



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Enhanced energy storage performance of BaTiO₃ and BiFeO₃ - based dielectric ceramics and their thin films for capacitor applications

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SHORT ABSTRACT

The rising global demand for energy consumption for meeting the commercial and economic growth concerns for sustainable energy resources, generation, harvesting, and storage. The energy storage devices include electrochemical capacitors, batteries, fuel cells, and dielectric capacitors. Among these storage devices, dielectric ceramics offer inherently high power density and ultrafast charging/discharging time ranging from micro-nano to second time. This thesis mainly focuses on lead-free dielectric ceramics and thin films for energy storage applications. A detailed investigation of two systems, (1-x)BaTiO₃-xBiFeO₃ (BTBF) and (1-x)BaTiO₃-xBi[Zn_{2/3}(Nb_{0.85}Ta_{0.85})_{1/3}]O₃ (BT-BZNT) from BaTiO₃-BiMeO₃ (where Me is trivalent or average trivalent metal ions) solid solution family in the bulk form is carried out. The ferroelectric studies for both compositions are analyzed to evaluate energy storage performance. The BTBF3 composition displayed a W_{rec} and η (%) of ~ 40 mJ/cm³ and 60.92%, respectively, at 25 kV/cm applied field, which is sufficiently lower as compared to other BaTiO₃-BiMeO₃ systems. A significant improvement in energy storage performance is observed in BT-BZNT ceramics. A remarkably high W_{rec} of 2.06 J/cm³ with an η (%) of 78% is achieved for BT-BZNT3 ceramics at an applied field of 180 kV/cm. The ultrahigh-energy efficiency of up to 96% is observed for higher concentrations in BT-BZNT ceramics. Herein, BT-BZNT3 and BT-BZNT4 ceramics exhibited a comparable energy storage performance at a lower applied field of 180 kV/cm, demonstrating the excellence of BT-BZNT ceramics over other BaTiO₃-BiMeO₃ family.

Similarly, the BLFO thin films at different oxygen partial pressures (OPPs) (15, 20, 25, and 30 SCCM) are deposited on n-type silicon and quartz substrates using pulsed laser deposition technique. Among the deposited films, 20 SCCM deposited films exhibited an enhanced energy storage density of 2.09 J/cm³, having an energy efficiency of 78.42% at the applied field of 488 kV/cm. The lower leakage current density of $\sim 1.08 \times 10^{-7}$ is estimated for 20 SCCM film, attributing to dense microstructure and

favorable oxygen ambiance. It is known that the physical properties of ferroelectric thin films are very sensitive to the presence of interfaces. These interfaces will inevitably influence the electrical properties and parameters of ferroelectric devices. Thus, the BLFO/BTO bi-layer thin films with varying top layer thicknesses and BZNT/BTO multi-layer heterostructures with alternate stacking of BTO and BZNT layers are deposited on n-type and Pt Si substrates. The heterostructure with BLFO/BTO3 displays an improved W_{rec} of 11.65 J/cm^3 with η of 85% at 746 kV/cm . The interfacial layer between BLFO and BTO enhances the energy density and efficiency ascribed to the enhancement of E_{BDS} induced via the interfacial barrier effect on the conducting filaments. Similarly, a remarkable enhancement in recoverable energy density (W_{rec}) of 52.19 J/cm^3 with energy efficiency (η) of 92.21% at 2.58 MV/cm is achieved for the higher number of stacking layered films among the BZNT/BTO multi-layer films. The enhancement in energy storage performance may be attributed to the intervening ferroelectric BTO and BZNT layers in the multilayered BZNT/BTO3 films. In both cases, a low value of leakage current density in the order of $\sim 10^{-6} \text{ A/cm}^2$ and $\sim 10^{-7} \text{ A/cm}^2$ is also observed for BLFO/BTO3 and tetra-layer BZNT/BTO films at an applied field of $\pm 500 \text{ kV/cm}$ respectively. The improved response of bi-layer (BLFO/BTO) and multi-layer (BZNT/BTO) films assures their appropriateness for energy storage device applications.

