THE EFFECT OF RF POWER ON ELECTRICAL CHARACTERISTICS OF $(Bi_{3.9}La_{0.1})(Ti_{2.9}V_{0.1})O_{12}$ FERROELECTRIC THIN FILMS FOR APPLICATION IN NON-VOLATILE MEMORY DEVICE

Chien-Min Cheng[1], Kuang-Yao Wu[1], Shih-Sian Zeng[1], and Kai-Huang Chen*[2]

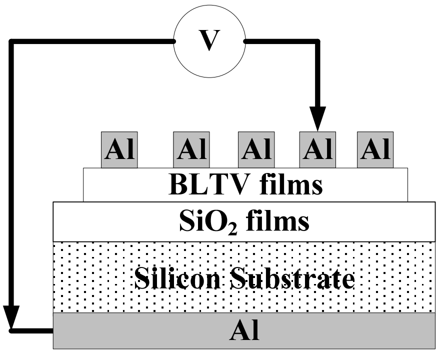
[1]Department of Electronic Engineering, Southern Taiwan University
Tainan, TAIWAN
[2]Department of Electronic Engineering and Computer Science, Tung-Fang Institute of Technology
Kaohsiung, TAIWAN
E-mail: d9131802@mail.tf.edu.tw

In this study, the $(Bi_{3.9}La_{0.1})(Ti_{2.9}V_{0.1})O_{12}$ (BLTV) ceramic target is fabricated by ourselves and the BLTV thin film is developed because of its excellent ferroelectric characteristics and lower leakage current density. The BLTV thin films have been successfully deposited on SiO_2/Si substrate under optimal radio frequency (RF) depositing parameters with different RF power. We have found that the RF power has large effect on the crystalline orientation, thickness (depositing rate) and roughness of BLTV thin films. The metal-insulator-metal (MIM, or called metal-ferroelectric-metal, MFM) structure is fabricated for the characteristic measurement of BLTV thin films. The influence of RF power on the dielectric constant and leakage current density of BLTV thin films will be also investigated. As RF power is equal to 130 W, the ferroelectric characteristics and lower leakage current density can be obtained.

Recently, many kinds of memory devices had been discussed, such as static random access memory (SRAM), dynamic random access memory (DRAM), the flash memory, ferroelectric random access memory (FRAM), magnetron random access memory (MRAM) and etc. The ferroelectric materials have been widely used for the various applications such as memory cell, tunable microwave devices (filter and phase shifter) and optical waveguide devices. The continuous increase of the storage capacitances is necessary for memory device application in the future. Bi-layer structured ferroelectrics (BLSFs), $SrBi_2Nb_2O_9$ (SBN), $Bi_4Ti_3O_{12}$ (BIT), and $SrBi_2Ta_2O_9$ (SBT) are known as a ferroelectric matreials. For the ferroelectric random access memories (FRAM), it is necessary to have high remanent polarization, high fatigue endurance, low leakage current and low processing temperature [1–4]. In this study, we report that the enhancement of ferroelectric properties in vanadium and lanthanum doped $Bi_4Ti_3O_{12}$(BIT) thin films prepared by a radio-frequency magnetron sputtering method. Currently, BLT thin films have attracted much attention due to polarization fatigue endurance and large spontaneous polarization (Ps).

In this study, the $(Bi_{3.9}La_{0.1})(Ti_{2.9}V_{0.1})O_{12}$ (BLTV) ceramic target was fabricated by ourselves. Raw materials of Bi_2O_3, La_2O_3, V_2O_5 and TiO_2 with purity higher than 99.5% were weighed firstly according to the composition of $(Bi_{3.9}La_{0.1})(Ti_{2.9}V_{0.1})O_{12}$. After ball milling for 1 h, the mixture was dried for 24 h and ground with an agate mortar for 1h. The calcining process was carried out at 1100^oC for 2h and the calcined powder was ground again for 1 h. The polyvinylalcohol (PVA) was added into the BLTV powder as binder, and the BLTV powder was pressed into pellets uniaxially in a steel die. Typical dimensions of the pellets were diameter of 58 mm and thickness of 5 mm. After debindering, the pressed target was sintered at 1200 ^oC under ambient conditions for 2 h, then the 2 inch BLTV ceramic target was fabricated.

