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Comparison of Microwave Dielectric Properties of $Ba_{0.6}Sr_{0.4}TiO_3$ Thin Films Grown on (100) $LaAlO_3$ and (100) MgO Single-Crystal Substrates

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The microwave properties of barium strontium titanate ($Ba_{0.6}Sr_{0.4}TiO_3$) thin films grown on (100) $LaAlO_3$ (LAO) and (100) MgO single-crystal substrates through the sol–gel technique were investigated. The interdigital capacitor (IDC) technique was used to measure the nonlinear dielectric properties in the frequency range from 1 GHz to 10 GHz. The results show that the Curie temperature, capacitance, and tunability of the films are strongly dependent upon the substrate. The film fabricated on the $LaAlO_3$ substrate has a higher tunability of 16.77% than that grown on the MgO substrate (~8.38%), measured at 10 GHz with an applied voltage of 35 V. The loss tangent is a linear function of the frequency in the microwave range, and the film grown on the MgO substrate has a lower loss tangent than that grown on the LAO substrate. This work reveals the great potential of $Ba_{0.6}Sr_{0.4}TiO_3$ (BST) films for application in tunable microwave devices.

Key words: Thin film, orientation, dielectric properties

INTRODUCTION

Ferroelectric materials have been extensively studied and become important for a variety of applications such as nonvolatile random-access memory devices, nonlinear optics, thermal sensors, tunable microwave devices, etc. $Ba_xSr_{1-x}TiO_3$ (BST), one of the widely studied ferroelectric materials, is of paramount interest as a medium for tunable microwave passive components.[1] There are now several review articles surveying thin-film ferroelectric microwave devices such as resonators, filters, and phase shifters.[2–4]

The microwave dielectric properties of BST films deposited by various deposition methods have been reported to be affected by many factors, such as oxygen vacancies, film thickness, grain size, dopant type, Ba/Sr ratio, etc.[5] To attain higher tunability and lower loss, many methods have been tried by researchers. These includes multilayers, doping, composites, high-temperature annealing, compensating Ba/Sr deficiencies, etc.[6–9] Moreover, the substrate effect on the structure and dielectric properties of perovskite-structured oxide thin films has also attracted attention in recent years. Systematic study of the structural and microwave dielectric properties of BST thin film is necessary for development and optimization of tunable microwave devices. Therefore, the purpose of this work is to investigate the effect of substrate on the nonlinear dielectric properties of $Ba_{0.6}Sr_{0.4}TiO_3$ thin films at microwave frequencies from 1 GHz to 10 GHz. The films were prepared on LAO and MgO substrates by sol–gel technology, respectively. IDC figures were used to evaluate the microwave dielectric properties of the thin films. In addition, the mechanism of the tunability and loss are discussed.

EXPERIMENTAL PROCEDURES

Barium acetate [$Ba(CH_3COO)_2$], strontium acetate [$Sr(CH_3COO)_2$], and tetra-*n*-butyl titanate [$Ti(OC_4H_9)_4$] were used as starting materials. Glacial acetic acid (CH_3COOH), and acetylacetone ($CH_3COCH_2COCH_3$) were used as solvent and polymerizing agent, respectively. Barium acetate (0.0054 mol) and strontium acetate (0.0036 mol)

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