OVERVIEW

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1. Epitaxial CoPt Films                          Bin Xu
2. High Speed Switching                        Volodymyr Voznyuk
3. Soft Underlayers                            Hong-Sik Jung
4. Thermal Relaxation in Soft Elements         Huaqing Yin


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Magnetoelastic Effects in Epitaxial Co$_{80}$Pt$_{20}$ Films

Bin Xu, Timothy J. Klemmer*, and William D. Doyle

* Seagate Research, Pittsburgh

Problem

• Strains and magnetoelastic effects in epitaxial Co$_{80}$Pt$_{20}$ films

Approaches

• Cr and W as underlayer for different mismatch
• Strain relaxation in Co80Pt20 films with different thickness
• Direct measurement of in-plane strains by x-ray Grazing Incidence Diffraction (GID)
Strain and Magnetoelastic Effects in Co$_{80}$Pt$_{20}$ Films with a Cr Underlayer

- Strains much lower than mismatch even for films as thin as 1 nm
- Strain relaxation not as well defined as $1/t^{2/3}$ in MBE films
- Out-of-plane strain likely released by fcc stacking fault
Future Work

• Construct a magnetostriction measurement setup with high magnetic field (~20 kOe) capability (in progress)

• Measure the magnetostriction of Co$_{80}$Pt$_{20}$ films as a function of thickness
Major advantage: low Mrt with rather large physical thicknesses of the layers!

\[
\text{Mrt}_{\text{SFM}} = \text{Mrt}_2 - \text{Mrt}_1
\]

<table>
<thead>
<tr>
<th>Sample</th>
<th>(t_1) (nm)</th>
<th>(t_2) (nm)</th>
<th>(t_2-t_1) (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL6</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SL8</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SL12</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF7</td>
<td>5</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>SF9</td>
<td>5</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>SF12</td>
<td>4</td>
<td>16</td>
<td>12</td>
</tr>
</tbody>
</table>

Ru layer: 0.7 nm
Intrinsic Switching Field ($H_0$) and $KV/kT$

Measured: AGM, $H_0$ and $KV/kT$ were extracted from the fit of the experimental data points to Sharrock's formula

SLM: $t = t_1$, SFM: $t = t_2 - t_1$ for $M_{rt}$.
Future work

• Short-time remanent coercivity measurements, using a newly built high-voltage pulse generator that should allow field pulses up to 8-9 kOe.

• Extend data for single layers up and down. Extract K for single layers and relate it to KV/kT and Ho dependencies.

• Investigate how the exchange coupling effect the properties.

• Pulse remanent coercivity measurements on perpendicular media without bias field.
Soft Underlayer for Perpendicular Media
Hong-Sik Jung and W. D. Doyle

- **Outstanding Results**
  1. Single domain
  2. Permeability $\geq 100$
  3. Wide angular range non-hysteretic reversal
  4. Radial easy axis
  5. High $4\pi M_s > 18$ kG
  6. High resistivity $> 70$ $\mu\Omega$-cm
  7. Less media noise below 5 MHz compared to a single NiFe layer ($H_c = 33$ Oe)

- **Problem**
  - Large number of layers to meet a permeability of $\sim 100$

- **Solution**
  - Increase the pinning field using CoFe with a high uniaxial anisotropy
CoFe/IrMn Exchange-coupled Multilayer Films

G/[CoFe(50)/IrMn(10)]3/CoFe(50)  G/Cu(20)/IrMn(10)/[CoFe(50)/IrMn(10)]4/CoFeN(20)

- Solutions to provide single domain remanent direction
  1. Increase $H_{eb}$ in the bottom CoFe layer by adding Cu/IrMn underneath.
  2. Use CoFeN to reduce $H_c$
  3. Increase $H_{eb}$ in the top CoFeN by reducing thickness from 50 to 20 nm.

