Tunable multiferroic properties and the magnetoelectric effect in nanocomposite $PbTiO_3$-$CoFe_2O_4$ epitaxial thin films [1]

We are using the combinatorial approach to explore novel multiferroic materials [2]. In particular, we are using the thin film binary composition spread technique to design nanocomposite multiferroic materials. The idea of the experiment is illustrated in Figure 1. We place a pure ferroelectric material at one of the linear spread and a pure magnetic material at the other end. Toward the middle of the spread, the two properties are gradually mixed. The nanocomposite composition spreads were grown using epitaxial wedge layer-by-layer deposition technique using pulsed laser ablation. We have used $CoFe_2O_4$ and $PbTiO_3$ as magnetic and ferroelectric materials, respectively, and the films were grown on MgO substrates. Ferroic properties are mapped across the spread using scanning probe techniques including scanning SQUID microscopy for ferromagnetic properties and scanning microwave microscopy for ferroelectric properties. We have found the nanocomposite spreads exhibit display continuously changing co-existence of bi-ferroic properties. TEM studies of the spreads indicate that depending on the composition and the growth conditions, a variety of nanostructure is obtained ranging from solid solution and superlattice-like structures to nanopancake structures and nanopillars. Magnetoelectric coupling was observed in at selected compositions on the middle of the spread using microwave microscopy. Composition spread techniques are also being used to pursue intrinsic multiferroic materials systems. This work has been carried out in collaboration with Leo Bendersky of NIST.

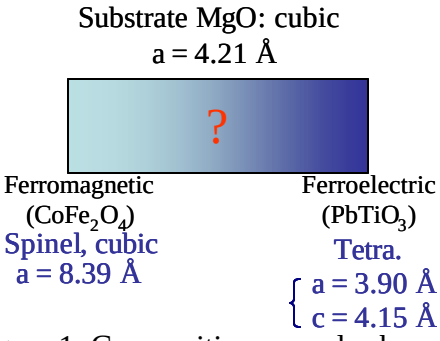

Figure 1. Composition spread scheme

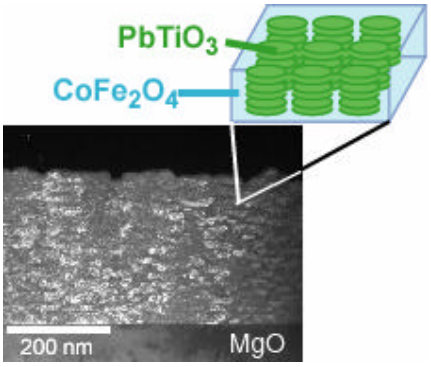

Figure 2. TEM of nanocomposite

References

1. M. Murakami et al., to be published.
2. H. Koinuma and I. Takeuchi, "Combinatorial solid-state chemistry of inorganic materials," Nature Materials **3**, 429 (2004).
3. K. Chang, et al., "Exploration of artificial multiferroic thin film heterostructures using composition spreads," Applied Physics Letters, **84**, 3091 (2004).