Thickness Effects on Electrical Properties of PVDF-TrFE (51/49) Copolymer for Ferroelectric Thin Film Transistor

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Abstract : In this study, polyvinylidene fluoride/trifluoroethylene (PVDF-TrFE) was investigated. For a metal-ferroelectic-metal (MFM) structure, We obtained that the 70 nm-thick film showed the maximum polarization of 8.24 μC/cm^2, 2Pr of 6 μC/cm^2 and the coercive voltage of ±3.1 V at 12 V. The 140 nm-thick film showed higher performance. However, the thicker film required a higher voltage. The current density was 10^{-6} ~ 10^{-7} A/cm^2 under 15 V. We can expect from these results that the electrical properties of the devices particularly ferroelectric thin film transistor using PVDF-TrFE copolymer, be able to be on the trade-off relationship between the remanent polarization and the leakage current.
Key Words : PVDF-TrFE, ferroelectric, thickness, FeRAM

1. Introduction

Polyvinylidene fluoride-trifluoroethylene (PVDF-TrFE) copolymer exhibits much superior ferroelectricity than those of β-phase PVDF. Recently researches to make ferroelectric nonvolatile memories with PVDF-TrFE begun in the 1990s, but the most of the activities faced a significant problem in reducing the operating voltages. In most cases, operating voltages were as large as 100 V or more [1]. The thickness of the polymer film should be as thin as possible so that the operating voltage can be low and this lower thickness limit is determined by the thickness at which the ferroelectric response remains relatively high [2]-[3].

In this work, we tried to investigate the electrical properties of the PVDF-TrFE (51/49) by changing the thickness of the film from 50 to 140 nm by spin-casting method for the ferroelectric thin film transistor.

2. Experiments

The PVDF-TrFE copolymer in the composition of 51/49 was studied. For spin-coating process, the material was dissolved in methylethyketone. The PVDF-TrFE solution was deposited on the Pt/Ti/SiO_2/Si substrate by spin-casting. To vary the thickness from 50 nm to 140 nm, we controlled the concentration of the solution and velocity of spinning. The coated films were dried at 120 ℃ on a hot-plate. For a metal-ferroelectric-metal (MFM) structure, Au electrodes were thermally evaporated onto the top of the sample using a shadow mask patterned with circle dot shapes (radius = 50 μm). The electrical properties of the samples were characterized using the Precision LC parameter analyzer (Radiant Tech., Inc.).

3. Results and Discussion

The research on the thickness dependence behavior showed that the polarization level decreased and switching field increased with the thickness reduction. Moreover, a large drop of the polarization was observed as the film thickness reduced to below 100 nm [4-6]. Figure 1(a) shows the polarization-electrical field (P-E) hysteresis curves of the metal-ferroelectric-metal (MFM) structure with the PVDF-TrFE (51/49) thin film with the different thickness. As it can be seen in Fig. 1(b), the 2Pr value gradually decreased from 10.19 μC/cm^2 to 6.47 μC/cm^2 as

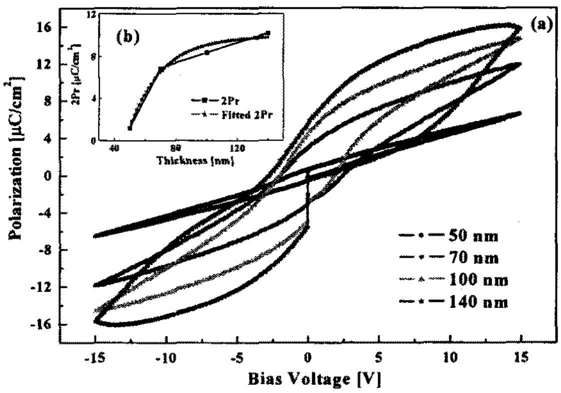

Figure 1(a) The P-E curves of the PVDF-TrFE(51/49) biased at ±15 V and (b) the tendency of the 2Pr value with the different film thickness.

the film thickness decreased from 140 nm to 70 nm. However, for the 50 nm-thick PVDF-TrFE (51/49) thin film, 2Pr value dropped sharply to 1.19 μC/cm^2. In the case of saturation voltage, on the other hand, the thicker film required the higher bias voltage to be saturated. For 140 nm-thick film, the saturation voltage was over 20 V. It meant that the appropriate thickness should be found in a range of 50 nm to 140 nm for application to memory device which would be operated at lower bias voltage.

Figure 2 shows that the leakage current density of the PVDF-TrFE (51/49) film. The leakage current density was as low as 1x10^{-6} A/cm^2 and 4x10^{-7} A/cm^2 at 10 V for 70 nm-thick and 140 nm-thick films, respectively. The thicker film showed the better insulating performance. When the VDF composited with TrFE to form PVDF-TrFE, the introduction of TrFE is very effective to obtain the ferroelectric phase, but enhances leakage current along dipole moment directions in a molecule. Sumiko Fujisaki *et. al.* presented that the leakage current density of the PVDF-TrFE (77/23) film was 1x10^{-5} A/cm^2 below only 5 V [7]. However, although the PVDF-TrFE (51/49) film in our work has larger TrFE than result of Sumiko Fujisaki *et. al.* report, the leakage current density was as low as 1x10^{-6} A/cm^2 at 15 V. On the other hand, 2Pr value was rather lower than result of Sumiko Fujisaki *et. al.* report. This phenomenon might be attributed to the short annealing time in our study. Thus we tentatively concluded important that electrical properties (polarization and leakage current) of the PVDF-TrFE film were

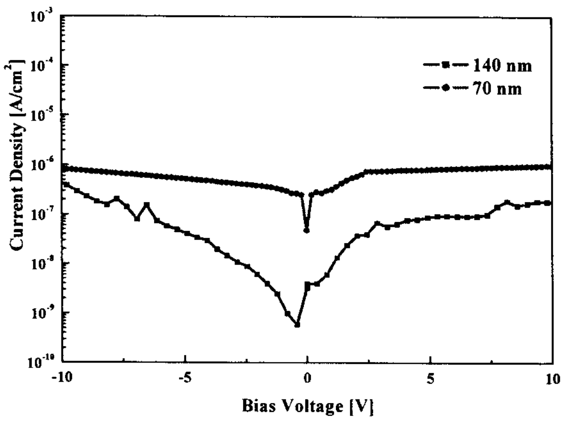

Figure 2. The characteristic of current density-voltage (J-V) with 70 nm, 140 nm-thick film.

strongly affected by annealing time and thickness as well as its composition ratio.

4. Conclusions

In this study, we investigated electrical properties of the PVDF-TrFE (51/49) film with the different film thickness. It was revealed from the P-E characteristics of the Au/PVDF-TrFE(51/49)/Pt structure that the remanent polarization value decreased, as the film thickness decreased. For below 70 nm, however, the remanent polarization value dropped sharply. The leakage current densities of the 70 nm-thick and 140 nm-thick films were as low as 1x10^{-6} A/cm^2 and 4x10^{-7} A/cm^2 at 10 V, respectively.

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