Stony Brook University
The Graduate School

Doctoral Defense Announcement

Abstract

Engineering Enhanced Piezoelectric Response in Ferroelectric Superlattices

By

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The piezoelectric effect is a useful property of certain crystals where the application of pressure on a crystal produces a voltage, and conversely in the inverse piezoelectric effect, the size of the crystal changes with the application of voltage. Piezoelectricity is widely used in devices such as ultrasound machines and various sensors and actuators. This thesis presents the development of two artificially layered material systems with enhanced piezoresponse and techniques developed to accurately characterize functional properties.

Large piezoelectric responses, such as those seen in $PbZr_xTi_{1-x}O_3$ in the vicinity of the compositional morphotropic phase boundary, can occur when the direction of the polarization in a ferroelectric material can rotate. Here we combine $PbTiO_3$, a ferroelectric with out-of-plane polarization when grown on $SrTiO_3$, and $CaTiO_3$, a ferroelectric with in-plane polarization when grown on $SrTiO_3$, into high quality superlattices in various material ratios to attempt to engineer polarization rotation and enhanced piezoelectric response. X-ray diffraction performed using a lab diffractometer and using NSLS X21 and X22C beam lines was used to measure the structure of superlattices, confirming compositional phase changes with rotations of polarization directions. Electrical measurements showed an enhancement of the dielectric constant and piezo force microscopy showed a twofold enhancement of the piezoresponse of $PbTiO_3$ at a particular material ratio in the superlattice.

In contrast to the polarization rotation driven behavior seen in $PbTiO_3/CaTiO_3$, when $PbTiO_3$ and $BaTiO_3$, a ferroelectric also with out-of-plane polarization when grown coherently on $SrTiO_3$, are combined in a superlattice, enhanced piezoelectric response is driven by other, interfacial, effects. To realize this system, the challenging growth of strained $BaTiO_3$ on $SrTiO_3$ is required. It was found that successful growth was highly dependent on electrical boundary conditions, an effect we have studied by the use of in situ synchrotron x-ray diffraction during growth at X21.

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