Boosting Energy Storage Performance of Low-Temperature Sputtered $\text{CaBi}_2\text{Nb}_2\text{O}_9$ Thin Film Capacitors Via Rapid Thermal Annealing

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Abstract

CaBi₂Nb₂O₉ thin film capacitors were fabricated on SrRuO₃-buffered Pt(111)/Ti/Si(100) substrates by adopting a two-step fabrication process. This process combines a low-temperature sputtering deposition with a rapid thermal annealing (RTA) to inhibit the grain growth, for the purposes of delaying the polarization saturation and reducing the ferroelectric hysteresis. By using this method, CaBi₂Nb₂O₉ thin films with uniformly distributed nanograins were obtained, which display a large recyclable energy density $W_{\text{rec}} \sim 69 \text{ J/cm}^3$ and a high energy efficiency $\eta \sim 82.4\%$. A superior fatigue-resistance (negligible energy performance degradation after 10⁹ charge-discharge cycles) and a good thermal stability (from -170 °C to 150 °C) have also been achieved. This two-step method can be used to prepare other bismuth layer-structured ferroelectric film capacitors with enhanced energy storage performances.

Full Text

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Figures

Figure 1

(a) XRD 2θ-scan patterns for CBNOA350, CBNOA700, and CBNO350-RTA thin films. (b) (c) (d) The surface and cross-sectional SEM images of the (b) CBNOA350, (c) CBNOA700 and (d) CBNO350-RTA films.

Figure 2

Room-temperature polarization-electric field (P-E) curves for the (a) CBNOA350 and (b) CBNO350-RTA thin films, and (c) (d) their corresponding energy storage performances. The red dashed-line curve in (b) is a representative P-E loop of the CBNOA700 film at its maximum applicable electric field (~ 1 MV/cm).

Figure 3

Room temperature (RT) switching current-electric field curves for (a) CBNOA350 and (b) CBNO350-RTA films under an applied electric field of ~ 2.76 MV/cm. (c) The schematic illustration of the linear dielectric (W_{ln}) and domain backswitching (W_{bs}) contributions to the recyclable energy density W_{rec} of the CBNO350-RTA thin film. (d) The contributions from W_{ln} and W_{bs} to W_{rec} as functions of the applied electric field (at RT).

Figure 4

(a) Frequency-dependent dielectric constant (ϵ_r) and loss tangent ($\tan\delta$) and (b) leakage current density of the CBNOA350, CBNO350-RTA and CBNOA700 films (at RT). (c) Recyclable energy storage density and energy efficiency as functions of charge-discharge cycles (at RT) for the CBNO350-RTA film, and the corresponding P-E hysteresis loops and performance stabilities ($W_{rec}/W_{rec-1st}$ circle, η/η_{1st} circle) at different stages of the cycling test. (d) Thermal stabilities (W/W_{RT} , $\square$ RT) of W_c , W_{rec} and η for the CBNO350-RTA film.