Deposition and Characterization of $(Ba,Sr)TiO_3$ for High-Permittivity Applications

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Project Summary:
Thin films of $(Ba,Sr)TiO_3$ (BST) have been extensively investigated as high-permittivity materials for microelectronics applications such as dynamic random access memory (DRAM) and advanced packaging components. By controlling the bottom electrode, electrode/film interface, and film stoichiometry and structure, the dielectric properties of the film can be tailored. In this study, BST thin films will be deposited by metalorganic chemical vapor deposition (MOCVD) at low temperatures (500-575°C) using liquid delivery of metalorganic β-diketonate precursors on Pt/Ti/Si(100), Pt/Cr/Si(100), and MgO(100) substrates. A high dielectric permittivity of $\varepsilon_r \geq 1500$ and low leakage current density of $J_L < 10^{-5}$ A/cm^2 are desired.

Film synthesis and subsequent characterization by grazing incidence x-ray diffraction (GIXRD) confirm that phase-pure crystalline BST films can been obtained by MOCVD. Rutherford backscattering (RBS) and Auger electron spectroscopy (AES) depth profiling indicate the formation of a thick titanium-rich interfacial region at the BST/platinum interface when the BST film is deposited on the Pt/Ti/Si electrode structure. To explore the mechanism behind this interfacial region, BST was deposited on Pt/Cr/Si and MgO substrates, where similar titanium enrichment was not observed. This can be explained by considering the unique catalytic chemistry of the metalorganic BST precursors possible on the bare platinum surface. This catalytic chemistry results in significant titanium enrichment at the platinum interface, until the BST film is thick enough to screen the precursors from the catalytic effects of the platinum. When deposited on an inert substrate such as MgO, BST precursor reaction mechanisms are unchanged from thicker BST deposition. On Pt/Cr/Si, it was found that when heated to deposition temperatures, significant Cr diffusion occurred to the platinum surface, where it oxidized into an inert CrO_x layer. This layer acts as an effective screening barrier between the platinum surface and BST precursors, preventing the formation of a Ti-rich interfacial layer. The presence of the nonstoichiometric interfacial region has adversely affected the dielectric properties of the films obtained thus far (highest $\varepsilon_r = 165$).

The presence of a thick Ti-rich interfacial layer due to catalytic platinum surface chemistry in these BST samples may point to the presence of a similar, if much thinner, layer in very high-quality crystalline thin films. This layer may be one cause of the "dead layer" effect believed responsible for the reduction in dielectric permittivity of thin film BST from the bulk ceramic value. In future work, metalorganic precursor deposition mechanisms on platinum, and effective screening techniques, will be further explored. Once the Ti-rich interfacial region can be minimized or eliminated, the dielectric properties of the films will be studied in detail.

Publications, Presentations, and Proposals:

"Investigation of the Interfacial Region of $(Ba,Sr)TiO_3$ Thin Films Deposited on Pt Substrates by MOCVD." Tiffany Kaspar, Laxmikant Saraf, Chris Aardahl, Scott Lea, Shuttha Shutthanandan, Dave McCready, J.W. (Bill) Rogers, Jr., Tom Dory. AVS 49th International Symposium in Denver, Colorado, November 2002.

Selected Figures:

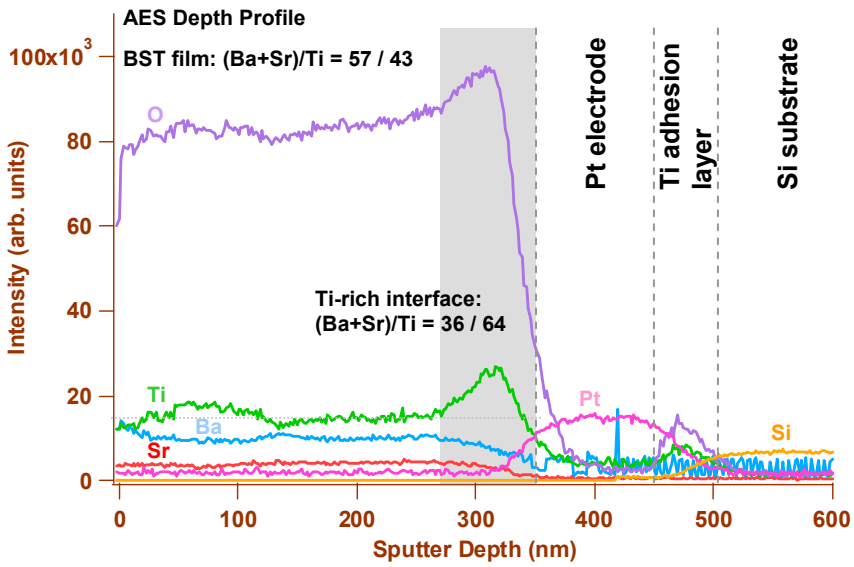

Figure 1: Auger electron spectroscopy (AES) depth profile of a $(Ba,Sr)TiO_3$ (BST) thin film deposited on a Pt/Ti/Si electrode structure by MOCVD. The Ti-rich interface is seen as an increase in the Ti signal in the film near the Pt electrode. The interfacial layer arises due to the unique BST precursor chemistry that occurs on the catalytic platinum surface.

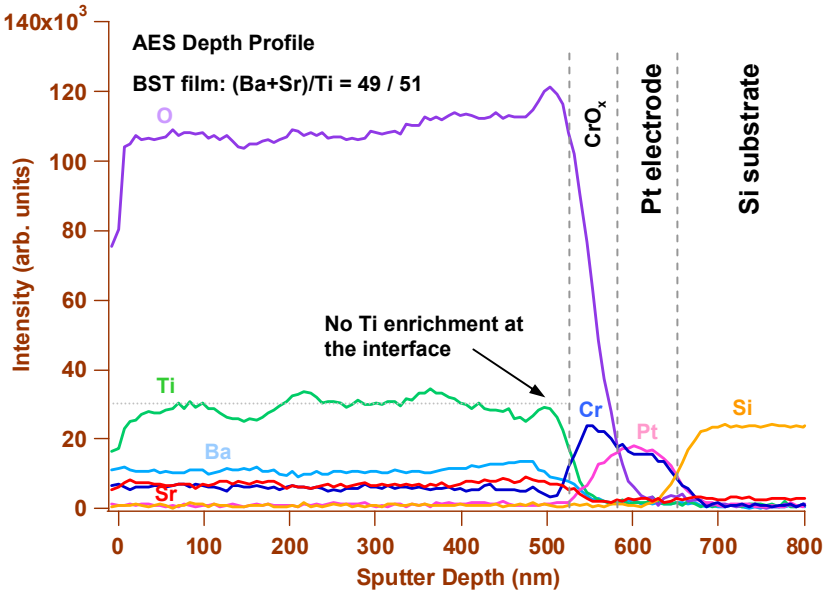

Figure 2: AES depth profile of BST film deposited on Pt/Cr/Si electrode structure by MOCVD. When heated, the Cr in the electrode diffuses through the Pt to form a CrO_x layer at the surface of the electrode structure. This inert oxide screens the BST precursors from the catalytic effects of Pt, which prevents the formation of the Ti-rich interface.