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Structure and dielectric properties of $(Sr_{1-1.5x}Bi_x)TiO_3$ thin films

Peng Shi, Wei Ren, Min Zhao, Xiaoyong Wei, Xiaoqing Wu, Xiaofeng Chen and Xi Yao

Electronic Materials Research Laboratory, Key Laboratory of the Ministry of Education
Xi'an Jiaotong University, Xi'an 710049, China
wren@mail.xjtu.edu.cn

EXTENDED ABSTRACT

Bismuth doped $SrTiO_3$ material has shown very interesting phenomena. Dielectric and ferroelectric relaxations have been recently reported in bismuth doped $SrTiO_3$ ceramics in the lower temperature range [1]. Moreover, several dielectric anomalies with temperature ranges were observed [2]. The anomalies phenomena may be contributed by the formation of several kinds of polar clusters after introducing bismuth in $SrTiO_3$. Bi-doped $SrTiO_3$ is emerging as a promising material for microwave tunable devices [3].

In this paper, thin films of bismuth doped $SrTiO_3$ $[(Sr_{1-1.5x}Bi_x)TiO_3]$ (BiST) ($x \leq 20\%$) were prepared by sol–gel method. Strontium acetate, Bismuth nitrate and tetrabutyl titanate were used as starting materials. Glacial acetic acid and ethylene glycol monoethyl ether were used as solvents. The precursor solution was stabilized with acetylacetone. The final concentration of the precursor solution was 0.4 mol/L. BiST wet films were spin-coated on $Pt/Ti/SiO_2/Si(100)$ substrate at 3000 rpm for 30 s at 25 °C. The wet films were baked and annealed for 5 min at 650 ^oC before deposited next layer. Six deposition cycles were repeated to get thicker films.

The phase structure and surface morphologies of thin films were carried out using x-ray diffractometer (CuKa, Rigaku D/max-2400) and an atomic force microscopy (AFM, DI Nanoscope), respectively, to assess the structures and crystallization. The structure of the thin films is revealed as a cubic perovskite structure with no other phase detected. There are no obvious peak shift and phase transition when the doping amount of bismuth is smaller than 15%. It is also confirmed by the measurement of a laser confocal Raman microscope.

The surface structure of BiST thin films was compact and smooth. The grain size of the aggregations was about 100 nm in diameter and 30 nm in height. The RMS roughness of the films in $2\times2\ \mu m^2$ changed from 6.3 nm to 9.6 nm with the increase doping content of bismuth. The thickness of the films measured by the cross-section observation of a scanning electron microscope (SEM) was about 400 nm.

The dielectric properties and capacitance–voltage (*C-V*) curves of the films were measured with a 4294A precision LCR meter (Agilent) in a metal-ferroelectric-metal configuration. The temperature dependence of dielectric properties and dielectric tunability had been studied as a function of the doping amount of bismuth. Fig.1 and Fig.2 show the frequency dependence of dielectric properties and tunability. The tunability vs temperature plots are shown in Fig.3. It can be seen that the dielectric constants and tunability of the films reach to the highest values at the doping content of bismuth at 5 %.

The *P–E* hysteresis loops were measured with a TF Analyzer 2000 standardized ferroelectric test system (AixACCT Systems) and the results are shown in Fig. 4. BiST thin films exhibit weak ferroelectric properties at room temperature.

The optical transmittance properties of the films deposited on fused silica substrates were measured by a UV/VIS/NIR spectrophotometer (JASCO V-570) and the optical band gap energy was calculated. The band gaps of the thin films change from 3.78 eV to 3.98 eV as the doping amount of bismuth changes from 5 % to 20 %.

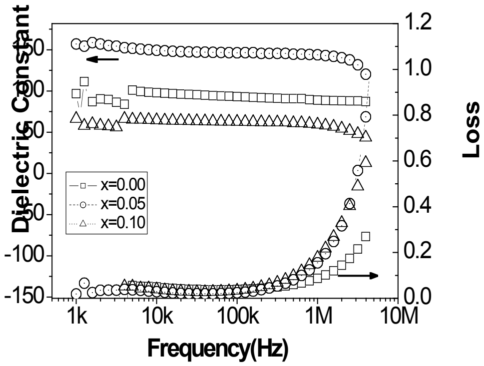

Fig.1 Frequency dependence of dielectric constants and loss tangent of BiST films with different Bi doping content.

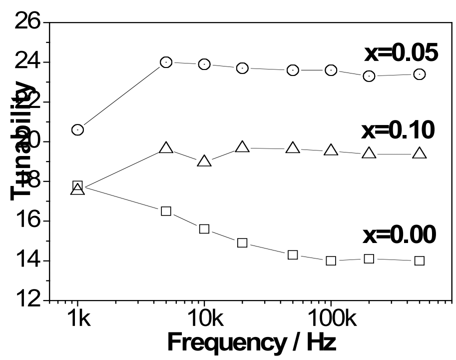

Fig.2 Tunability *vs*. frequency plots of BiST thin films with different Bi doping content (Bias field: 250 kV/cm）

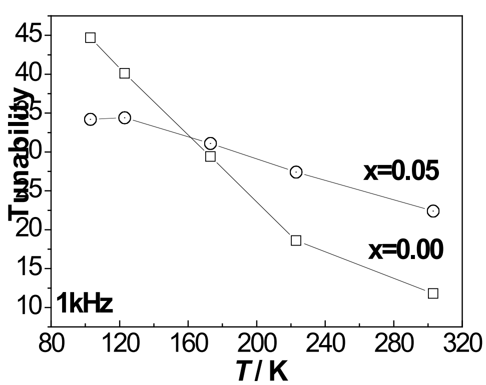

Fig.3 Tunability vs temperature plots of BiST thin films with different Bi doping content (Bias field: 250 kV/cm）

The details of structure and dielectric, optical properties of $(Sr_{1-1.5x}Bi_x)TiO_3$ thin films will be presented and discussed in details

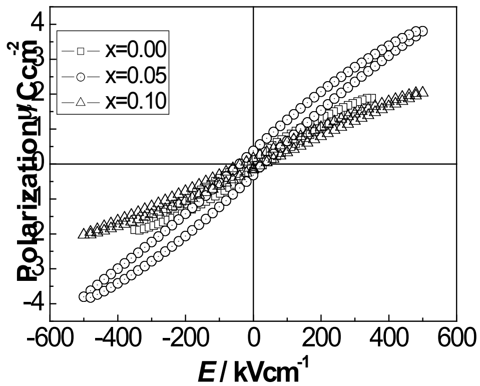

Fig.4 P-E loop of BiST thin films at room temperature with different Bi doping content.

Acknowledgment

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