2004년도 대한전기학회 하계학술대회 논문집 2004.7.14-16

Pt/Pb(Zr,Ti)O_3/Pt 박막의 전기적 특성과 공진주파수에 관한 연구

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The Electrical Properties and Resonant Frequency of Pt/Pb(Zr,Ti)O_3/Pt Films

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Abstract - The modeled resonant frequency and electrical properties of Pb(Zr, Ti)O_3 (PZT) film with various thicknesses have been investigated in film bulk acoustic wave resonators (FBARs). PZT films and Pt electrodes were fabricated by rf-magnetron sputtering. Fabrication process of electrodes and PZT were patterned by simple lift-off process and then back side of silicon was etched by 45wt% KOH. The crystal structure of PZT films with 0.5, 1 and 2 μm thickness was investigated by x-ray deflection (XRD) and scanning electron microscopy (SEM). The dielectric constant and performance characteristics of PZT FBAR strongly depended on the film thickness. The resonant frequency of PZT films decreased with increasing film thickness. These sputtered PZT FBAR with simple lift-off process enable us to fabricate high Q values with resonant frequencies. (0.71 - 1.48 GHz)

1. INTRODUCTION

Great attention has been paid to piezoelectric films as promising materials for use in accelerometers, microsensors, and microactuators into intelligent systems [1-3]. Such devices have been developed by microfabrication techniques based on microelectromachanical systems (MEMS) research [4]. Among various piezoelectric materials, using MEMS technology, Pb(Zr, Ti)O_3 (PZT) is one of the most promising materials for potential applications due to its large P-E hysteresis, high dielectric constant, good pyroelectric effect, piezoelectric effect and electroopic effect [5]. Moreover, piezoelectric PZT films are of major interest in the RF filters of active structures MEMS due to its large electromechanical coupling coefficient, small size and low insertion loss [6]. Recently, Schreiter et al reported that PZT film resonators with varying compositions have been investigated in film bulk acoustic resonators (FBARs) and introduced possible new applications [7]. Ren et al. studied the analytical solutions of FBARs with the electrode-piezoelectric-electrode sandwich structure [8]. In despite of the tremendous effort, there is still remained piezoelectric PZT film for FBARs. It is reported that PZT films required on 1 μm and over, since piezoelectric properties related with film thickness [9]. But it is difficult to prepare the thick PZT films above 1 μm thickness because of the crack [10]. Also, little work has been reported PZT films for FBARs. In this work, sputtered PZT films with various thicknesses are reported for FBARs and measurement their properties.

2. EXPERMENTAL

The FBARs are fabricated by micromachining techniques and composed of a PZT film with Pt top and bottom electrode [11]. PZT films with 0.5 m, 1 m and 2 m thickness were prepared by by rf magnetron sputtering technique on Pt/TiO_2/SiO_2/Si substrates, the detail of which have been previously reported [12-13]. The microstructure and crystal orientation of PZT films were analyzed using X-ray diffraction (Mac Science M18XHF-SRA) and scanning electron microscopy (SEM). The performance characteristics of PZT FBARs were measured using RT66A ferroelectric tester (Radiant Technologies), capacitance-voltage meter (Kotronix 3520) and vector network analyzer (HP 8722D), respectively. Analytical solutions of the wave equation for the Pt/PZT/Pt sandwich structure in FBARs are referred by Ren's report. The FBAR with piezoelectric PZT films was designed with following fabrication process. 1) P-type Si (100) wafer was prepared as substrate and 1 m thermal oxide was deposited by thermal evaporator. 2) The substrate surface was patterned with a photo resist (PR) by direct exposure under UV. 3) Pt electrode is selectively deposited by sputtering, to form the 200 m wide bottom electrode. 4) Lift-off process used to pattern a PZT and electrodes using sputtering method. 5) Annealing at elevated temperature yields a piezoelectric PZT layer. 6) Backside SiO_2 expect supporting layer was removed for using a mask [5]. 7) Backside Si wafer was selectively etched by 45wt% KOH solutions at 80℃, thus completing the construction of the Pt/PZT/Pt FBARs.

3. RESULTS AND DISCUSSION

Figure 1 showed XRD patterns of piezoelectric PZT films with various thicknesses. It can be seen that nucleation of PZT films was depended on film thicknesses. The intensities of PZT films were increased with the film thickness and nucleated with random orientation. It was well known that the thickness of PZT films directly affected the nucleation, the microstructure (grain size, phase and orientation) and the electrical properties.

