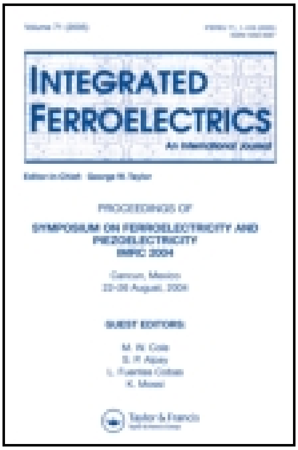

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Effects of Thermal Stabilities for the Ultra Thin Chromium Layers Applied on $(Ba,Sr)TiO_3$ Thin Films

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This work reports the temperature-electric properties for the $(Ba,Sr)TiO_3$(BST) thin film capacitor using the multi-film structure of BST/ultra-thin-chromium(Cr) layer/BST. The BST(200 nm)/Cr(1–3 nm)/BST(200 nm) multi-films reveal excellent properties in the thermal stabilities of dielectric property, low leakage current and less power dissipation.

Keywords: BST (77.84.−s); thermal stability (68.60.Dv); dielectric property (77.55.+f)

INTRODUCTION

In past decades, many studies showed that the BST film, applied on Gigabit DRAMs' capacitor, had poor thermal stability and large leakage current [1–4], so the multi-film structure of BST/ultra-thin-chromium(Cr) layer/BST was investigated to enhance the thermal stability and reduce the leakage in this study.

EXPERIMENTS

The multi-film capacitors of BST(200 nm)/ultra-thin-Cr(1–3 nm)/BST (200 nm) were fabricated on $Pt/Ti/SiO_2/Si$ substrates using radio frequency

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magnetron co-sputtering technique. The current-voltage characteristics were measured by HP-4156C. The dielectric properties and the tangent loss were investigated by HP4194 analyzer. The electric-temperature testing was carried out using a hot plate.

RESULTS AND DISCUSSIONS

Figure 1 shows the properties of the leakage current versus Cr-thickness for the BST/Cr/BST multi-film under electric field of 200 KV/cm. The leakage current strongly depends on the thickness of the ultra-thin Cr film, and it exhibits minimum value at the Cr thickness of 2 nm. Besides, the leakage current increases as temperature rises; however, the current for the films with 2 nm Cr layer at 150°C is still lower than that without Cr layer at room temperature. Thus, the optimum leakage current properties can be obtained under the proper thickness control of the Cr film.

The thermal variation factor (TVF) of a capacitor is defined below.

$$TVF_{(C)} = \frac{(C_{T1} - C_{T2})}{C_{T1}(T_1 - T_2)} \tag{1}$$

where T is the measurement temperature, and C_{T1} & C_{T2} are the capacitances measured at T_1 & T_2. Figure 2 shows that the TVF of the films with Cr

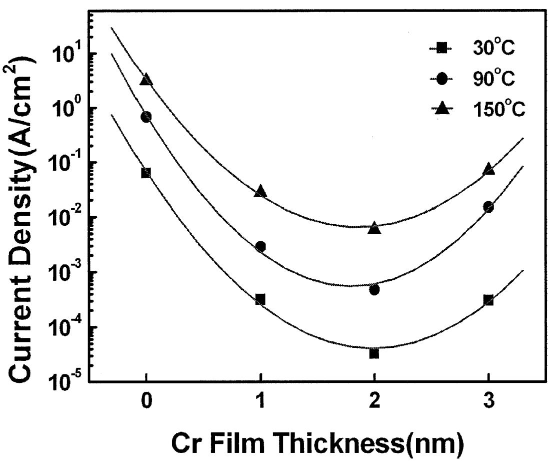

FIGURE 1 The leakage current versus Cr thickness at various measuring temperatures.

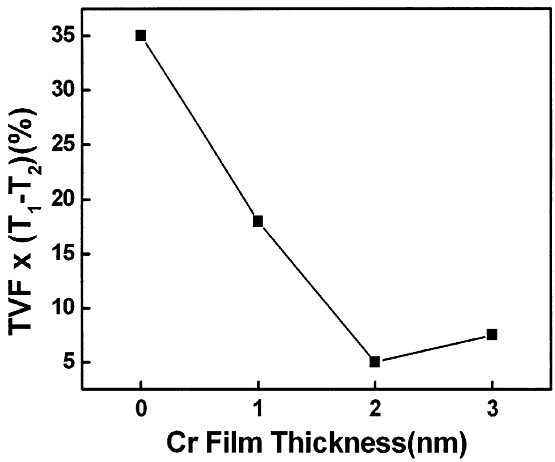

FIGURE 2 Thermal variation factor (TVF) for the capacitance of the BST/Cr/BST multi-film measured at $T_1 = 30°C$ and $T_2 = 150°C$.

medium-layer is greatly lower than that without Cr layer. In other words, the capacitance variation at different temperature can be dramatically reduced while the Cr layer is applied as the medium-layer of the BST capacitor. The minimum TVF, about 5% for 120°C temperature difference, is observed at the Cr thickness of 2 nm, so the excellent thermal stability of capacitor can be achieved by adjusting Cr thickness.

