Magnetic

The integration of magnetic sensors and magnetic particles may lead to many interesting engineering products in future. For the following questions, assume a system that consists of a magnetic particle on top of a giant magnetoresistance sensor (GMR).

a) The GMR sensor for the detection of the magnetic field from the magnetic particle works in a current-in-plane (CIP) mode. Also typically, a tri-layer structure with a free layer, a spacer layer and a fixed layer, also called a spin valve structure is used for this purpose. Explain the giant magnetoresistance (GMR) effect using a two-channel (also named as two-resistor) model. (1.0 point)

b) Plot a possible domain structure of the free layer of the GMR sensor if the sensor has a circular shape with diameter around 10 μm. Assume the free layer of GMR sensor has zero crystalline and stress anisotropy and thickness less than 10 nm. (0.5 point)

c) To avoid multi-domain structures and to enable the sensor working at a linear range (resistance vs external field), one design is to have a stripe type sensor. To do so, we need to pin the fixed layer (e.g. FeCo) with an antiferromagnetic layer (e.g. IrMn). Describe how to pin a fixed magnetic layer using a magnetic annealing process. (0.5 point)

d) Assume the GMR sensor is 100 nm in width and 10 μm in length. The free layer of the sensor is FeCoNi (4 nm) with saturation magnetization around 1500 emu/cm^3. Calculate the maximum external magnetic field needed to saturate the sensor to a hard axis direction. (0.8 point)

e) The magnetic particle on top of the GMR sensor is spherical with a composition $Fe_{60}Co_{40}$. Assume its cubic magnetocrystalline anisotropy and saturation magnetization is 6 x 10^{5}erg/cm^3 and 1900 emu/cm^3, respectively. Find the critical diameter for such a magnetic particle to function as a paramagnetic particle. Assume the required thermal stability factor is 25. Boltzmann constant is 1.38×10^{-16}erg K^{-1}. (0.7 point)

f) Plot and explain the general trend of the coercivity vs. the diameter of this FeCo nanoparticle. (0.5 point)