Structure and Magnetic Properties of High-Moment Films

Chet Alexander, Soon Cheon Byeon, Jim Rantschler, and Yunfei Ding

Giovanni Zangari, and Xiaomin Liu

Research sponsored by NIST-Boulder and UA MINT Center

MINT Fall Review, November 2001
Outline

1. The distribution of nitrogen atoms within epitaxial (110) FeTiN films

2. Studies of damping in FeTiN and NiFe films
   Chet Alexander, Soon Cheon Byeon, Jim Rantschler, and Yunfei Ding

3. Electrodeposited high-moment films
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The distribution of nitrogen atoms within epitaxial (110) FeTiN films

The addition of N atoms to the Fe lattice causes changes in structural and magnetic properties. The N atoms occupy interstitial positions in the Fe lattice.

Mobility of nitrogen atoms cause instability [1]

Study the thermal stability of nitrogen atoms: WHERE are the nitrogen atoms?

Sample Growth

Deposition:
Sputtering deposition on KEY system
H-Si(100)/Cu(100) 2000Å/FeTiN(110) 1000Å
The FeTiN was sputtered at 35W, 0.45mT, 1.2 Å/S\(^1\)

Lattice fit:

Cu<110> 5.112 Å/
Si(100) 5.431 Å

Fe<111> 4.965 Å/
Cu<110> 5.112 Å

Lattice Distortion

The d(200)/d(020) spacings measured at $\psi = 45^\circ$ and d(002) values measured at $\psi = 88^\circ$

The d(110) spacings measured at $\psi = 0^\circ$ and d(011)/d(101) values measured at $\psi = 60^\circ$
FMR Measurement of Anisotropy

The calculation of crystalline anisotropy constant $K_1$

$$F = K_1(\alpha_1^2\alpha_2^2 + \alpha_2^2\alpha_3^2 + \alpha_3^2\alpha_1^2)$$

Inside (110) plane:

$$F = K_1\left(\frac{\sin^4 \theta}{4} + \sin^2 \theta \cos^2 \theta\right)$$

Consider four lattice orientations:

$$K_1 = M_S \cdot \left|H(\theta' = 45^\circ) - H(\theta' = 0^\circ)\right| / 2.34$$

Figure: Anisotropy constant $K_1$ vs. nitrogen concentration
Conclusions

• In epitaxial FeTiN (110) film, at low nitrogen concentration (<~4at%), nitrogen atoms tend to occupy the sites (x,y sites) between (110) planes, this trend seems to be growth related.
• At higher nitrogen concentration (>~4at%), the sites inside (110) planes (z sites) are preferred.
• In-plane magnetocrystalline anisotropy tends to decrease when z sites are preferentially occupied.
• Direct coupling between magnetization and an occupied site is not be able to be observed due to the four-fold lattice structure, single crystal film will be deposited in the proceeding study (See Poster by Yunfei Ding)
Studies of Damping in and NiFe/ FeTiN films

Goal: To get a better understanding of the factors which control damping in high-moment films

Samples: Stable FeTiN films with different N content and NiFe/X/FeTiN films

Experimental Techniques: FMR at different frequencies, permeability measurements to 6 GHz, Step-response techniques, transverse –bias permeability, magnetostriction, XRD
Determination of FeTiN Damping Constant from FMR Data

\[ \Delta H = \Delta H_0 + 2(\alpha/\gamma)\omega \]

\[ \alpha = 0.0035 - 0.0040 \]

\( \Delta H_0 \) small, but large error
FeTiN Damping Constant at Low Bias Fields

\[ \alpha = \alpha_0 + \frac{1}{\sqrt{M_s}} \frac{\Delta H_k}{\sqrt{H_b + H_k}} \]

\[ \Delta H_k = 0.2 \text{ Oe} \]

Multilayers and Damping

- The more strongly coupled sample has larger and more similar damping in its magnetization than its cousin with a thicker SiO₂ layer does.

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FeTiN XRD and Magnetostriction Data

At% N in FeTiN

18.86 at% N
15.39 at% N
13.51 at% N
11.16 at% N
11.99 at% N
9.88 at% N
8.51 at% N
6.76 at% N
6.05 at% N
5.33 at% N
2.95 at% N
0.00 at% N

2θ (Cu Kα, degree)

FeTiN Magnetostriction

λ x 10^6

At. % Nitrogen

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An NSF Materials Research Science and Engineering Center
Continuing Work

Experiments are continuing with samples of FeTiN with different N content and different microstructure. The goal is to correlate the differences in structure to the differences in damping.

Also experiments are continuing to provide data to help derive a model for the effect of exchange coupling on the damping. (See poster by Jim Rantschler)
Fe-Co-Ni Films by Electrodeposition

X. Liu, G. Zangari

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

$E_{me} > 0$

bulk $B_s = 20kG$

$E_{me} < 0$

stripe domains

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Outlook and Future Work

- Optimum soft properties and high $B_s$ are associated with the coexistence of BCC and FCC phases
- $B_s$ is higher than in bulk alloys of corresponding composition, and increases with the % of BCC phase
- Frequency response related to magnetoelastic effects and dispersion of the easy axis
- **In the near future, investigate**
  - correlation microstructure/high frequency performance
  - origin of the “giant” magnetic moment
  - upper limit of $B_s$
  - processing of FeCoNi small elements and their properties
  - electrochemistry of the system: effect of Cl$^-$ anions

More details in the poster session - two posters (look for Ms. Xiaomin LIU)