Figure 3 depicts the dispersion relation of the tangent-loss for the BST films with/without medium-Cr-layer. The resonant frequency of the BST(200 nm)/Cr(2 nm)/BST(200 nm) multi-film is a little higher than that of mono BST film (400 nm). The resonant frequency shifts about 600 kHz with temperature for the mono BST film, but it almost keeps the same for the BST/Cr/BST multi-film. The tangent loss of the BST films with/without medium-Cr-layer increases as temperature rises, as shown in Fig. 4. Hence, the resistive loss dominates the mechanism of the tangent loss. In addition, the tangent loss of the BST/Cr/BST film is lower than that of the mono BST-film due to lower leakage current for the films with Cr layer, as mentioned in Fig. 1.

X-ray diffraction reveals no significant differences of the crystallinity between the BST(200 nm)/Cr(2 nm)/BST(200 nm) and the mono BST film (400 nm), but, intriguingly, the films with/without medium Cr-layer behave large differences in leakage current and the temperature-electric properties.

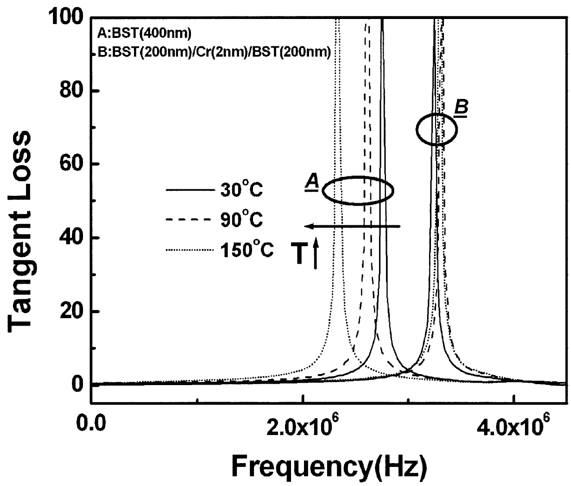

FIGURE 3 The dispersion relation of tangent loss for the mono BST film (400 nm) and the BST(200 nm)/Cr(2 nm)/BST(200 nm) multi-film under different measuring temperatures.

It can be inferred that the BST/Cr interface strongly influences the electric properties. The leakage current may be suppressed by the scattering centers formed by the discontinuous Cr clusters of ultra-thin Cr film, but the current will rise again due to the improved interface when the thickness of the Cr

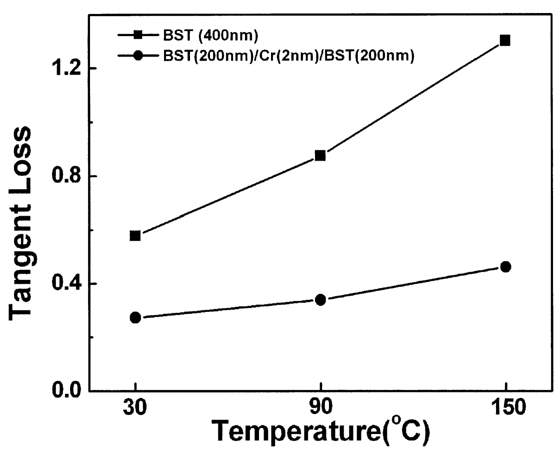

FIGURE 4 The tangent-loss versus temperature for the mono BST film (400 nm) and BST(200 nm)/Cr(2 nm)/BST(200 nm) multi-film at 1 MHz.

film increases. Besides, the series interface-capacitor of BST/Cr layers may result in the insensitive dielectric-temperature behaviors.

CONCLUSIONS

The BST/Cr/BST multi-film with ultra thin Cr layer shows excellent electric behaviors and thermal stabilities. The leakage current can be greatly suppressed while the Cr film with proper thickness is applied on this structure. The fluctuation of the dielectric properties and resonant frequency at various temperatures can be minimized using the ultra-thin Cr layer. Hence, the optimum electric and dielectric properties can be obtained by adjusting the proper Cr thickness.

ACKNOWLEDGEMENTS

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