Magnetization reversal mechanisms in Fe$_{60}$Sm$_{40}$ thin films

J.L. Weston$^1$, A. Butera$^2$, G. Zangari$^1$, J.A. Barnard$^3$

$^1$MINT Center and Metallurgy and Materials Engineering
$^2$Centro Atomico Bariloche, Rio Negro, Argentina
$^3$Materials Science and Engineering, University of Pittsburgh

This work was supported by NSF-DMR-9713497 and made use of MRSEC shared facilities supported by NSF-DMR-9809423

MINT Fall Review, November 2001

This work is scheduled for publication in Physica B
Ultrafast magnetization decay in FeSm/FeTaN multilayers

- Recently, it was discovered that FeSm/FeTaN with an in-plane anisotropy exhibit an ultrafast magnetization decay [Weston, JAP 89, 6831 (2001)].
- This ultrafast reversal has been observed in Co/Pt multilayers [Fry JAP 85, 5169 (1999)] and TbCo films [Labrune JMMM 80, 211 (1989)], both with a perpendicular anisotropy.
“Isotropic” FeSm

- FeSm was sputtered in the absence of applied field onto Si (100).
- Film thicknesses 10, 20, 40, 80 nm.
- Remanence of isotropic films ~ 0.6 and minor loops show that wall pinning slows remagnetization process.
Uniaxial FeSm

- An applied field of 60 Oe was applied to Si (100) while FeSm was sputtered.
- Easy axis measurements shown remanence of ~1.
- Minor loops show very rapid remagnetization indicating very rapid domain propagation.
Comparison of magnetization decay

- One of the most striking differences between the uniaxial and isotropic films is in the rate of magnetization decay.
- Arrhenius-Neel decay predicts a maximum decay ($\delta$) of 169% per decade or peak magnetic viscosity, $S_v$, of 0.74 [Arias JMMM 171, 209 (1997)].
- Series A (uniaxial FeSm) exhibits a $\delta$ of $\sim$ 350%
Time dependence of coercivity

- In order to investigate the time dependence of the coercivity, the remanent coercivity was measured at 1 to 50 s hold times.
- The time dependence (the fluctuation field) was determined and plotted versus log (film thickness).
- \( H_f \) for isotropic films depends strongly on thickness, while no dependence is observed in uniaxial films.

\[
H_{cr}(t) = -H_f \cdot \ln\left(\frac{t}{1s}\right) = -\left(\frac{k_b T}{M_s V_{act}}\right) \ln\left(\frac{t}{1s}\right)
\]
Fatuzzo model

- Originally designed to model the reversal of ferroelectrics, the Fatuzzo model has been used to model the magnetization decay of certain perpendicular magnetic materials [Fatuzzo Phys. Rev. 127, 1999 (1962)] [Lyberatos J. Phys: Condens 9, 2623 (1997)].

- Instead of a $t/\tau$ term in the exponential, an expanded form for the nucleation ($\tau$) and growth ($\kappa$) of domains is used.

$$M(t) = M_s (2e^G - 1)$$

$$g = -2\kappa^2 \left[ 1 - \left( \tau + \frac{1}{\kappa} \right) + \frac{\left( \tau + \frac{1}{\kappa} \right)^2}{2} - e^{-\tau} \left( 1 - \frac{1}{\kappa} \right) - \frac{(1 - \tau)}{2\kappa^2} \right]$$
Fatuzzo modeling

- For each reverse field, the parameters associated with nucleation and domain growth can be determined.

Nucleation $\tau = R t$

Growth $\kappa = \nu / R r$

By plotting the parameters as a function of field, it is possible to extract activation energies/volumes for the processes

$$R = R_0 e^{-\left(\frac{M_s V_{\text{act}}}{k_B T} H\right)}$$
Conclusions

• FeSm, with an in-plane uniaxial anisotropy, has been found to exhibit an ultrafast magnetization decay, a process heretofore observed in materials with a perpendicular anisotropy.

• By varying the deposition parameters, the magnetization decay process can be controlled. An applied field during deposition induces an in-plane uniaxial anisotropy, which changes the energy barrier distribution, so that the decay is not slowed by domain wall pinning. No intentional field during deposition changes the energy barrier distribution, so that domain wall pinning slows the decay.

• The Fatuzzo model can be applied to a material with an in-plane reversal process.