



Interplay between structural roughness and magnetization reversal in thin Fe films



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Outline

Fe films, 300Å thick, were deposited by molecular beam epitaxy on amorphous SiO₂ substrates previously coated with an Ag buffer layer of varying thickness (0-50-100-150Å).
The surface roughness of the Ag buffer layer grows with increasing thickness.
Magnetization measurements revealed that both the magnetization reversal process and the coercivity are profoundly influenced by the surface roughness.

Motivation

Magnetic properties of thin films and nanostructures

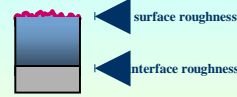
e.g. magnetic anisotropy
coercivity
reversal process
magnetoresistance
domain structure

Surface/interface roughness
Preparation conditions
Crystalline structure
Composition
Thickness
Size

- many experimental difficulties, only indicative results
- difficulties to match theory with experimental results

Different systems

Single rough boundary

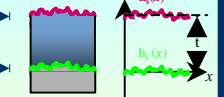


$$\xi_s, \sigma_i > 0$$

$$\sigma_i = 0, \xi_i = \infty$$

Important parameters:
- Vertical interface width or rms roughness σ
- Lateral correlation length ξ or average grain size

Double rough boundary

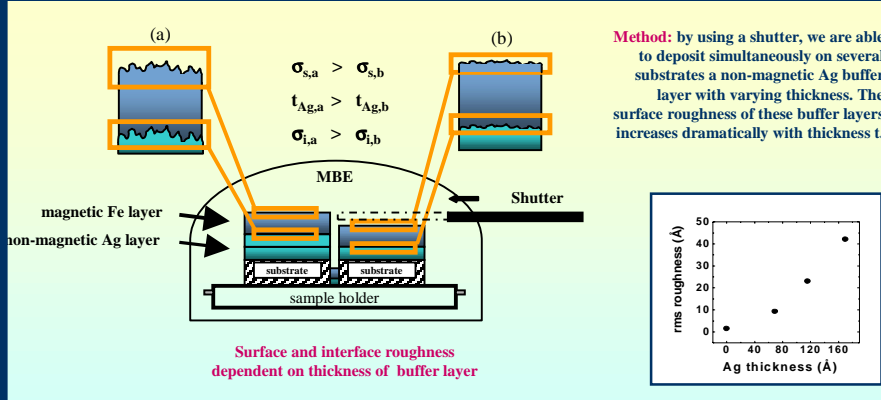


(i) Correlated boundaries
 $h_i(x) = t + h_s(x)$

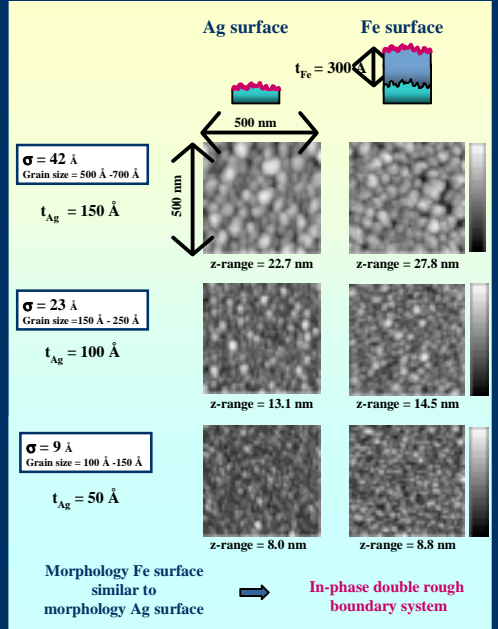
$$\Rightarrow \sigma_i \approx \sigma_s \text{ and } \xi_i \approx \xi_s$$

(ii) Uncorrelated boundaries
 $h_i(x) \neq h_s(x)$

Roughness control of a double rough boundary system



Structural characteristics (AFM)

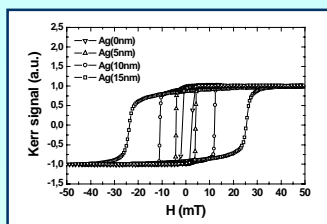


Magnetic properties (MOKE)

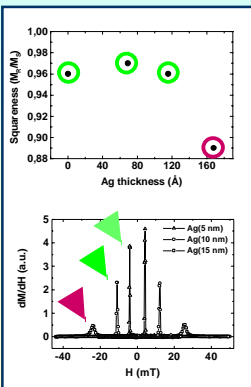
Polycrystalline 300Å thick Fe film

- \Rightarrow no in-plane anisotropy
- \Rightarrow Néel domain walls:
- Core domain wall width $w = \pi(2A/\mu_0 M_s^2)^{1/2} \approx 100 \text{ \AA}$
- with exchange stiffness $A = 1.7 \cdot 10^{-11} \text{ J/m}$
- and magnetostatic energy density $\mu_0 M_s^2/2 = 19 \cdot 10^5 \text{ J/m}^3$

Hysteresis loops of in-plane magnetization



Hysteresis loop characteristics

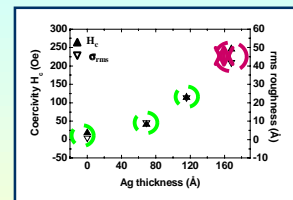


- Squariness $\approx 1 \Rightarrow$ magnetization reversal dominated by domain wall nucleation and motion
- Squariness $< 1 \Rightarrow$ complex process, combination of both spin rotation and domain wall motion.
- Squariness $\ll 1 \Rightarrow$ magnetization reversal dominated by irreversible spin rotation

- Sharp reversal Ag(50), Ag(100) \Rightarrow coercivity caused by delay of domain wall nucleation:
 $H_{coercive} = H_{nucleation}$
- Less sharp reversal in domain wall energy \Rightarrow Structural inhomogeneities cause fluctuations Ag(150)
- \Rightarrow if domain wall width $w \ll$ correlation length of these fluctuations
- \Rightarrow domain wall pinning occurs
- $H_{coercive} = H_{nucleation} + \Delta H_{pinning}$

Discussion

Coercivity versus surface characteristics

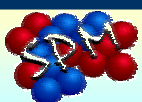


Coercivity determined by vertical interface width or rms roughness:

$$H_c = H_n = f(\sigma_{rms}, \xi) = a\sigma_{rms}$$

Since domain wall width w (100Å) \ll grain size (500-700Å)
 \Rightarrow lateral characteristics of surface start playing a role
 \Rightarrow enhanced coercivity:

$$H_c > a\sigma_{rms}$$



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