piezoelectric layer. These actuation (or sensing) modes have been applied to scanning force microscopes (SFM) and IR detectors, etc[4, 5].

Several piezoelectric materials have been employed for the micro-cantilevers. Minne et al. have fabricated piezoelectric ZnO micro-cantilevers which have a dc response of 15 nm/V[6]. AlN has also been used for the micro-cantilevers. Micro-cantilevers with sputtered PZT films have been fabricated and exhibited a dc response of 50 nm/V[3].

Among these piezoelectric materials, PZT materials have advantages over other piezoelectric materials since PZT has superior piezoelectric properties to the other materials. For example, d_{31} of PZT is higher by 50 times than that of ZnO[3, 7]. Moreover, the piezoelectric properties of PZT materials can be tailored by varying the ratio of Zr/Ti.

In this study, we have integrated PZT thin films into the micro-cantilever which has the low stress SiN_x as a supporting layer for a unimorph structure. We report the fabrication of the micro-cantilevers and electro-mechanical characteristics.

FABRICATION

Fig. 1 shows fabrication steps of the micro-cantilever. Low stress SiN_x and low temperature oxide (LTO) have been prepared by low pressure chemical vapor deposition (LPCVD). Metallic layers, Pt and Ti

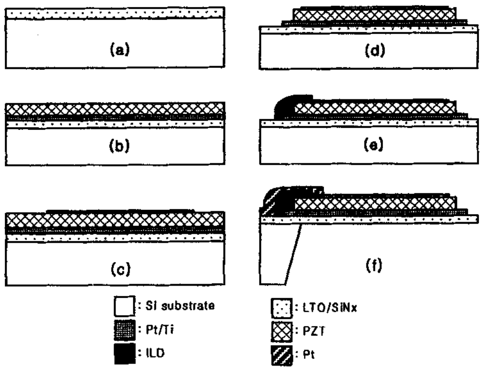

FIGURE 1. Cantilever fabrication process.

were deposited using the DC magnetron sputtering technique on the LTO/SiN_x/Si substrate (Fig. 1-(a)), which was followed by the deposition of PZT thin film and the top electrode (Fig. 1-(b)). The thickness of the PZT thin films was a 400 nm.

The Pt top electrode was defined on PZT/Pt/Ti/LTO/SiN_x/Si by photo-lithography and lift-off (Fig. 1-(c)). The thickness of the Pt electrode was sputtered about 70 nm. After the patterning of the top electrode, the etching of the PZT thin film and the bottom electrode was performed (Fig. 1-(d)) with inductively coupled plasma (ICP) etching systems.

The deposition and patterning of the inter-layer dielectric (ILD) for the isolation between top (TP) and bottom electrodes (BE) were carried out (Fig. 1-(e)). The ILD layer was patterned by a magnetically enhanced inductively coupled plasma (MEICP) etching system. The top pad (TP) was also defined by a lift-off process (Fig. 1-(f)).

In order to etch the silicon back side, we defined the pattern of a SiN_x and LTO by a MEICP etching system. Then the back side silicon substrate with silicon (100) was wet etched by KOH and D.I. water solution. Finally, Fig. 1-(f) shows the side view of the piezoelectrically driven micro-cantilever. In our previous work[8], we reported the fabrication process of the micro-cantilever in detail.

The P-E hysteresis loop of micro-cantilever was measured using a RT-66A. The dielectric constant and loss value of the micro-cantilever were measured using an impedance analyzer (Hewlett-Packard, HP4194A). The displacement characteristics were examined using a laser doppler vibrometer (LDV).

RESULTS AND DISCUSSION

Fig. 2 shows the variation of a hysteresis loop as the fabrication procedure proceeds. The significant variation of the polarization and coercive field in the hysteresis loops was not observed.

The dielectric constant and dielectric loss measured in the micro-cantilever structure. These capacitance and loss have been measured by a small signal of 10 kHz and 0.04 V ac. The dielectric constant and dielectric loss in the PZT cantilever was 700 and 2 %, respectively.

FIGURE 2. Variation of hysteresis loop along with the cantilever fabrication process.

Fig. 3 shows the SEM image of a micro-cantilever and a array consisting of four cantilevers with different dimensions and geometry. The micro-cantilever was flat, as shown in figure 3, due to the low

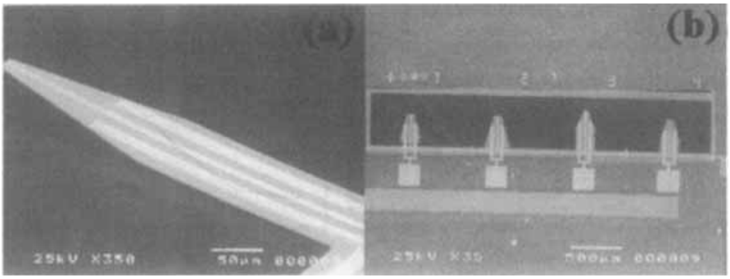

FIGURE 3. SEM images of (a) a cantilever and (b) PZT cantilever array.

stress of consisting layers. The PZT layer had a residual tensile stress of 130 MPa, which was small compared with other PZT films reported.

Fig. 4-(a) illustrates electro-mechanical characteristics of the micro-cantilever shown in figure 3-(a), i.e., the displacement at the applied bias voltage of 1 V as a function of frequency. The displacement was measured at the end of the micro-cantilever. The micro-cantilever had a dc response of 0.5 μm/V. The micro-cantilevers have a resonant frequency of 17.3 kHz. Upon applying a dc voltage, the displacement characteristics of the cantilever end is illustrated in figure 4-(b). The cantilever exhibited a displacement of 9 μm at 5 V bias voltage.

CONCLUSIONS

Diol-based PZT thin films were prepared on platinized LTO/SiN_x/Si substrates by the sol-gel method. The PZT and the bottom electrode (Pt/Ti) were etched by ICP, while ILD, LTO and SiN_x were etched by MEICP. Finally, we had fabricated the micro-cantilevers with the PZT layer, i.e., Pt/PZT/Pt/Ti/LTO/SiN_x/Si. The dielectric constant and dielectric loss of the PZT thin films in the cantilever structure were 700 and 2 % at 10 kHz, respectively. The micro-cantilevers had a dc response of 0.5 μm/V. These micro-cantilevers also had a resonant

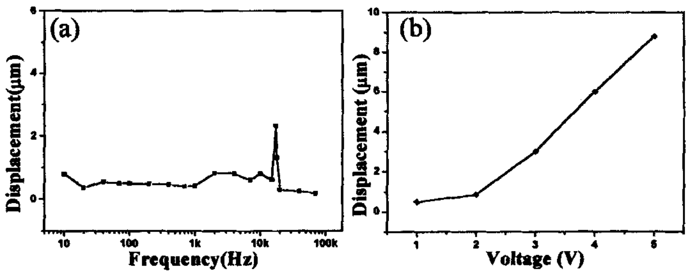

FIGURE 4. Vertical displacement (a) with a driving frequency and (b) with a driving voltage.

frequency of 17.3 kHz and the piezoelectric coefficient d_{31} of the PZT thin films was –56.4 pm/V.

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