Characterization of Ferroelectric Films by Spectroscopic Ellipsometry

by

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(ABSTRACT)

Process dependent microstructural effects in ferroelectric $SrBi_2Ta_2O_9$ (SBT) thin films were characterized and distinguished from material dependent optical properties using a systematic multi-layer modeling technique. Variable angle spectroscopic ellipsometry (VASE) models were developed by sequentially testing Bruggeman effective-media approximation (EMA) layers designed to simulate microstructural effects such as surface roughness, porosity, secondary phases, and substrate interaction. Cross-sectional analysis by atomic force microscopy (AFM), transmission and scanning electron microscopy (TEM) and (SEM) guided and confirmed the structure of multi-layer models for films produced by pulsed laser deposition (PLD), metal-organic chemical vapor decomposition (MOCVD), and metal-organic deposition (MOD).

VASE was used to estimated the volume percentage of second phase Bi_2O_3 in SBT thin films made by MOD. Since Bi_2O_3 was 10 orders of magnitude more conductive than SBT, second phase Bi_2O_3 produced elevated leakage currents. Equivalent circuits and percolation theory were applied to predict leakage current based on Bi_2O_3 content and connectivity. The complex role of excess Bi_2O_3 in the crystallization of SBT was reviewed from a processing perspective.

VASE helped clarify the nature of the interaction between SBT films and Si substrates. When SBT was deposited by MOD and annealed on Si substrates, the measured capacitance was reduced from that of SBT on Pt due mainly to the formation of amorphous SiO_2 near the SBT/Si interface. VASE showed that the thickness and roughness of the SiO_2 reaction layer increased with annealing temperature, in agreement with TEM measurements. Unlike PZT, SBT crystallization was not controlled by substrate interaction.