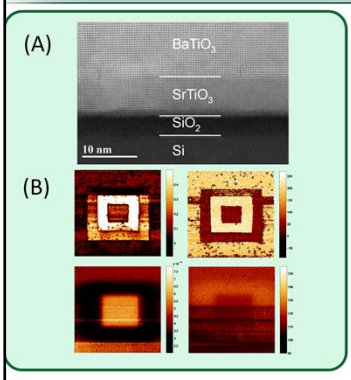
Ferroelectric Switching of $BaTiO_3$ Without Bottom Electrodes



(A) Transmission electron microscope image of a BTO thin film on the Si substrate
(B) PFM amplitude (left) and phase (right) images for a 16 nm (top images) and 1.6 nm (bottom images) BTO films

PFM work was performed at the Center for Nanophase Materials Sciences

Scientific Achievement

Ferroelectric switching of epitaxial $BaTiO_3$ (BTO) thin films has been demonstrated on Si substrates with an out-of-plane c-axis and no bottom electrode.

Significance and Impact

The long suspected but unachieved ferroelectric switching of epitaxial BTO on Si substrates has been reported. This material has direct implications for the development of low temperature and low power consuming field effect transistors, paving the way for the next generation of memory and logic computing devices

Research Details

- BTO thin films were deposited on Si using mature atomic layer deposition techniques
- Synchrotron x-ray diffraction and scanning transmission electron microscopy studies reveal that the long-axis of the tetragonal BTO structure is perpendicular to the Si substrate
- Piezoresponse force microscopy (PFM) studies reveal that the polarization can be switched reversibly with a 180° phase change

C. Dubourdieu, J. Bruley, T.M. Arruda, A. Posadas, J. Jordan-Sweet, M. M. Frank, E. Cartier, D. J. Frank, S. V. Kalinin, A. Demdov, V. Narayanan, *Nature Nanotech.* **2013** *8*, 748

U.S. DEPARTMENT OF ENERGY | Office of Science IBM OAK RIDGE National Laboratory Center for Nanophase Materials Sciences at OAK RIDGE NATIONAL LABORATORY

Epitaxial growth of $SrTiO_3$ on Si by molecular beam epitaxy has opened up the route to the integration of functional complex oxides on a Si platform. Chief among them is ferroelectric functionality using perovskite oxides such as $BaTiO_3$. However, it has remained a challenge to achieve ferroelectricity in epitaxial $BaTiO_3$ films with a polarization pointing perpendicular to the Si substrate without a conducting bottom electrode. Here, we demonstrate ferroelectricity in such stacks. Synchrotron X-ray diffraction and high-resolution scanning transmission electron microscopy reveal the presence of crystalline domains with the long-axis of the tetragonal structure oriented perpendicular to the substrate. Using piezoforce microscopy, polar domains can be written and read and are reversibly switched with a phase change of 180°. Open, saturated hysteresis loops are recorded. Thus, ferroelectric switching of 8-40 nm thick $BaTiO_3$ films in metal-ferroelectric-semiconductor structures is realized, and field-effect devices using this epitaxial oxide stack can be envisaged.

Research conducted at ORNL's Center for Nanophase Materials Sciences was sponsored by the Scientific User Facilities Division, Office of Basic Energy Sciences, US Department of Energy.