Magnetic Properties of a Thin Layer of Oriented Single Domain Magnetic Nanoparticles

Korey D. Sorge, James R. Thompson, Frank A. Modine, Tony E. Haynes, Thomas C. Schulthess, Shin-ichi Honda, Alkiviathes Meldrum, John D. Budai, C.W. White, and Lynn A. Boatner, Solid State Division, Oak Ridge National Laboratory Oak Ridge, TN.

Magnetic ions—Fe, Co, and Ni—have been implanted into the near-surface region of single crystals of Al_2O_3 and yttria stabilized zirconia (YSZ). With thermal processing, the implanted species precipitate to form predominantly single-domain, single-crystal ferromagnetic nanoparticles that crystallographically align with the host substrate, thereby forming a magnetically anisotropic nanocomposite surface. In the case of Fe, precipitates were formed in YSZ by implantation of Fe^+ at an energy of 140 keV and a dose of 8×10^{16} ions/cm^2, followed by annealing in a reducing atmosphere. Similarly for Co, precipitates were formed in Al_2O_3 by implantation of Co^+ at an energy of 140 keV and a dose of 8×10^{16} ions/cm^2, followed by annealing in a reducing atmosphere. To form Ni precipitates, Ni^+ was implanted in Al_2O_3 at an energy of 750 keV and doses of 5×10^{16}, 1×10^{17}, and 2×10^{17} ions/cm^2, followed by annealing in a reducing atmosphere. Typical dimensions for the particle size and layer thickness are 10 nm and 80 nm, respectively, allowing for nearly 10% volume filling in the layer, as measured by RBS/channeling, transmission electron microscopy, and x-ray diffraction. Studies on these ferromagnetic particle layers were conducted in the temperature range of 5 to 300 K and applied fields of 10 kG using a superconducting quantum interference device (SQUID)-based magnetometer. An analysis of the magnetic properties including retentivity, coercivity, and saturation moment will be presented as well as the effects of magnetocrystalline and shape anisotropy. Additionally, the particle/host orientation dependence will be treated by comparisons with Ni precipitates in an amorphous substrate of SiO_2.

Research sponsored by the Laboratory Directed Research and Development Program of Oak Ridge National Laboratory (ORNL), managed by UT-Battelle, LLC for the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.