Materials Science & Engineering Doctoral Defense

Characterization of Magnetic Nanostructures Using Off-Axis Electron Holography

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abstract

This dissertation research has involved microscopic characterization of magnetic nanostructures using off-axis electron holography and Lorentz microscopy. The nanostructures investigated have included Co nanoparticles (NPs), Au/Fe/GaAs shell/core nanowires (NWs), carbon spirals with magnetic cores, magnetic nanopillars, Ni-Zn-Co spinel ferrite and CoFe/Pd multilayers. The studies have confirmed the capability of holography to describe the behavior of magnetic structures at the nanoscale.

The phase changes caused by the fringing fields of chains consisting of Co NPs were measured and calculated. The difference between chains with different numbers of Co NPs followed the trend indicated by calculations. Holography studies of Au/Fe/GaAs NWs grown on (110) GaAs substrates with rotationally non-uniform coating confirmed that Fe was present in the shell and that the shell behaved as a bar magnet. No fringing field was observed from NWs with cylindrical coating grown on (111)B GaAs substrates. The most likely explanation is that magnetic fields are confined within the shells and form closed loops. The multiple-magnetic-domain structure of iron carbide cores in carbon spirals was imaged using phase maps of the fringing fields. The strength and range of this fringing field was insufficient for manipulating the carbon spirals with an external applied magnetic field. No magnetism was revealed for CoPd/Fe/CoPd magnetic nanopillars. Degaussing and MFM scans ruled out the possibility that saturated magnetization and sample preparation had degraded the anisotropy, and the magnetism, respectively. The results suggested that these nanopillars were not suitable as candidates for prototypical bit information storage devices.

Observations of Ni-Zn-Co spinel ferrite thin films in plan-view geometry indicated a multigrain magnetic domain structure and the magnetic fields were oriented in-plane only with no preferred magnetization distribution. This domain structure contributes to the ultra-high permeability of these materials. Perpendicular magnetic anisotropy (PMA) of CoFe/Pd multilayers was revealed using holography. Detailed microscopic characterization showed structural factors such as layer waviness and interdiffusion that could contribute to degradation of the PMA. However, these factors are overwhelmed by the dominant effect of the CoFe layer thickness, and can be ignored when considering magnetic domain structure.

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