Microstructure and Damping in FeTiN and CoFe films

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Introduction

This study was carried out to look for relationships between damping in ferromagnetic films and magnetostriction or microstructure. Sputtered films of FeTiN, CoFe and CuCoFe were prepared and characterized by FMR, XRD, XPS, and magnetostriction measurements, to examine these possible relationships. The FMR studies have been carried out at multiple frequencies to determine the intrinsic damping constant, $\alpha$, and the extrinsic damping constant, $\Delta H_0$, as well as values of the anisotropy field $H_k$, the gyromagnetic ratio, $\gamma$, and the saturation magnetization value $4\pi M_s$. 
FMR Determination of $4\pi M_s$, $H_k$ and $\gamma$

Ferromagnetic resonance (FMR) studies were used to determine the values of $H_k$, $4\pi M_s$ and the gyromagnetic ratio, $\gamma$, by rotating the sample in the plane of the films to determine the $H_k$ value ($(H_{HA} - H_{EA})/2$), and then finding the $4\pi M_s$ and $\gamma$ values from a fit to

$$f = \gamma \sqrt{(H + H_k + 4\pi M_s)(H + H_k)}$$

for a plot of the square of the resonance frequency against the resonance field. A plot for a sample with 6.1% N is shown in Fig. 1. Values of $H_k$, $4\pi M_s$ and $\gamma$, determined for a range of films with different N content are given in Table I.
FMR Determination of $\alpha$ and $\Delta H_0$

Previous investigators (1) have shown that the FMR linewidth $\Delta H$ can be related to the damping and can be expressed as

$$\Delta H = \Delta H_0 + 2 \frac{\alpha f}{\gamma}$$

The frequency dependent part is a good measure of the intrinsic or viscous damping described by $\alpha$ in the Landau-Lifshitz-Gilbert equation, whereas the extrinsic term $\Delta H_0$ is thought to be related to magnetic inhomogeneities (2). A graph of the FMR linewidth versus frequency for a sample with 6% nitrogen is shown in Fig. 2. Values of $\Delta H_0$ and $\alpha$ were determined by fits to these data and the results for FeTiN films with a range of nitrogen content are shown in Table I.
FMR Data for FeTiN with 6% N

Figure 1.

Figure 2.

\[ \Delta H_0 = 16 \text{ Oe} \]
\[ \alpha = 0.0047 \]

\[ 4\pi M_s = 16371 \text{ Oe} \]
\[ \gamma = 2.95 \text{ MHz/Oe} \]
\[ H_k = 11 \text{ Oe} \]
TEM and Grain Size for FeTiN

Glass/FeTiN 50nm

0% N\textsubscript{2}

1cm scale=87nm

22.2 ± 6 nm

Glass/FeTiN 50nm

6% N\textsubscript{2}

1cm scale=87nm

9.6 ± 2.5 nm

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Grain Size and Nitrogen Content in FeTiN Films

Exchange length calculations for FeTiN and CoFe, using

\[ L_{ex} = \sqrt{\frac{A}{2\pi M_s^2}} \]

give \( L_{ex} = 4 \) nm for FeTiN and \( L_{ex} = 3 \) nm for CoFe
$\Delta H_0$ values versus Grain Size for FeTiN and Cu/CoFe

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Linewidths and $\Delta H_0$ for CoFe and Cu/CoFe
### Microstructure and Magnetic Properties of FeTiN and CoFe

<table>
<thead>
<tr>
<th>%Nitrogen</th>
<th>$4\pi M_s$ (Oe)</th>
<th>$H_k$ (Oe)</th>
<th>$\gamma$ (MHz/Oe)</th>
<th>$\Delta H_0$ (Oe)</th>
<th>$\alpha$</th>
<th>$\lambda$ ($\times 10^{-6}$)</th>
<th>Grain size (nm)</th>
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</table>
Conclusions

We observe no variation in the intrinsic damping constant $\alpha$ as a function of microstructure in FeTiN samples, but we do find that the parameter $\Delta H_0$ depends strongly on the size of grains relative to the exchange length: as the grain size approaches the exchange length, $\Delta H_0$ decreases. In CoFe samples we find the same $\Delta H_0$ vs. grain size relationship, but no observation of an $\alpha$ and microstructure relationship was possible because the intrinsic damping was obscured by the extrinsic linewidth for the CoFe sample. Our results are consistent with the results of Celinski and Henrich for amorphous and ultrathin samples (3). We observe no plausible relationship between magnetostriction and either the intrinsic or extrinsic damping parameters in either FeTiN or Cu/CoFe films.
References

