

PROBLEMS CHAPTER 7

7.1 Show that the magnetostriction constants of Fe and Ni are not of the sign you would expect for dipole forces between atomic "bar" dipole magnets.

7.2 Consider a bar of iron with [110] along its length and the top surface is (001). It is under tensile stress along its length.

$$\lambda_{100} = 20.5 \times 10^{-6}, \lambda_{111} = -21.5 \times 10^{-6}, c_{11} = 2.4 \times 10^{11},$$

$$c_{12} = 1.4 \times 10^{11}, c_{44} = 1.2 \times 10^{11} \text{ N/m}^2$$

- a) Write the strain tensor in the bar coordinates and in the crystallographic coordinates.
- b) Which terms in Eq. 7.9 are relevant to the effects of stress on the orientation of \mathbf{M} ?
- c) If the stress is such as to produce a strain e of 0.1%, compare the magnitude of the magneto-elastic and magneto-crystalline anisotropy.
- d) Evaluate the appropriate energy terms to determine the direction of \mathbf{M} at $e = 0.01$.
- e) Derive the equation of motion of the magnetization as a function of field and strain. Plot $m-H$ for $e = 0$ and $e = 1\%$. Qualitatively describe your results.

7.3 Derive Eqs. 7.7, the equilibrium strains, from Eqs. 7.6.

7.4 Show that setting $\lambda_{111} = \lambda_{100} = \lambda_s$ in Eq. 7.16 gives Eq. 7.17.

7.5 Consider a thin epitaxial Ni film on Cu(100) ($a_{\text{Ni}} = 3.524\text{\AA}$, $a_{\text{Cu}} = 3.615\text{\AA}$).

Assume for Ni $\lambda_{100} = -46 \times 10^{-6}$, $c_{11} = 2.5 \times 10^{11}$, $c_{12} = 1.6 \times 10^{11}$ and $c_{44} = 1.18 \times 10^{11}$ N/m²

a) Compare the relative strength of crystal anisotropy, magnetoelastic anisotropy, and magnetostatic energy as far as determining the direction of \mathbf{M} .

b) Assume $e_{12} \approx 0$, find the equilibrium direction of \mathbf{M} in zero field and for small Ni thickness.

c) As the film grows, describe what happens to e_{ij} ($i \neq j$).

d) If $e_{12} = 2e_{11}$, find the direction of \mathbf{M} .

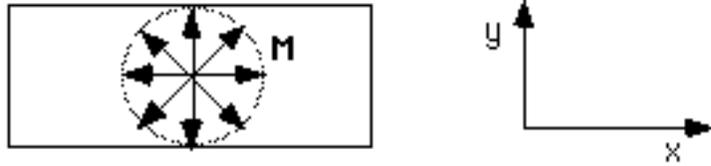
e) Discuss.

7.6 Show that the two alternate ways of defining the magnetoelastic coefficients (Eqs. 7.8 and 7.34) are equivalent. How are the B s and b s related?

7.7. It has been written in a technical article. "Typically, magnetic transition metals produce magnetostrictive strains e [at saturation] of order 10^{-5} to 10^{-4} which vary about the direction of magnetization roughly as $e = (3/2)\lambda_s(\cos^2\theta - 1/3)$ where λ_s is the saturation magnetostriction constant. Conversely, stresses σ imposed on the material which result in strains of order 10^{-5} to 10^{-4} (i.e. $e = \lambda_s$) contribute significantly to the total magnetic anisotropy: the uniaxial stress-induced anisotropy energy density is $(3/2)\lambda_s\sigma$." Critique these statements by considering the energy densities in each case).

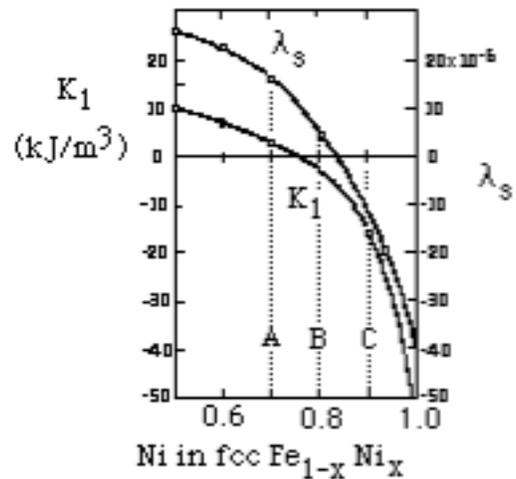
7.8 Use Eq. 7.10 to describe the field and strain directions you would use to measure the two magnetostriction constants λ_{100} and λ_{111} on a Ni sample cut as shown in Fig. 7.3. Do not assume that the sample has randomly distributed magnetization directions in zero field.

7.9. Assume a multidomain polycrystalline sample with the domain magnetizations randomly oriented as represented below.



Describe how you would expect the magnetization distribution to change if the sample has positive magnetostriction λ_s and a tensile stress σ_{xx} is applied for $H = 0$. Contrast this with the change caused by application of $H = (H_0, 0, 0)$ for $\sigma_{ij} = 0$. Plot M_x vs. H_x for $\sigma_{xx} = 0$ and $\sigma_{xx} \neq 0$. Plot M_x vs. σ_{xx} for applied fields in the range $H_x \leq H_K$.

7.10. Consider the anisotropy constants, K_1 , and the polycrystalline magnetostriction constants, λ_s , shown below for fcc NiFe alloys. This problem is about the behavior of alloys having compositions A, B and C.



- Sketch and label the lowest order crystal anisotropy surfaces in the x - y plane for thin films of compositions A and C (i.e. assume $\alpha_z = 0$).
- For unstrained bulk samples of compositions A, B and C, in which crystallographic directions are the samples easily magnetized?
- For unstrained single crystal samples A, B and C, a field is applied in the $[100]$ direction. Sketch the shape of the M - H curve in each case assuming zero coercivity. Use approximately the same field scale in each case so the M - H curves can be compared.
- If the samples are subject to strains, which composition, A, B or C, would make the best soft magnetic material? Why?

e. For single crystal samples A, B and C apply a field in the [100] direction as in part c above but now also put the sample under tensile stress parallel to the field direction. Sketch with a dashed line over your result in c, the shape of the strained $M-H$ curve in each case assuming zero coercivity.

f. What is the approximate value of the magnetoelastic coupling coefficient, B_1 , for sample B? If a strain is applied along [100] to cancel the crystal anisotropy in this sample and have the magnetization lie along the x axis in zero field, what would be the nature of that strain (tensile or compressive along [100]) and what is its approximate magnitude?