Preparation of the SBT Film on the LZO/Si Structure for FRAM Application

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Abstract : To fabricate the metal-ferroelectric-insulator-semiconductor (MFIS) structure for the ferroelectric random access memory (FRAM) application, we prepared the ferroelectric $Sr_{0.9}Bi_{2.1}Ta_2O_9$ (SBT) and the insulator LaZrOx (LZO) thin films on the silicon substrate using a sol-gel method. In this study, we will investigate the feasibility of the SBT/LZO/Si structure as one of the promising gate configuration for the 1-transistor (1-T) type FRAM, by measurements of the electrical properties and the physical properties.

Key Words : FRAM, MFIS, $Sr_{0.9}Bi_{2.1}Ta_2O_9$, $LaZrO_x$

1. Introduction

As one of the next-generation non-volatile memories, the ferroelectric random access memories (FRAM) have attracted much attention [1]. In particular, the ferroelectric-gate field-effect transistors (Fe-FETs) with a single-transistor memory cell have promising advantages of the high-density integration and the non-destructive read-out operation [2]. Despite its superior potential, however, the short retention time caused by poor interface properties between the ferroelectric film and the Si substrate is one of the most serious problems for the Fe-FETs [3]. One possible solution to overcome interface problem is the incorporation of one insulating buffer layer between the ferroelectric film and the Si to obtain a metal-ferroelectric-insulator-semiconductor (MFIS) structure [4]. Several buffer layers such as ZrO_2, HfO_2, $LaAlO_x$, or $HfAlO_x$, have been investigated [5-8].

In this study, we investigated the $Au/SrBi_2Ta_2O_9/LaZrO_x/Si$ MFIS structure for a Fe-FETs application. The $LaZrO_x$ (LZO) with a dielectric constant of ≈20 has been tried as a buffer insulator for the superconductor $YBa_2Cu_3O_{7-x}$ (YBCO) [9]. In particular, it has been reported that the LZO has a cubic pyroclore structure with a lattice parameter, which leads to a mismatch of 0.68% with Si ($2a_{Si}$=10.86Å) [10]. The $SrBi_2Ta_2O_9$ (SBT) as a ferroelectric is one of the most promising candidates because of its high fatigue endurance, good retention and low leakage current [11].

2. Experiments

We prepared the $LaZrO_x$ (i.e., molar ratio of La/Zr=1) solution of 0.1 M concentration and the $Sr_{0.9}Bi_{2.1}Ta_2O_9$ solution of 0.3M concentration, respectively.

To fabricate the LZO/Si structure, p-type Si(100) wafer was used as a substrate. The substrate was dipped in a dilluted HF solution to remove the native oxide layer from the surface of Si. We spin-coated the LZO solution on a Si at 4000 rpm for 25 seconds. The coated LZO film was annealed at 750 ℃ for 30 minutes in O_2 ambient by rapid thermal annealing (RTA).

The SBT film was deposited on the LZO/Si structure to form a SBT/LZO/Si structure. The SBT solution was also spin-coated at 3000rpm for 20 seconds. The coated films were dried at 250 ℃ for 10 minutes on hot-plate to remove organic material. After several repetitions of these processes to obtain the desired thickness, the films were finally crystallized at 800 ℃ for 30 minutes in O_2 ambient by RTA. For electrical measurements, Au electrodes were formed onto the samples using shadow mask by thermal evaporation.

The physical and electrical properties of SBT/LZO/Si structure were measured by atomic force microscopy (AFM) and x-ray diffraction (XRD) measurement, HP 4280A capacitance-meter and HP 4155C precision semiconductor parameter analyzer, respectively.

3. Results and Discussion

Fig. 1 shows the AFM images of LZO/Si and SBT/LZO/Si structure. The measured area was 500× 500nm^2 and 2×2μm^2 for LZO/Si and SBT/LZO/Si structure, respectively. The surface roughness of LZO thin film was 0.359nm. The deposited LZO film has very flat and smooth surface morphologies. Surface roughness of buffer layer is very important because the surface structure of a buffer insulator affects the electrical properties of the MFIS structure. The surface roughness of SBT/LZO/Si was 11.373nm . The measured values are indicated that it is a little bit rough surface morphology.