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Future Work

1. Study the domain structure in FeTaN/IrMn and CoFe/IrMn multilayers as a function of magnetic field.

2. Increase the saturation magnetization by increasing the Fe content in CoFe.

3. Study the dependence of exchange coupling and its annealing behavior on microstructure in FM(FeTaN, NiFe, and CoFe)/IrMn bilayers and trilayers.
Thermal Decay in Soft Patterned Elements

H. Q. Yin and W. D. Doyle

MINT Center and Department of Physics and Astronomy, The University of Alabama
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Thermal Decay of Patterned Magnetic Element Arrays

➢ **Samples**

• Patterned Ni$_{80}$Fe$_{20}$ element array
• Thin film thicknesses: 7.9, 10, 18.3, 43.5 nm
• Element sizes: 1 x 5 µm$^2$, 1 x 10 µm$^2$, 1 x 15 µm$^2$, 2 x 10 µm$^2$
• Spacing between elements: 2 µm

➢ **Experiments**

• Hysteretic properties
• Time dependent coercivity
• Images of the remanent domain structures during time decay
Thermal Decay Parameters Extracted from the Time-dependent Coercivity Data

\( H_{CR} = H_0 \left[ 1 - \left( \frac{U}{kT} \right)^{-1} \ln \left( \frac{f_0 t}{\ln 2} \right) \right]^{\frac{2}{3}} \)

\( V_E = w^2 t \)

\( V_i: \) Activation volume assuming \( K = K_U = 2 \times 10^3 \) erg/cm\(^3\)

<table>
<thead>
<tr>
<th>t (nm)</th>
<th>Sample</th>
<th>( H_0 ) (Oe)</th>
<th>U/kT</th>
<th>( V_E ) (cm(^3))</th>
<th>( V_i ) (cm(^3))</th>
<th>( H_0/H_{kp} )</th>
<th>( V_E/V_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.9</td>
<td>1 x 5</td>
<td>69</td>
<td>113</td>
<td>( 3.5 \times 10^{-15} )</td>
<td>( 2.3 \times 10^{-15} )</td>
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<td>1.5</td>
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<td>7.9</td>
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<td>243</td>
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<tr>
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<td>205</td>
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<td>( 3.0 \times 10^{-15} )</td>
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<td>8.1</td>
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<tr>
<td>18.3</td>
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<td>167</td>
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<tr>
<td>18.3</td>
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<td>( 9.9 \times 10^{-15} )</td>
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<tr>
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<td>322</td>
<td>( 1.1 \times 10^{-14} )</td>
<td>( 5.4 \times 10^{-15} )</td>
<td>0.16</td>
<td>2.1</td>
</tr>
<tr>
<td>18.3</td>
<td>2 x 10</td>
<td>13</td>
<td>292</td>
<td>( 5.6 \times 10^{-14} )</td>
<td>( 7.7 \times 10^{-15} )</td>
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<tr>
<td>43.5</td>
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<td>64</td>
<td>67</td>
<td>( 1.8 \times 10^{-14} )</td>
<td>( 1.4 \times 10^{-15} )</td>
<td>0.16</td>
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<tr>
<td>43.5</td>
<td>1 x 10</td>
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<td>66</td>
<td>( 3.7 \times 10^{-14} )</td>
<td>( 1.4 \times 10^{-15} )</td>
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<tr>
<td>43.5</td>
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<td>52</td>
<td>94</td>
<td>( 2.5 \times 10^{-14} )</td>
<td>( 1.9 \times 10^{-15} )</td>
<td>0.13</td>
<td>12.9</td>
</tr>
</tbody>
</table>
Differential Phase Contrast Images

10 nm NiFe (0.7 x 2.8 μm²)

+ 6000 Oe → - 14.7 Oe
Thermal Relaxation with a Vortex

“C”

“S”

In collaboration with G. Yi, P. Aitchison, and J. Chapman, University of Glasgow

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Future Work

1. Continue Lorentz imaging on smaller elements as a function of time and temperature.

2. Characterize relaxation in pulse fields to test “adjacent bit” disturb threshold for cumulative pulses.

3. Determine the correct value of the exponent in Sharrock’s formula for small soft elements.