NOVEL DIELECTRIC THIN FILMS FOR FREQUENCY AGILE MICROWAVE DEVICES

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Electronic scanning antennas (ESA's) are one of the key components for the next generation of advanced communication systems. ESA's provide rapid scanning capability, which enables modes such as multiple target tracking, track while scan and sensor fusion operation [1]. One of the major challenges, which must be overcome before such advanced ESA systems can be realized, is the development of affordable, low loss, high tunability, low power, lightweight, and high performance microwave frequency phase shifters [2, 3]. The enabling technology for such phase shifters is centered on the development of single-phase nano-scale constituent electroceramic thin films with enhanced dielectric, insulating, and microstructural properties [4, 5].

In this work, the influence of low concentration Mg doping on the structural, microstructural, surface morphological and dielectric properties of $Ba_{1-x}Sr_xTiO_3$ (BST) thin films has been evaluated. The films were fabricated via the metalorganic solution deposition (MOSD) technique on PtSi and single crystal (100) MgO substrates using carboxylate-alkoxide precursors and postdeposition annealing at temperatures up to 800 ^{o}C. The structure, microstructure, surface morphology and film/substrate compositional quality were analyzed and correlated to the films dielectric and insulating properties. Specifically, x-ray diffraction (XRD) was used to assess film crystallinity, phase formation and film orientation. Atomic force microscopy (AFM) and field emission scanning electron microscopy (FESEM) were employed to access surface morphology, plan view grain formation, and to detail the films cross-sectional microstructure. The elemental distribution within and across the film-substrate interface was assessed using Auger electron spectroscopy (AES) depth profiling. The films dielectric properties were characterized utilizing both low frequency (100 kHz) and microwave frequency (10 GHz) measurement techniques. The 100 kHz measurements were conducted in the metal-insulator-metal (MIM) capacitor configuration. Capacitance (C_p), dissipation factor (tan δ) and dielectric permittivity (ε_r) were measured with an HP 4192A impedance analyzer. The film's dielectric properties at microwave frequency were measured via the tuned coupled-split dielectric resonator technique. Using this measurement technique, for first time ever, has allowed the true "sole" dielectric loss and permittivity of the BST-based films to be assessed and optimized without the influence of device design (radiative losses) and electrode metallization (conductor losses). The films insulating properties, leakage current (I_L), were evaluated via I-V measurements.

The dielectric properties are summarized in Table I. Table I demonstrates that amounts as low as ~1 mol% of the Mg dopant had a noticeable influence on the dielectric and insulating properties of the thin films. The Mg doped BST films exhibited improved dielectric loss and insulating characteristics compared to the undoped BST thin films. The Mg doping served to modify the film's dielectric and insulating properties by reducing the oxygen vacancy concentration. Mg doping prevented the reduction of Ti^{4+} to Ti^{3+}, by neutralizing the donor action of the oxygen vacancies. Additionally, the Mg dopant served to enhance the insulation resistance of the BST based film. The enhanced material properties of Mg-doped MOSD fabricated BST thin films merits strong potential for utilization in phase shifters, for the next generation of microwave electronic scanning antennas.

TABLE I. Dielectric and insulating properties of the pure and 1 mol% Mg doped BST thin films.

Sample	freq.	ε_r (0 bias)	tan δ (0 bias)	tunability % (300kV/cm)	ρ x10^{12} (Ω-cm)
BST/MgO	10 GHz	406	0.025	---	---
1 mol% Mg -BST/MgO	10 GHz	348	0.022	---	---
BST/PtSi	100 kHz	450	0.013	50.1	0.40
1 mol% Mg -BST/PtSi	100 kHz	423	0.009-0.01	43.0	0.55

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