Fig. 2 shows a typical capacitance-voltage(C-V) characteristic for Au/LZO/Si and Au/SBT/LZO/Si structures. C-V curve of Au/LZO/Si appears no hysteresis loop in Fig. 2(a). The equivalent oxide thickness(EOT) value, derived from the accumulation capacitance, was 8.83nm. As shown in Fig. 2(b), the C-V curve showed the clockwise hysteresis loops as the arrows indicated, which related with the ferroelectric behavior of the SBT film. The memory window width increases as the bias voltage increases from ±2V to ±8V. The value of memory window width was about 0.8V for the bias voltage with ±5V sweep range.

Fig. 3 shows the typical XRD patterns of the SBT films, deposited on LZO/Si structure and annealed at 800℃. These patterns revealed that SBT films were crystallized in polycrystalline phase with random orientation.

As shown Fig. 4, the value of leakage current density Au/SBT/LZO/Si structure was lower than 1×10^{-7} A/cm^2 at 8V. This rusult shows that the insulating property of the LZO film is good.

4. Conclusions

We fabricated MFIS structure of Au/SBT/LZO/Si by a sol-gel method. The equivalent oxide thickness (EOT) values of LZO thin film was about 8.83㎚. AFM images of the LZO film showed a very flat and smooth surface morphology. SBT films on LZO/Si structure showed the typical XRD patterns and the C-V curve showed the clockwise hysteresis loops. Also, the memory window width increases as the bias voltage increases and the value of memory window width was about 0.8V for the bias voltage with ±5V sweep range. The value of leakage current density was lower than 1×10^{-7} A/cm^2 at 8 V.

From these experimental results, Au/SBT/LZO/Si MFIS structure with $LaZrO_x$ buffer layer is suitable for ferroelectric random access memory application.

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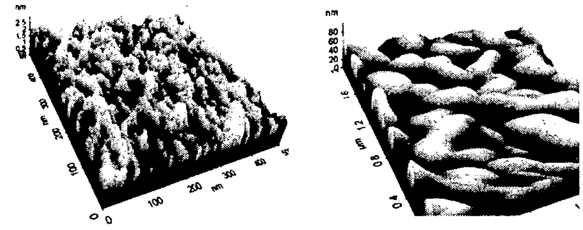
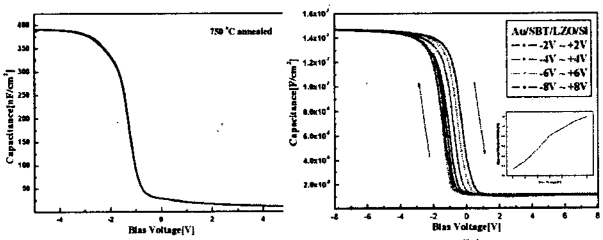


(a) (b)

Fig. 1 AFM image of LZO (a) and SBT (b) film



(a) (b)

Fig. 2 Capacitance-voltage characteristics of Au/LZO/Si (a) and Au/SBT/LZO/Si (b) at 1MHz

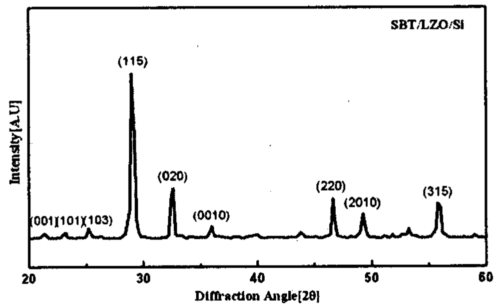


Fig. 3 X-ray diffraction pattern of SBT film on LZO/Si

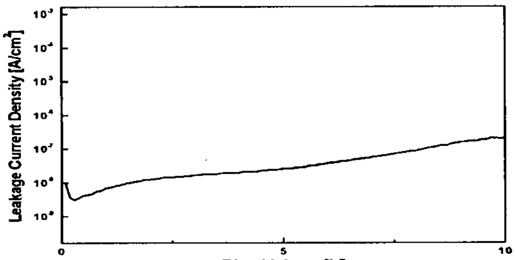


Fig. 4 Leakage current density of Au/SBT/LZO/Si