Control of polarization vortex states in nanoconfined ferroelectrics

Recent developments in chemical synthesis techniques have enabled creation of monodisperse perovskite ferroelectric nanoparticles of various shapes and sizes. These particles can be embedded in a dielectric medium [1] to form novel functional microscale architectures. The on-going effort to harness these nanomaterials for a wide range of applications has shown promising new pathways such as engineering multiferroicity, flexible electronics, to improvements in photovoltaic efficiencies among others.

In this talk, I will first highlight the open-source finite element code Ferret that is used for studying equilibrium polarization topologies in these nanostructures. Our research efforts have found that, for particles comprised of PbTiO3 and BaTiO3, the polarization at room temperature is greatly affected by the particle size, shape, and choice of embedded matrix environment [2,3]. Specifically, we observe the presence of vortex-like states at a distinct size range. This leads to radically different polarization vs. electric field response loops that can be controlled by tuning the material parameters. In addition to the high dispersed case, we recently conducted an investigation of an interacting dimer system. The nonlinear polarization switching is shown to be strongly tunable on the interparticle spacing and applied electric field geometry. The physical origin of this effect lies in the long-range elastic strains that propagate between the particles [4]. Surprisingly, the anisotropy of the field response reveals precise control of the ordering of the vortex-like polarization patterns. We also probe whether or not other exotic polar textures can exist in these nanoconfined structures, such as the recently observed polar skyrmions [5] or the predicted Hopfion-like states [6]. I will also highlight related work utilizing the density functional theory to parameterize energy landscapes of multiferroic compounds, such as BiFeO3 and the magnetic skyrmion-host GaV4Se8, thus enabling this type of phase field modeling of their order parameter topologies.