The influence of annealing atmosphere on structure, ferroelectric and photovoltaic performance of BiFeO$_3$ thin films

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ABSTRACT

In this paper, the BiFeO$_3$ thin films have been prepared on FTO substrates by sol-gel method, and they were rapidly annealed under different atmosphere in air and N$_2$ respectively. The influence of different annealing atmosphere on the structure, ferroelectric and photovoltaic performance was studied. The XRD and SEM results show that the BiFeO$_3$ thin films annealed under N$_2$ atmosphere showed a smaller grain size and well crystallinity. Low leakage current density and P-E hysteresis were found in the BFO film annealed in N$_2$ atmosphere. The ultraviolet-visible absorption spectrum of BFO thin films annealed under N$_2$ atmosphere showed broader wavelength range and stronger intensity, the band gap could be modulated to 2.33 eV. At the same time, the BFO thin films annealed under N$_2$ atmosphere have greater open-circuit voltage (0.31 V) and short-circuit current (6.21 mA/cm$^2$). Above results show that the ferroelectric and optical performances of BFO thin films have been improved annealed under N$_2$ atmosphere.

I. INTRODUCTION

Ferroelectrics have recently attracted attention as a candidate class of materials for use in photovoltaic devices due to its abnormal photovoltaic effect [1-4]. However, the efficiency reported so far is still low. Hence it is urgent to develop ferroelectric material with narrow bandgap and strong ferroelectric property. In this paper, the BiFeO$_3$ thin films were prepared on the FTO conductive glass by sol-gel method, the samples were annealed at 550$^\circ$ in air and N$_2$ respectively, the influences of N$_2$ on its structure, bandgap, ferroelectric and photovoltaic properties were studied.

II. EXPERIMENTAL SECTION

In this paper, BiFeO$_3$ films with annealed different atmospheres were prepared on FTO glass substrates by sol-gel method using Fe(NO$_3$)$_3$·9H$_2$O and Bi(NO$_3$)$_3$·5H$_2$O as raw materials.

The morphology and structure were analyzed by scanning electron microscopy (SEM, S-3400N) and X-ray diffractometer (XRD, D/MAX 2200 VPC). The absorbance in the visible range was measured using the Evolution 220 UV-visible Spectrophotometer and its bandgap was calculated. After the Au electrode was deposited, the ferroelectric and leakage current was tested by Radiant Technologies’ Precision premier II. The IV characteristics of the battery were tested using the Keithley 2400 digital source meter, the light sources were HTLD-411365 nm laser and SS150 Solar Simulator, the density adjustment and proofing are 100 mW/cm$^2$.

III. RESULTS AND DISCUSSION

The XRD results in Fig.1 show that the BFO film is well formed and the films exhibit a high degree of preferential orientation, the SEM images in Fig.2 show that the annealed films in N$_2$ have good crystallinity and the grain is tight. The leakage and ferroelectric properties in Fig.3 indicated that N$_2$ annealed films has better ferroelectricity and lower leakage current density. In addition, the UV-Visible absorption spectra in Fig.3 show that the BFO films annealed at different atmospheres differ in light absorption. The bandgap of the BFO film can be adjusted to 2.33 eV by N$_2$ annealing. The photocurrent density-voltage characteristic curves in Fig.4 show that
the pure BFO thin films has certain PV characteristics under the light condition, and the open-circuit voltage and short-circuit current can be observed. After the N₂ annealing, the open-circuit voltage and short-circuit current density of the film are greatly increased, under the irradiation of 365 nm and 250 mW/cm² laser, the open-circuit voltage and short-circuit current reach 0.31 V and 6.21 mA/cm². In addition, we have further studied the basic mechanism of the effect of N₂ on the photovoltaic properties of BFO thin films, and provided a strong evidence for the application of thin films in the field of photovoltaic power generation.

Figure 1 XRD patterns of BFO thin films annealed at 550° under various atmosphere.

Figure 2 SEM images of BFO thin films annealed at 550° under various atmospheres.

Figure 3 Leakage current densities, P-E hysteresis curves, the ultraviolet-visible absorption spectrum of BFO thin films annealed at 550° under various atmosphere.
Figure 4 The J-V curve of BFO thin films annealing in air (a) and in N₂ (b) under dark and 365 nm 250 mW/cm² laser lamp.

IV. REFERENCES