Magnetic Relaxation in Patterned Submicron Rectangular Permalloy Elements

J.W. Harrell and Zhiyong Jia
Dept. of Physics & Astronomy and MINT Center
University of Alabama, Tuscaloosa, AL

and

Jing Shi
Dept. of Physics, University of Utah
Project Objective and Motivation

• Magnetically soft, submicron sized magnetic elements have potential applications as storage elements in MRAM devices.

• Thermal stability and switching mechanisms are becoming increasingly important issues as element sizes decrease.

• We are studying magnetic relaxation in patterned submicron permalloy elements prepared by Jing Shi (Univ. of Utah).
J. Shi, J. Li, S. Tehrani, MMM01, preprint

200 nm x 200 nm x 10 nm permalloy elements
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200 nm x 200 nm x 10 nm permalloy elements
200 nm x 200 nm x 10 nm permalloy elements

\[ H_c = H_0 (1 - \alpha T^n) \]

- \( n = 1 \)
- \( n = 1/2 \)
AGM measurements –
200 nm x 200 nm x 10 nm elements
200 nm x 300 nm x 10 nm elements

hysteresis

\[ M \]

\[ H \text{ (Oe)} \]

\[ -800 \ -400 \ 0 \ 400 \ 800 \]

dcd remanence

\[ \frac{dM_r}{dH} \]

\[ M_r \]

\[ H_{c2} \]

\[ H_{c1} \]

\[ -400 \ -300 \ -200 \ -100 \ 0 \]

\[ H \text{ (Oe)} \]
200 nm x 400 nm x 10 nm elements

hysteresis

\[ dM_r/dH \times 10 \]

\[ H_{cr2} \]

\[ H_{cr1} \]

\[ M_r \]

\[ -300 \quad -200 \quad -100 \quad 0 \]

\[ H (\text{Oe}) \]
200 nm x 1000 nm x 10 nm elements

hysteresis

\[ M \]

\[ H \text{ (Oe)} \]

dcd remanence

\[ dM_r/dH \]

\[ H \text{ (Oe)} \]
Dynamic Coercivity

\[ H_{cr}(t) = H_0 \left\{ 1 - \left[ \frac{kT}{\Delta E} \ln(f_0t) \right]^n \right\} \]

- 200x200: \( n = \frac{1}{2} \)
- Others: \( n = 1 \)

Exponent (n) in Sharrock-law fit determined from temperature dependence measurements of Shi et al.
Dynamic Coercivity Parameters vs Aspect Ratio

\[ H_{cr}(t) = H_0 \left\{ 1 - \left[ \frac{kT}{\Delta E} \ln( f_0 t ) \right]^n \right\} \]

Graph showing \( \Delta E/kT \) and \( H_0 \) vs aspect ratio.
Conclusions and Future Work

• Preliminary measurements confirm complex switching mechanisms in low-aspect ratio elements.

• Future work:
  - Reduce gradient field used in AGM measurements
  - Measure time dependence of multiple switching fields.
  - Measure time dependence as function of temperature.
  - Measure high speed switching.