Domain wall nanoelectronics through combinatorial synthesis and scanning probe approaches.

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Ferroics are functional materials that exhibit regions possessing a similar order parameter, i.e., spontaneous polarization, magnetization, or strain, termed as "domains", which are separated by naturally occurring ring interfaces termed as domain walls. Domain interfaces in ferroic oxide systems represent one of the fascinating new themes in nanoelectronic materials. There exists a superior class of materials in which more than one order parameter coexist simultaneously, and they are referred as multiferroics.

Bismuth Ferrite-$BiFeO_3$ (BFO) has been the one of most studied material in recent years as it is an ideal high-temperature application multiferroic material, i.e., in BFO more than one 'order parameter' can co-exist. There has been significant effort put into understanding both the physical and the structural properties of BFO with the aim to realize environmental friendly and high-efficiency device for memory and spintronics applications. However, the presence of stereochemically active Bismuth atom results in a low resistance and very high leakage characteristics in BFO that has always been a challenge for developing devices. It is therefore of interest to explore the possibilities to stabilize the Bismuth. One way to do is via doping of rare earth elements in the Bi site and thus improve the stoichiometry of the structure and reduces the leakage current since rare earth elements are relatively stable elements. This has directed our thoughts towards synthesizing rare-earth based perovskite manganite structures and integrating it with BFO.

This research aims to investigate various means of implementation of electrical and strain coupling techniques to tune the domain structure and domain interfacial properties and thus enhance the multiferroic properties of BFO for real-life applications.

As a first step, we have synthesized BFO thin-films with varying film thickness on oxide ceramic substrates. The study demonstrated the existence of cycloidal spin order in 100 nm BiFeO3 thin films through the careful choice of crystallographic orientation and control of the electrostatic and strains boundary conditions.

We have further explored the possibility of tuning properties of domain structures in BFO thin-films by investigating how the electrical boundary conditions, can be used effectively to control the domain structures and domain conductivity of BFO thin films. It is shown that domain structure and properties can be tuned by the selection of right electrodes and by varying the thickness of the electrodes. X-ray diffraction (XRD) and atomic force microscopy (AFM) are employed for the morphological and structural characterizations. Structural and electronic characterization of intrinsic nanodomain structures is conducted with the aid of extensive piezo-force microscopic (PFM) studies at room temperature and also both room temperature and low-temperature conductive-AFM. Also, change in size and shape of the domains is also studied by varying the thickness of the BFO.

In addition to the above, as a first stage of realizing BFO and rare-earth manganites heterostructures, we have successfully synthesized $LaMnO_3/CaMnO_3$ superlattices are deposited using Pascal LASER MBE system and atomic control of layer by layer growth was achieved by in-situ RHEED monitoring. The grown heterostructures are investigated structurally via atomic force microscopy, X-ray diffraction, and reflectometry measurements. Magnetic properties of the film have also been investigated via Vibrating sample Measurement system located at ANSTO.

As a final component, the thin film and nanostructured superlattice interfaces are currently being investigated by temperature and field dependent XAS and XMCD at National Chiao Tung University, Taiwan, to understand charge transfer and interfacial magnetization properties.