High Moment Alloys

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Outline

Studies of Sputtered CoFe Films
  Background
  Future Work: Anisotropy; Magnetostriction
Magnetization reversal in Patterned Alloys
  Background
  Future Work: Thermal Relaxation and Damping
Electroplated Alloys
  Background
  Future Work: CoFe and alternative alloys; small poles in AlO₂
Nanostructured Epitaxial Fe Films
  Background
  Future work: Control surface tension, strain and atomic bonding
to produce self-assembled nanostructured films.

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Effect of Various Underlayers on $H_c$

G/Underlayer(t nm)/Fe$_{65}$Co$_{35}$(50 nm)

- W/o underlayer
- Ta(2.5 nm)
- Cu(2.5 nm)
- NiFe(2.5 nm)
- Ru(2.5 nm)

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Cross-sectional TEM Images of Fe$_{65}$Co$_{35}$ Films

Without underlayer:
Grain size is undefined.

Ta $50 \pm 13$ nm

Cu $9.6 \pm 1.4$ nm

NiFe $9.4 \pm 1.9$ nm

Ru $9.3 \pm 0.9$ nm

In collaboration with S. Matsunuma, Hitachi Maxell.
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Calculated and Measured Ratio of $H_c$ in Fe$_{65}$Co$_{35}$ Films

* Parameters in Fe$_{65}$Co$_{35}$

\[
\begin{align*}
K_1 &= 7.3 \times 10^4 \text{ ergs/cm}^3 \\
K_2 &= 2.5 \times 10^4 \text{ ergs/cm}^3 \\
K_{u,w_0} &= 1.1 \times 10^4 \text{ ergs/cm}^3 \\
K_{u,Ta} &= 0.4 \times 10^4 \text{ ergs/cm}^3 \\
K_{u,Cu} &= 2.7 \times 10^4 \text{ ergs/cm}^3 \\
\lambda_{100} &\approx \lambda_{111} \\
D_{g, w_0} &= 60 \text{ nm} \\
D_{g, Ta} &= 50 \text{ nm} \\
D_{g, Cu} &= 10 \text{ nm}
\end{align*}
\]

\[
\frac{H_c}{H_{c,Cu}} = \frac{K_u^{1/4}}{K_{u,Cu}^{1/4}} \frac{K_{\text{local}}}{K_{\text{local},Cu}} \frac{D_g^{3/2}}{D_{g,Cu}^{3/2}}
\]

The calculated ratio
- = 12.5 for FeCo without an underlayer
- = 6.9 for FeCo with Ta

The measured ratio
- = 14.0 for FeCo without an underlayer
- = 7.8 for FeCo with Ta

($H_{c,w_0} = 120$ Oe, $H_{c,Ta} = 67$ Oe, and $H_{c,Cu} = 8.6$ Oe)

Reduction in Saturation Magnetostriction of FeCo

\[ 4\pi M_s \quad \leftrightarrow \quad \lambda_s \]

1. Adjusting the composition of FeCo [1]
2. Adding Sm into FeCo [2]
3. Composite structure: FeCo(Sm)/FeTa


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Cu/CoFe FMR Anisotropy Study

Torque, VSM, FMR techniques

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MOKE-Waveguide System

- Lockin Amp
- Detector
- Analyzer
- Coils
- Coplanar waveguide
- Polarizer
- Modulator
- Lens
- Computer w/LabView
- Pulse Generator
- Laser
- Sample
- 300 psec rise time
- 1-100 nsec pulse width

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MOKE and MOKE – Switching Studies of NiFe

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FMR of Patterned NiFe

FMR, hard axis
NiFe, Patterned
2 x 20 \( \mu \) x 50 nm

\( 4\pi M_s = 9560 \) Oe
\( \gamma = 2.99 \) MHz/Oe

FMR Linewidth data
NiFe, patterned
2 x 20 \( \mu \) x 50 nm

\( \alpha = 0.008, \Delta H_0 = 6 \) Oe

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Identified Compositions with high $B_s$ 21.5 kG, low $H_c \sim 1$ Oe

Growth of BCC + FCC phases induces small grain size, soft magnetic properties
Recent Efforts

Detect first stages of phase transformation by monitoring stress during heat treatment

Study high frequency properties of soft materials as function of their structure (with Chet Alexander)
Fe-Co with Bulk Moment

- Fe-Co with $B_s = 24.5$ kG, low $H_c$, low $\lambda_s$
  - Avoid precipitation and incorporation of Fe(OH)$_3$ in the film
    - Selective complexants to bind Fe$^{3+}$
    - Pulse plating (PP) and pulse reverse plating
  - Decrease internal stresses
    - Use additives to compete with hydrogen adsorption at the surface
    - Optimize $t_{off}$ in PP to desorb hydrogen
    - Composition modulation of FeCo by novel chemistries (could also decrease $\lambda_s$)
Fe-Co-X with high moment

- $(\text{Fe}_{50}\text{Co}_{50})_{1-y}\text{X}_y \ (\text{X} = \text{Va, Mo}, \ y \sim 1 \ \text{at}%)$ exhibit high moment and softer magnetic properties than FeCo.

- Previous efforts have given limited soft magnetic properties.

- Utilize novel chemistries, various current/voltage waveforms.

\[
\text{Co}_{49.5}\text{Fe}_{49.5}\text{V}_1 \quad B_s > 20 \ \text{kG}
\]
Remanent States of nm-scale Soft Magnetic Structures

- 1 Tb/in² require heads with 10 - 50 nm pole cross section
- Pole dimensions comparable to $l_{\text{exch}}$ and domain wall width
- Magnetic properties and remanence configuration are not understood
- Direct macroscopic - static and dynamic - measurements
Nanostructured Epitaxial Fe Films

We are learning to control the forces of surface tension, strain and atomic bonding to produce self-assembled nanostructured films.

Magnetization data confirms that a small change in process temperature produces markedly different structures.

Ref. Poster by P. Mani, et al.

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