The as-deposited BLTV thin films were deposited on a SiO_2/Si substrate by means of radio frequency (rf) magnetron sputtering using a 2-inch BLTV ceramic target. The target was placed 8 cm away from the substrate. The as-deposited BLTV thin films were deposited for 2 h under the optimal sputtering parameters, such as a rf power of 70 W~130 W, a chamber pressure of 10 mTorr, and oxygen concentration of 40%. To complete the metal-ferroelectric-insulator-semiconductor (MFIS) structure as shown in fig. 1, an array of circular top contacts with a diameter of $0.00785cm^2$ was formed by depositing an Al film, which had a 300 nm thickness and resulted from thermal evaporation. The morphologies and thicknesses of BLTV thin films were observed and measured using the scanning electron microscopy (SEM). X-ray diffraction (XRD) (SIEMENS D5000) patterns using Cukα radiation and Ni filter were used to determine the crystalline phase and preferred orientation of deposited BLTV thin films. The dielectric constant and leakage current density of BLTV thin films were investigated by measuring the characteristics of capacitance-voltage (C-V) and current-voltage (I-V). Hewlett-Packard (HP 4194A) impedance analyzer was used to measure the dielectric constants of BLTV thin films. The capacitor was measured at 100 kHz with an AC bias for high frequency capacitor-voltage (C-V) curve. Current-voltage (I-V) characteristics were also measured by a Hewlett-Packard (HP 4156) semiconductor parameter analyzer.



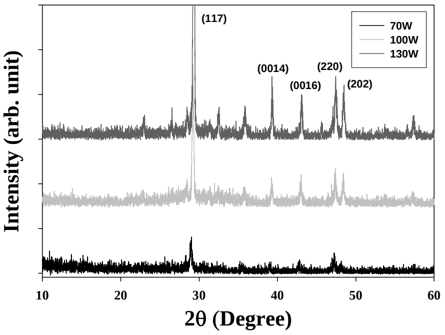


Fig. 1. Metal-Ferroelectric-Insulator-Semiconductor (MFIS) structure.

Fig. 2. XRD pattern of the BLTV film.

The optimal sputtering parameters for depositing BLTV thin films are the substrate temperature of 580^{o}C, chamber pressure of 10 mTorr, and oxygen concentration of 40% under different RF power. The BLTV thin films deposited on the optimal parameters have the maximum depositing rate, uniform grain growth and acceptable roughness. The XRD patterns of BLTV thin films deposited under optimal parameters are developed as a function of RF power and the results are shown in Fig. 2. In Fig. 2, the strongest diffraction peak (2θ= 30^o) along the (117) plane of SiO_2/Si substrate could be observed from the XRD patterns. For the BLTV orientation, the crystalline intensity of (117) plane increases with the increase of RF power. The crystal intensity of (117) plane of BLTV thin film prepared at 130 W is stronger than other planes of BLTV thin films under different RF power. These results suggest that different RF power has the different re-sputtering effect to influence the characteristics of BLTV thin films and it is an important parameter to influence the characteristics of BLTV thin films.

From the observation of C-V curves, the capacitance decreases with the increase of RF power, reaches a minum at RF power of 130 W and then decreases at 70 W. As the RF power increases from 70 to 130 W, the ε_r values of BLTV thin films critically decreases as the RF power of 130 W is used. The change of crystalline structure and the decrease of roughness may be the reason to decrease the dielectric constant in the 130 W as-deposited BLTV thin films.The leakage current density of the as-deposited BLTV thin film was about 10^{-11}A/cm^2 the applied voltage of 20 V. From the results obtained, the leakage current density of the as-deposited BLTV thin films for 100 W rf power was lower than those for 130 W RF power.The denser and smooth surface of the BLTV film could be attributed this reason.

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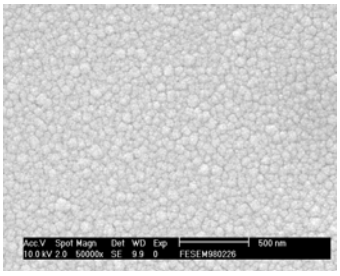

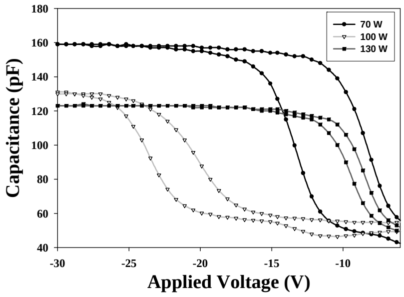

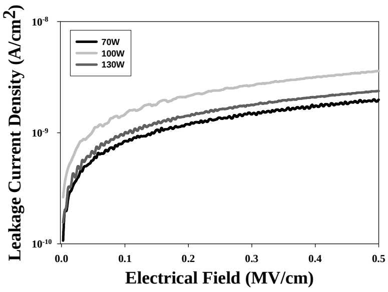

Fig. 3. SEM micrographs of the BLTV thine film in the MFIS structure the RF power is 100w.

Fig. 4. The leakage current density of

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