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Low Voltage Operation of Ferroelectric $Sr_{0.9}Bi_{2.1}Ta_2O_9$ Thin Films Crystallized by Excimer Laser Annealing

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1. Introduction

Non-volatile memory using ferroelectric thin film has been proposed as next generation memory, and research on this type of memory has been quit actively in recent years. Ferroelectric $SrBi_2Ta_2O_9$ thin films (SBT films) are attracting attention because they do not suffer from fatigue when polarization switching occurs[1]. Moreover, SBT films may possibly be operated at voltages as low such as 1.5V[2]. In a previous study we have prepared SBT films by an originally-developed sol-gel method[3]. In this study, we report the low voltage operation of ferroelectric $Sr_{0.9}Bi_{2.1}Ta_2O_9$ thin films crystallized by excimer laser annealing of thin SBT films for low voltage operation.

2. Experimental Method

The SBT film used for this study was deposited in an originally-developed alkoxide-based solution[3]. We formed a 100 nm thick SiO_2 oxidized film on a 6-inch Si wafer, then formed a 60 nm Pt lower electrode by sputtering. This solution was coated onto a substrate using a spin coater operating at 2,000 rpm. The coated film was dried for 30 minutes at 150°C and prebaked for 60 minutes at 450°C. This cycle was repeated twice. After coating and prebaking, the prebaked film was annealed by excimer laser (Lambda 4308, The Japan Steel Works, Ltd.) at various power settings (from 75 to 300 mJ/cm^2). Then, a 200nm diameter upper Pt electrode was formed by RF sputtering through a metal mask. The samples were heat treated at 700 or 800 °C for 30 minutes with a temperature rise rate of 10°C/min. The SBT film was 0.10 μm thick after crystallization. Hysteresis loops were measured by RT6000S (Radiant Co. Ltd.).

3. Results and Discussion

3.1. Electric properties

Figure 1 shows the hysteresis loops of SBT films annealed at 150 mJ/cm^2. Well-saturated hysteresis loops with high squareness values (remanent polarization / saturation polarization, Pr/Ps) are observed at applied voltages ranging from 1 to 5V. As shown in Fig.1, a well-saturated hysteresis loop may be clearly observed at an applied voltage of only 1V. Figure 2 demonstrates the effect of applied voltage on the Pr, Pr/Ps and coercive field (Ec) of the SBT films, using the values at an applied voltage of 5V as a standard (with the values at 5V equal to 1.0).

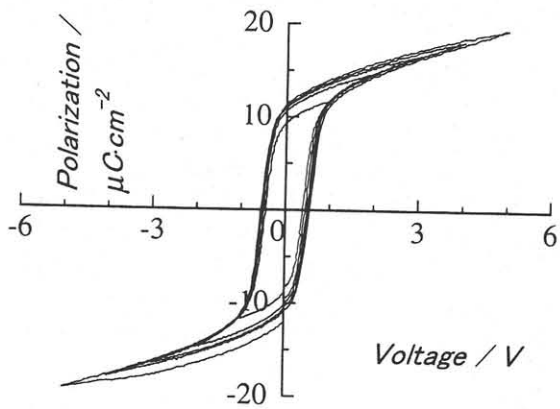


Fig.1 Hysteresis loops of SBT films annealed at 150mJ/cm^2.

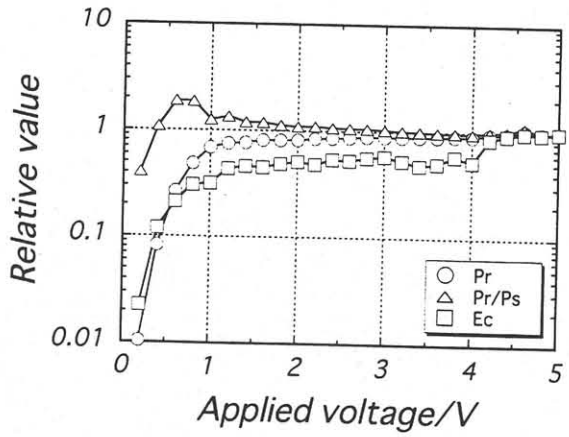


Fig.2 Effect of applied voltage on remanent polarization (Pr), squareness (Pr/Ps) and coercive field (Ec) of SBT films shown in Fig.1.

