Origin of magnetization-induced anisotropy for Ni-Fe films

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If a magnetic field is applied in the plane of a polycrystalline Fe-Ni film during the deposition normal to the substrate or during the annealing at the temperature of the substrate T_{tr}, a uniaxial anisotropy is induced with the easy axis parallel to the field direction. The mechanism is considered unsolved. This work shows that the anisotropy originates from the shape anisotropy caused by the anisotropy of the width of the void-network as a result of the shape anisotropy of the grain and the isotropy of the grain distribution, elastic energy caused by the fixed magnetostriction and the atomic pair-ordering. The anisotropy constant at temperature T_m is the sum of the above three anisotropy constants:

$$K = K_s + K_\lambda + K_{ap}, \qquad (1)$$

$$K_s = \frac{I_s^2(T_{tr}) I_s^2(T_m) b}{16\mu_0^2 q \gamma} \quad (T_{tr} \geq 250\ \mathrm{C}),$$

$$= \frac{I_s^4(T_m) b}{16\mu_0^2 q \gamma} \quad (T_{tr} = 20\ \mathrm{C}), \qquad (2)$$

$$K_\lambda = \frac{9}{4}\lambda_s(T_m)\lambda_s(T_0)E \quad (T_m < T_0 < T_{tr}),$$

$$= \frac{9}{4}\lambda_s(T_m)\lambda_s(T_{tr})E \quad (T_m, T_{tr} < T_0),$$

$$= \frac{9}{4}\lambda_s^2(T_m)E \quad (T_m > T_0) \qquad (3)$$

$$K_{ao} = K_{ao\exp} \frac{J_s^2(T_{tr}) J_s^2(T_m)}{J_s^4(300)} \frac{T_{tr}}{300}. \quad (T_{tr}\ \text{in absolute temperature}) \qquad (4)$$

Here, I_s is the saturation polarization, λ_s the magnetostriction constant, E the Young's modulus, γ and q the surface tension of the grain bordering the void network and the relative area of the surface, respectively, K_{aoexp} the experimental value of K_{ao} at room temperature[1], and b the width of the void- network. T_0 is the temperature below which the atoms lose their mobility to release the stress during the experiment, the value of which is estimated from the best fit of eq. 3 with the experiment of Ni (Fig. 1). The value of q is fixed to 2/3. b is a fitting parameter. The theory reproduces the experiments fairly well as is shown in the figures.

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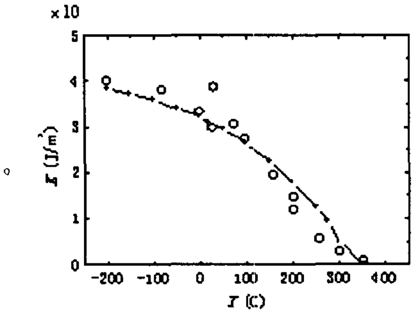
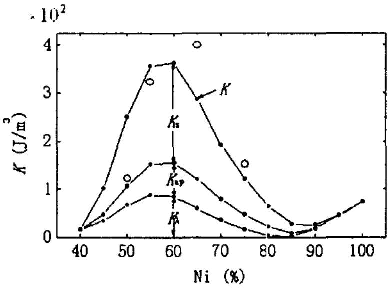
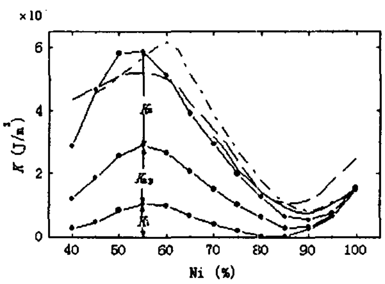


Fig.1. K vs. T_m for the Ni film annealed at 400 ^{0}C. Full symbols: cal. (T_0=275 C); open symbols: exp.[2]



(a)



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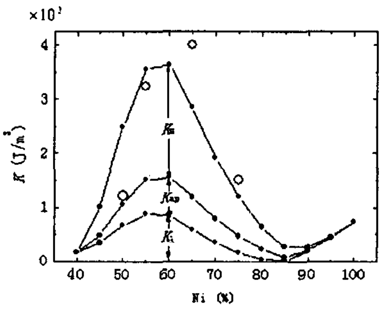
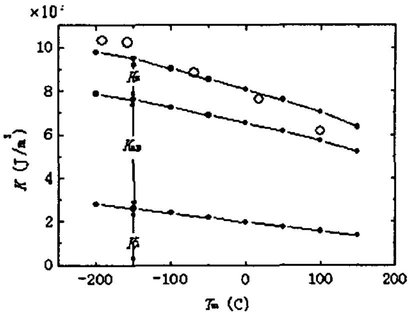
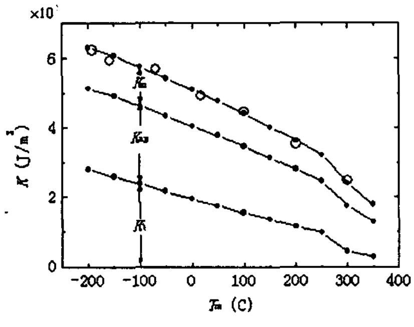


(c)

Fig. 2. K vs. Ni % at 20 ^{0}C. Full symbols: cal.; open symbols or lines: exp. (a) b=1.5 nm, T_{tr}=20 C; deposited at 20 C [3]. (b) b=3.0 nm, T_{tr} = 250 C; exp. [4]: dashed line: T_{tr} =240 C, full line: T_{tr} =250 C, dotted line: T_{tr} =250 C. (c) b =4.0 nm, T_{tr} =450 C; annealed at 450 C [3].



(a)



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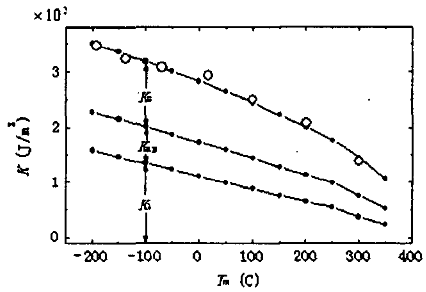

(c)

Fig. 3. K vs. T_m for 55%Ni-Fe film. Full symbols: cal., open symbols: exp[5]. (a) b=1.2 nm, T_{tr}=20 C; evaporated at 20 C. (b) b =1.9 nm, T_{tr} =350 C; annealed at 350 C. (c) b=2.0 nm, T_{tr} =450 C; annealed at 450 C.

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