Controlling the Magnetic State of Nickel Nanocrystals Arrays in Granular Multiferroic Composites

Multiferroics systems offer unique ways to control magnetism at the nanoscale by having multiple materials in one composite. As an example, the traditional multiferroic composite uses a piezoelectric layer to strain a magnetostrictive layer, allowing an applied electric field to control magnetism through strain coupling. Recent theoretical modeling of nanocrystal-based multiferroic composites predicted a new multiferroic coupling mechanism where the ensemble spin orientation of magnetic nanocrystal arrays can be tuned by interparticle exchange coupling—which in turn can be modified by the dielectric environment of the nanocrystals. By tuning the extent of exchange coupling, the composite material can be switched between a superparamagnetic, or magnetically fluctuating, state, and a ferromagnetic, or magnetically fixed, state. To investigate geometric effects in this system, nanoparticle arrays and interparticle distances were first controlled to modify the degree of exchange coupling and thus the magnetic state. We then used thermal switching of a ferroelectric to modify the dielectric environment of the nanocrystals, where the degree of exchange coupling increases as the dielectric constant increases. Finally, an applied electric field was used to modify the dielectric environment of the ferroelectric, demonstrating the ability to switch between magnetic states.

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Thursday, April 26, 2018  
2033 Young Hall  
12:00 PM