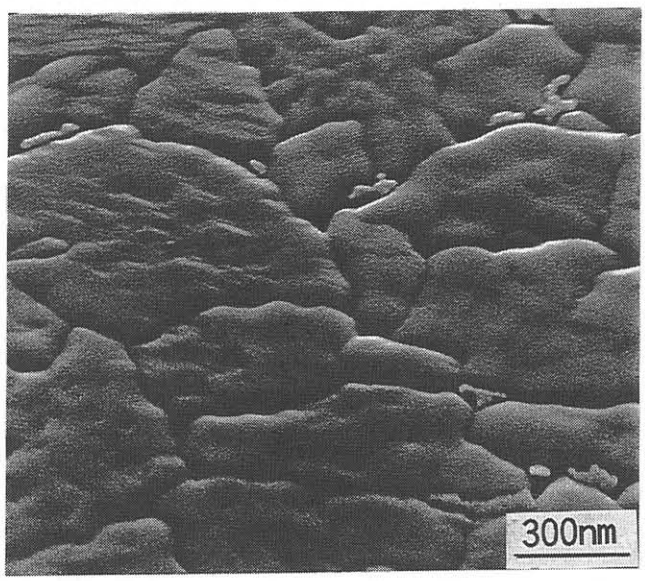
Up to 1V, all values change abruptly with increasing applied voltage, but then change gradually in the higher applied voltage region. The Pr value (circle) increases abruptly with increasing applied voltage up to 1V, but then increases gradually in the higher applied voltage region. The Pr/Ps value (triangle) increases abruptly with increasing applied voltage up to 0.6V, but then decreased up to 1V and reaches constant value. Up to 0.6V, an increased amount of Pr is

greater than that of Ps, then the Pr/Ps values increases abruptly. An increasing tendency of the Ec value is almost the same as that of the Pr value. As shown in Fig.2, all values almost saturate at an applied voltage of only 1V. Therefore, the SBT films may be operated 1V. When the same thick SBT films were annealed by furnace annealing (FA) or rapid thermal annealing (RTA), they had such a high leakage current density that their hysteresis loops have not been measured. Only by the excimer laser annealing, the clear hystersis could be observed.

3.2. Structure

Figure 3 shows SEM micrographs of the surface (a) and cross-section (b) of the SBT film. The surface of the SBT film demonstrates the closely packed grain structure that is a characteristic of this sol-gel method, which is quite different from the rod-like structure of the SBT films prepared by MOD[4]. Figure 3b shows cross-sectional SEM micrographs of the SBT films. Uniform cross-section is observed with no voids. It is known that the SBT crystals show anisotropic growth, the growth rate of direction parallel to c-plane is much higher than that normal to c-plane and show rod-like structure. The anisotropic growth tends to make voids between grains and increases leakage current density. As shown in Fig.3a, the SBT films prepared by sol-gel method shows closely packed grain structure. However some void are observed for the SBT films by the sol-gel method except for excimer laser annealing. As mentioned above, a high leakage current density makes measurement of hysteresis loops impossible. Since the SBT film show clear hysteresis loops, this structure makes the leakage current density low. This close structure keeps the leakage current density low and makes low-voltage operation possible. Moreover, the thin SBT film with no void is good for etching, because a SBT film containing Sr is hard materials to etch.

a) Surface



b) Cross-section

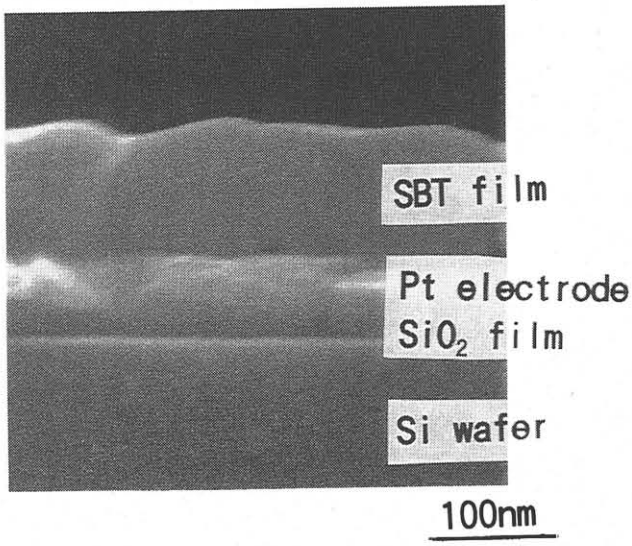


Fig.3 SEM micrographs of SBT films shown in Fig.1 and 2.
a) Surface
b) Cross section

4. Conclusion

Excimer laser annealing of SBT films was studied and the following results were obtained.

1) Hysteresis loops could be observed in SBT films with a 0.1mm thickness because of their low leakage current density.
2) Since a well-saturated hysteresis loop may be obtained at an applied voltage of 1V, the film shows possibilities for 1V operation.
3) The surface morphology of the SBT film has a closely packed grain structure.
4) The cross-section is close in structure, and no voids are observed.

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