A giant dielectric permittivity of BMNO-Bi composite films grown at room temperature by radio-frequency sputtering

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Introduction

The dielectric behaviour of ferroelectric-metal bulk composites has attracted much attention due to extraordinary dielectric enhancement.[1-2] Metal nanocrystals self-assembled in dielectric thin films grown at room temperature were expected to enhance the dielectric permittivity of the films.

Experimental Procedure

A BMNO ceramic disk 2 inches in diameter was used as a target and the rf-power was maintained at 40 W. The base and working pressures were 8 × 10^{-4} and 7 × 10^{-1} Pa, respectively. The BMNO-Bi composite films were grown *in situ* in a pure argon atmosphere of 100 sccm using a single BMNO target. Self-assembled Bi nanocrystals in the amorphous BMNO thin films were identified using high resolution transmission electron microscope (HRTEM) and X-ray photoelectron spectroscopy (XPS), respectively.

Results and discussion

For BMNO protection layer, variations in capacitance density and the dielectric permittivity for thickness were shown in Fig. 1(a). 40-nm-thick BMNO films showed a dielectric permittivity of 30. Leakage current density of the BMNO films for various film thicknesses was shown in Fig. 1(b). 40-nm-thick BMNO films showed about leakage current density of about 10^{-7} A/cm^2 at 5 V. 40-nm-thick BMNO/600-nm-thick BMNO-Bi nano-composite films/40-nm-thick

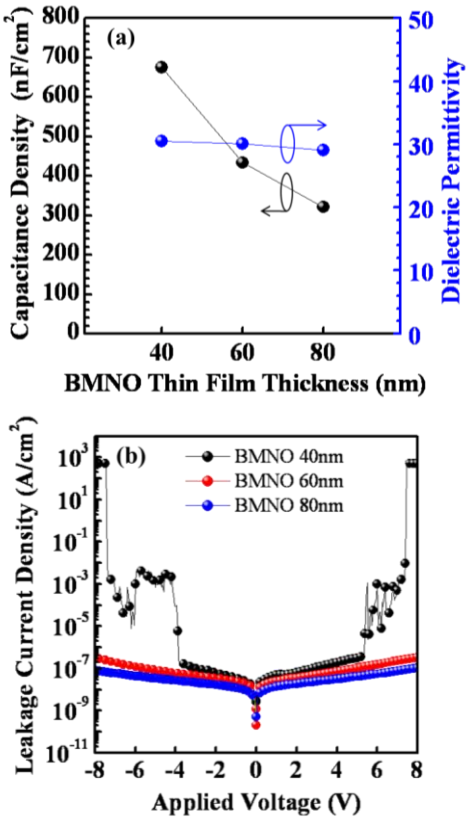

Fig.1 (a) Dielectric properties vs. BMNO film thickness and (b) leakage current vs. voltage for film thicknesses.

BMNO, was clearly observed by TEM cross-sectional images. The "A" and "B" in right side of Fig. 2(a) indicate the clear images in the BMNO protection layer/BMNO-Bi nano-composite film and BMNO-Bi nano-composite film/BMNO protection layer/Cu/Si structure, respectively. The 40-nm-thick BMNO protection layer was identified to be an amorphous structure, while BMNO-Bi nano-composite films were composed of bismuth nanocrystals assembled in the BMNO amorphous.

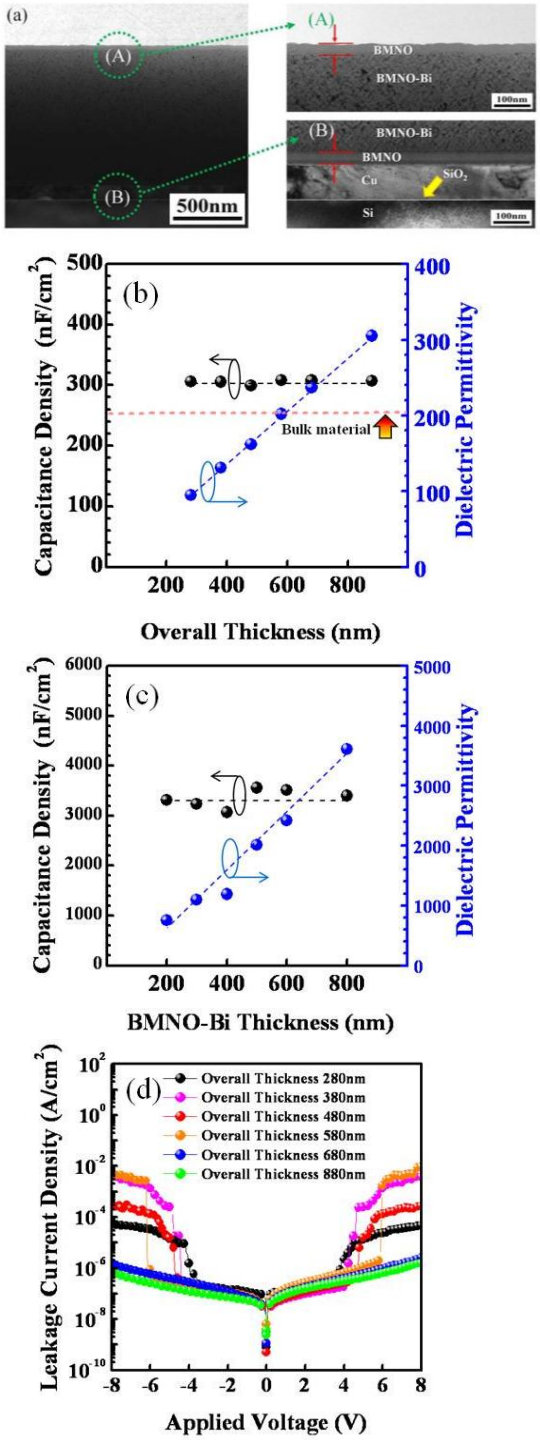

Fig.2 (a) TEM cross-sectional images of BMNO/BMNO-Bi. Capacitance density and dielectric permittivity for (b) overall thicknesses and (c) for composite film thicknesses. (d) Leakage current density vs. voltage for overall thicknesses.

The overall dielectric permittivity of the BMNO/BMNO-Bi nano-composite films/BMNO capacitors, which is shown in Fig. 2(b), showed a typical thickness dependence and the 680-nm-thick films exhibited a dielectric permittivity of ~ 240.

The composite films showed a capacitance density of about 3,000 nF/cm^2 regardless of the film thickness, while the dielectric permittivity of the composite films increased linearly with increasing film thickness, indicating a dielectric permittivity of about 3,600 at a thickness of 800 nm (Fig. 2(c)). The 280 and 480-nm-thick films exhibited a breakdown voltage of about 4 and 5 voltage, respectively. However, films of thicknesses above 680 nm showed the leakage current densities below ~ μA/cm^2 at 8 V (Fig. 2(d)).

Conclusions

The 800-nm-thick BMNO-Bi nano-composite films sandwiched between 40-nm-thick BMNO protection layers exhibited a dielectric permittivity of about 310. The 800-nm-thick BMNO-Bi composite films showed a capacitance density of 3,000 nF/cm^2 and a dielectric permittivity of 3,600.

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