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Nanocomposites of $Ba_{0.6}Sr_{0.4}TiO_3$-Sm_2O_3 for Enhanced Tunability and Reduced Dielectric Loss

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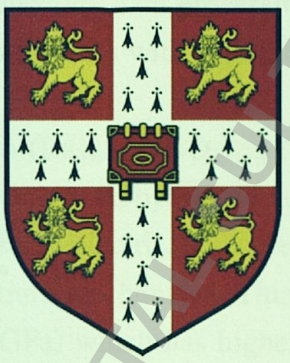

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Abstract

The rapid and enormous progress in the wireless network communication industry has resulted in a demand for tunable radio frequency (RF) and microwave devices. In order to provide a optimal bandwidth, accurate data processing and fast data transmission, the tunable devices based on ferroelectric films with high tunability and low dielectric loss are needed.

This thesis presents a study on $(Ba_{0.6}Sr_{0.4}TiO_3)_{1-x}$-$(Sm_2O_3)_x$ denoted as BSTO-SmO nanoscaffold composite ferroelectric grown by pulsed laser deposition. The work focuses on the new paradigm in ferroelectric, dielectric, piezoelectric and leakage current property control that arises from vertical strain mechanism. This vertical strain control is induced from the stiff Sm_2O_3 phase (125 GPa) which has higher elastic moduli in comparison to $Ba_{0.6}Sr_{0.4}TiO_3$ phase. As a result, a structural distortion with high tetragonality (c/a ratio of 1.0303) is observed in $Ba_{0.6}Sr_{0.4}TiO_3$ (BSTO).

The high tetragonality of the BSTO phase has found to have significant impact on the tunability (dielectric permittivity manipulation via electric field), where the high tunability (76%) scales inversely with loss. This behaviour is opposite to what has been demonstrated in previous reports. Furthermore, the BSTO-SmO with $x = 0.75$ film remains ferroelectric from room temperature to high temperature (beyond 400°C), while maintaining high tunability (76%), low temperature coefficient of tunability (0.18%/°C) as well as piezo-poling (attains up to 120 °C). Low dielectric loss values of <0.01, which is within the acceptable range for practical applications, has been achieved. The BSTO-SmO films also possess low leakage current density ($<10^{-9}$A/cm^2), significantly lower than the BSTO films. In addition, the X-ray diffraction techniques (symmetry rocking curves and the Williamson-Hall plots) which allow a non-destructive method to determine the lateral geometry of the nanocolumns and matrix before conducting any TEM measurement are presented.