Problem 13 FALL 2006 Magnetics

Written Preliminary Exam – Magnetics
Fall, 2006

A. Calculate the saturation magnetization of $Fe_{20}Co_{80}$ in μ_B/atom and emu/cm^3. Pure Co has a magnetization of 1450 emu/cm^3 and assume both Fe and Co have an atomic volume of 11 Å^3. Hint: μ_B=0.927 x 10^{-20} emu and the atomic number of Co is one greater than Fe. *(1 point)*

B. Single domain grains of this material are arranged such that all the uniaxial anisotropy axes lie randomly within the plane of a thin film. Calculate the squareness for both in plane and perpendicular loops ignoring interactions. *(1 point)*

C. For anisotropy constant K, estimate the coercivity and the average switching field. *(1 point)*

D. Discuss qualitatively the effect of intergranular exchange coupling on the coercivity. *(1/2 point)*

E. Draw a high field torque curve measured in a plane perpendicular to the thin film. Define your angles and mark maxima and minima torques and zero crossings. *(1/2 point)*

A. The moment of a Co atom is $\frac{1450 \frac{emu}{cm^3} \cdot 11 \times 10^{-24} cm^3}{0.927 \times 10^{-20} emu/\mu_B}$

$\therefore \vec{m}_{Co} = 1.72\ \mu_B$

There will be 0.2 more d-holes per atom in $Fe_{20}Co_{80}$. Therefore, the moment will increase by $\sim 0.2\ \mu_B$

$\therefore \vec{m}_{FeCo} = 1.92\ \mu_B$

$M = 1.92\ \mu_B (0.927 \times 10^{-20}\ emu/\mu_B) / 11 \times 10^{-24}\ cm^3$

$M = 1620\ \frac{emu}{cm^3}$

B. Consider an individual grain with easy axis at angle θ to the applied field

Remanence $= M \cos\theta$

For the inplane loop, average over all directions

$$SQ = \frac{\int_{-\pi/2}^{\pi/2} \cos\theta\, d\theta}{\int_{-\pi/2}^{\pi/2} d\theta} = \frac{\sin\theta\,\big]_{-\pi/2}^{\pi/2}}{\theta\,\big]_{-\pi/2}^{\pi/2}} \rightarrow SQ = 2/\pi$$

For perpendicular loop, $\theta = 90^\circ \rightarrow SQ = 0$

C. If $\theta = 0^\circ$, then $H_c = H_s = 2K/M$

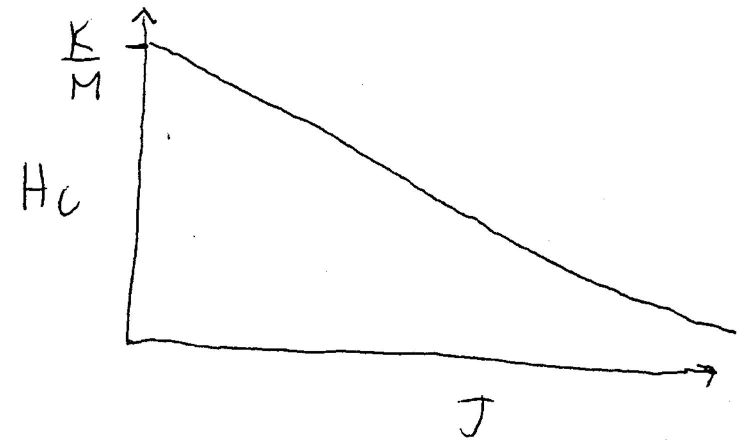
If $\theta = 45^\circ$, then $H_c = H_s = K/M$

If $\theta = 90^\circ$, then $H_c = 0$ and $H_s = 2K/M$

This suggests $H_c = K/M$

and $\langle H_s \rangle = (5/3)\, K/M$

D. If the grains are very strongly coupled then the average anisotropy of the material ($K_{ave} = 0$) will prevail. The coercivity will approach zero.



E. Let θ = angle between $\vec{M}$ and film normal and ϕ = angle between grain easy axis and plane of torque curve.

$$E = 2\pi M_s^2 \cos^2\theta - K \sin^2\theta \cos^2\phi$$

Average over orientation of the anisotropy axis.

$$\langle E \rangle = \frac{1}{2\pi}\int_0^{2\pi} (2\pi M_s^2 \cos^2\theta - K\sin^2\theta\cos^2\phi)\, d\phi$$

$$= 2\pi M_s^2 \cos^2\theta - \frac{K}{2}\sin^2\theta$$

$$\therefore \ \tau = \frac{d\langle E \rangle}{d\theta} = -4\pi M_s^2 \cos\theta \sin\theta - K\cos\theta\sin\theta$$

$$\therefore \ \tau_{max} = 2\pi M_s^2 + K/2 \rightarrow$$