

Optimization of RF Sputtered Barium Strontium Titanate (BST) Thin Films for High Tunability

T. R. Taylor¹, P. Padmini², J. S. Speck¹ and R. A. York²

¹ Materials Research Laboratory

² Department of Electrical and Computer Engineering

University of California, Santa Barbara, California 93106.

Abstract:

Ferroelectric thin films are currently being used to develop tunable microwave circuits based on the electric field dependence of the dielectric constant. $(\text{Ba}_{0.5}\text{Sr}_{0.5})\text{TiO}_3$ films prepared on Pt/TiO₂/SiO₂/Si substrates are found to exhibit a tunability (defined as $\epsilon_{r(\text{max})}/\epsilon_{r(\text{min})}$; $\epsilon_{r(\text{max})}$ is the relative dielectric constant at zero bias and $\epsilon_{r(\text{min})}$ is the relative dielectric constant at a higher or defined field) of nearly 4:1. This is the highest reported tunability to the authors' knowledge, and until now such tunabilities were only realizable by MOCVD. Our main focus has been to optimize the sputtered BST films for higher tunability for applications such as varactor-diode replacements in transmission lines and the non-linear medium in frequency triplers. BST films were systematically prepared under a range of Ar/O₂ ratios, total pressure, and substrate temperature; it was found that the texture of the deposited film depended on each of these parameters. Predominantly (100) texturing results from an Ar/O₂ ratio of 90/10 (sccm), a sputtering pressure of 50 mTorr, and a 550°C substrate temperature. The dielectric permittivity (ϵ_r) versus bias (V) characteristics of these films shows the highest tunability for (100) textured films. The large field dependence of the dielectric permittivity of the (100) textured films has been attributed to the biaxial tensile stress imposed by Si on BST, making the quasi-polar axis

(c-axis) oriented in-plane; thus, leading to the quasi a-axis parallel to the film normal. In a proper tetragonal ferroelectric $\epsilon_c < \epsilon_a$, which is in agreement with field induced quasi poling and lowering of the dielectric permittivity. The tensile stress in the film arises due to the difference in thermal expansion coefficients between the film ($\sim 7-8 \times 10^{-6}/^\circ\text{C}$) and the Si ($2.5 \times 10^{-6}/^\circ\text{C}$) substrate. This has prompted us to study growth on other substrates with low to high thermal expansion coefficient such as glass ($0.75 \times 10^{-6}/^\circ\text{C}$), and sapphire ($8 \times 10^{-6}/^\circ\text{C}$).