Home Problem Set #6 자성재료특강 Due : 12. 8 (월) ,2008

1. A specimen of magnetic material is in the shape of a cube of side L and consists of an array of slab-like antiparallel domains of width d separated by 180 domain walls. The magnetostatic energy per unit volume of a magnetized body is given by

$$E_{ms} = (1/2)\mu_0 N M_s^2 (d/L)$$

where N is the demagnetizing factor and M_s is the saturation magnetization within the domains.

(a) If N = 0.5, M_s = 1×10^6A/m and L = 10 mm, calculate the domain-wall surface energy which is necessary to give a domain spacing of d = 5×10^{-6} m

(b) If the above material has a cubic lattice with the atomic spacing 0.3 nm, and the anisotropy is 1×10^5 joule/m^3, calculate the exchange energy between each pair of moments located on the atomic sites needed to get the above result.

2. Find the domain wall energy γ, wall thickness l and critical dimension l_c for single-domain particles of a M_s = 0.38×10^6A/m, lattice spacing 3×10^{-10} m and exchange energy J = 3×10^{-21} joule. Assume this material has a spin of S = 1/2 (*i.e.*, $1\mu_B$ per atom).

3. 다음의 질문에 답하라.

(a) 코발트에서 자벽 에너지 밀도 σ_{dw}와 자벽 두께 δ_{dw}를 계산하여라. (a =최단근접 거리=2.51Å 및 anisotropy constant K = 45×10^5 ergs/㎤을 사용하시오.)

(b) K =33×10^5 ergs/㎤ , T_c= 450℃ 그리고 M_s = 380 emu/㎤ 인 바륨페라이트의 자벽 에너지 밀도 σ_{dw}와 자벽 두께 δ_{dw} 및 단자구입자를 형성할 수 있는 임계 입자 크기 r_c값을 구하여라.

4. The exchange energy for a pair of atoms of the same spin S can be given by E_{ex} = $-2JS^2\cos\phi$, where J is the exchange integral and is roughly equal to 0.3 $k_B T_c$. The anisotropy energy E_a of domain wall is of the order of the anisotropy constant K_1 times the volume of the wall. For simplicity we assume simple cubic, with an atom at each corner of a cell edge a, and the plane of the wall parallel to a cubic face {100}. Let the wall be n atoms thick. Consider only two terms of the series expansion of $\cos\phi$, which is given by $\cos\phi = 1 - \phi^2/2$

(a) Show that, for a 180°wall, the wall thickness is given by

$$l_d = \sqrt{\frac{JS^2\pi^2}{Ka}}$$

(b) Show that the total wall energy per unit area for a wall thickness $l_d = na$ is given by

$$\gamma_{tot} = 2Kl_d$$

(c) Calculate the energy E_{wall} (= $E_a + E_{ex}$) and width of a domain wall in iron. Take a = distance of closest approach = 2.48 Å, $k_B = 1.38\times10^{-16}$ ergs/K, T_c = 1043 K, S = 1/2, and $K_1 = 4.8\times10^5$ ergs/cm^3.

5. (a) Show that total energy is given by $E = 2\sqrt{1.7\ M_s^2\gamma L}$ if the magnetostatic energy of the multidomain crystal per unit area of the top surface is given by $E_{ms} = 1.7M_s^2D$, and the domain wall energy $E_{wall} = \gamma(L/D)$, where D is the thickness of the slab-like domains for $D \ll L$.
(b) For cobalt, taking γ = 7.6 ergs/cm^2 and L = 1 cm, find the number of domains in a crystal 1 cm cube in size.
(c) Calculate the ratio of total energy before and after division into domains, taking M_s = 1442 emu/cm^3 for Co, if magnetostatic energy E_{ms} of the single-domain crystal with a uniaxial anisotropy is given by $E_{ms} = 2\pi M_s^2 L$ for a flat plate-shaped crystal. Give a concluding remark for this calculated result.
(d) For cobalt, find the value of a critical size L_c below which the single-domain crystal will have the lower energy than the multidomain crystal.

6. Solve for the magnetization versus field for (a) a thin film of amorphous iron boron silicon (assume M_s = 1.6 T and K = 0) with the field applied normal to the film surface and (b) a single-crystal sphere of Ni with the field applied along the [111] direction.