Problem 12
Magnetics
Fall 2015 PhD Preliminary Written Exam

Consider a free-standing circular shaped nano-magnetic disk with single crystal hexagonal-close-packed (HCP) structured Cobalt. The magnetic disk is 20 nm in diameter and 10 nm in thickness unless it is mentioned specifically. The saturation magnetization (Ms) of the Cobalt is 1400 emu/cm^3. The magnetocrystalline anisotropy constant (Ku) of the Cobalt is 4.5 x 10^6 erg/cm^6. The c-axis of the Cobalt single crystal is in the plane of the magnetic disk.

(1) Plot the M-H loops for the Co disk for the cases with the magnetic field along the c-axis of Co disk, perpendicular to the c-axis and normal to the Co disk plane. Show your calculation for the coercivity at zero Kevin. (1.0)

(2) Assume the top surface of the Co disk is covered with 2 nm Permalloy (Fe20Ni80) to form a composite structure. The saturation magnetization (Ms) of the Permalloy is 800 emu/cm^3. The magnetocrystalline anisotropy constant (Ku) of the Permalloy is zero. Plot the M-H loop for the case with the magnetic field along the c-axis of the Co disk. Show your calculation for the coercivity at zero Kevin. (1.0)

(3) Assume half of the Co disk is oxidized with an anti-ferromagnetic CoO layer to form an CoO/Co exchange biased structure. The CoO/Co composite disk is heated up beyond the Néel temperature of CoO with a large enough magnetic field along the c-axis of the Co disk, and then cool down to room temperature. Plot the M-H loop for the case with the magnetic field along the c-axis of Co disk. Show the change of the coercivity and the loop center position in your plot and explain why. (1.0)

(4) Find out the critical diameter for the original (unaltered) Co disk to function as a paramagnetic particle at room temperature. Assume the required thermal stability factor is 25. Boltzmann constant is 1.38x10^{-16}erg K^{-1}. (0.5)

(5) Assume two Co disks are sandwiched with a 3 nm Cu layer to form a giant magnetoresistance (GMR) structure as a read sensor. If a large linear sensing range is demanded, show the preferred magnetization direction for each of Co layer and the transfer curve. If a short sensing range is allowed, show another possibility for the magnetization direction for each Co layer and the transfer curve. (0.5)