Magnetic properties of cobalt nanowires and nanotubes

Jia Grace Lu, Dongdong Li, Gerd Bergmann, Richard Thompson

Department of Physics and Astronomy, University of Southern California, Los Angeles, California, USA

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Development of novel magnetic materials has played an important role in modern day science and technology. Nanomagnetism research not only sparks interests in fundamental physics, but also renders promising technological applications. In this work, ferromagnetic Co nanowires have been synthesized via low voltage electrodeposition method. High resolution transmission electron microscopy and x-ray diffraction results show that the nanowires are uniform in size, and consist predominantly *hcp* structure with the magnetocrystalline easy axis (*c*-axis) perpendicular to the wire axis. SQUID measurement illustrates the dominance of shape anisotropy, manifested by the weak temperature dependence of the enhanced coercive field along the wire axis. Furthermore, the magnetic domain structures of individual, segmented or multiple nanowires are studied via magnetic force microscopy. It shows a strong dipole at the ends of the wire, together with a spatial magnetization modulation along the wire with a period around 700 nm. Based on theoretical modeling, such intrinsic modulation originates from the competition between the magnetocrystalline polarization along the easy axis and the shape anisotropy along the wire axis. Low temperature magnetoresistance measurement shows irreversible magnetization switching in addition to the anisotropic behavior due to magnetization orientation dependent electron scattering.

On the other hand, Cobalt nanotube arrays embedded in hexagonally ordered anodic aluminum oxide templates are fabricated by direct electrodeposition with low current density under several mA/cm^2. The wall thickness is about 15 nm and outer diameters are in accordance with pore diameter around 80 nm. Nearly 100% filling rate is achieved which benefits from the through pores which enable the efficient penetration of electrolyte.

Transmission electron microscopy and selected-area electron diffraction are performed to show that the nanotubes are predominantly *hcp* single crystals with c-axis (easy axis) perpendicular to the tube axis. SQUID and MFM results indicate that the magnetization follows a circumferential direction around the tube, which is manifested in the weak magnetic signal in the MFM imaging as well as a sheared hysteresis dependence for field applied along the tube axis. This phenomenon has been confirmed by theoretical modeling taking into account the magnetocrystalline, shape demagnetization and magnetic exchange energies.

References

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