Fig. 2 illustrated the surface morphology of the PZT films annealed at 700C for 1 min (a) 0.5 m, (b) 1 m and (c) 2 m films using scanning electron microscopy. Small and well-developed grain structures with dense and uniform distribution were founded in the surface of PZT films with (a) 0.5 m. To increase film thickness, the surface morphology of PZT films with (b) 1 m and (c) 2 m was greatly changed and large grains and dark phases were founded in the surface. It was reported that these dark phases were associated with Pb-deficient phyrochlorelike phases [14].

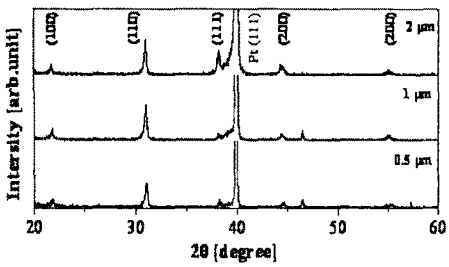
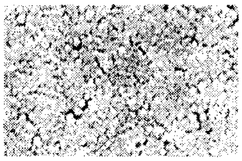


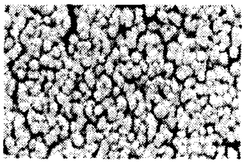
Fig. 1. XRD diffraction patterns of PZT films with various thicknesses.

Fig. 3 showed the P-E hysteresis loops of the PZT films with various thicknesses. The PZT films with 2 m thickness exhibited higher polarization compare with others. These results indicated that the different crystal structure which depend on the film thickness have been affected by electrical properties of PZT film.

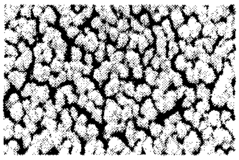
Fig. 4 showed dielectric constants of PZT thin films with various thicknesses. It was showed that the dielectric constants of PZT films depended on film thickness. The PZT films with (a) 0.5 m, (b) 1 m and (c) 2 m thickness have dielectric constant 675, 882 and 966, respectively. Many researchers reported that dielectric constants of PZT films were directly related with film thickness, which was explained by the film structure such as grain growth and variation of the lattice parameter [15].



(a) 0.5 ㎛



(b) 1 ㎛



(c) 2 ㎛

Fig. 2. SEM photographs of PZT films with various thicknesses. (a) 0.5 m, (b) 1 m and (c) 2 m.

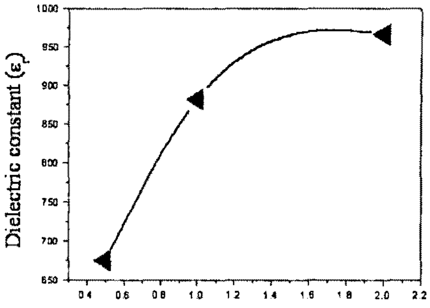


Fig. 4. Dielectric properties of PZT films as a function of thickness.

Fig. 5 showed the simulated S_{11} parameter for Pt/PZT/Pt FBARs with 0.5 m, 1 m and 2 m. As shown in fig. 5, the resonant frequency of PZT films decreased with increasing film thickness. The resonant frequency with 0.5 µm thickness PZT FBAR is 1.48 GHz. In the future works we will be investigated experimental results compared with the simulated results.

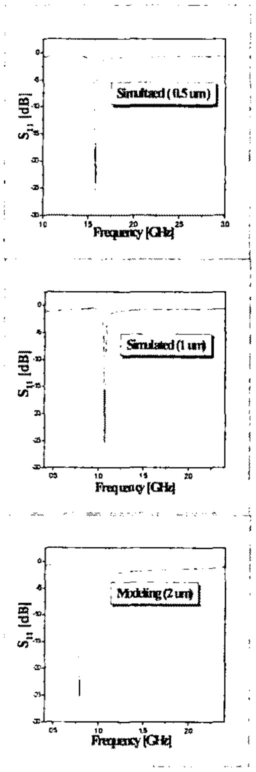


Fig. 5. Simulated results of S_{11} parameters as a function PZT film thickness.

4. CONCLUSIONS

In this paper, sputtered PZT films were investigated for FBARs with various thicknesses. The resonant frequency of PZT films by the variations of the thickness exhibited 1.48, 1.01 and 0.71 GHz, respectively. The simulated results indicated that the thickness of PZT films existed in an inverse proportion to the resonant frequency. Sputtered PZT FBARs with simple lift-off process enable us to fabricate high Q values and future works will be investigated experimental results compared with the simulated results.

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