High Moment Materials for Writer

Chester Alexander
Department of Physics and MINT, UA
Subhadra Gupta
Metallurgical and Materials Engineering, UA
A. Pogorily, E. Shypil
Institute of Magnetism, Kyiv, Ukraine

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Outline

Stress and Magnetostriction in High Moment Ru/FeCo Laminated Films

Jinmei Dong, James Weston, Earl Ada, Chester Alexander, and Subhadra Gupta (UA), Katrina Rook (Veeco)

Magnetization in Exchange-Coupled FM/Gd Bilayers

A. Pogorily, E. Shypil, Institute of Magnetism, Kyiv, Ukraine; Chester Alexander UA
Stress and Magnetostriction in High Moment
Ru/FeCo Laminated Films

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Motivation

• Need for soft, high moment films for inductive writer heads.
  – Fe$_{60}$Co$_{30}$ has high moment (2.4 T).
  – Sputtered films are hard unless grain size and/or crystalline texture is modified by nucleating the film on a seed layer, e.g., NiFe, Ru etc.
  – Large magnetostriction
  – Lamination of the pole layer has been proposed to achieve near-zero demagnetization.
Summary of Present Effort

• We initiated a study of Ru/FeCo laminates.
• Film properties studied
  – Coercivity and Magnetic Moment
  – Magnetostriction
  – Stress
• Film parameters varied
  – Seed layer thickness
  – Number of laminations
  – Deposition pressure
  – See Poster: Stress and Magnetostriction in High Moment Ru/FeCo Laminated Films
Stress and Magnetostriction of Single Bilayer vs. Ru Seed Layer Thickness

![Graph showing stress and magnetostriction vs. Ru thickness (nm)](image)
Stress and Magnetostriction vs. Number of Bilayers at a Ru Seed Layer Thickness of 50 nm
Easy Axis Coercivity of Single Bilayer vs. Ru Seed Layer Thickness

![Graph showing the relationship between Ru seed layer thickness and Easy Axis Coercivity (Oe). The graph plots Ru seed layer thickness on the x-axis and Easy Axis Coercivity (Oe) on the y-axis. The data points suggest a general increase in Easy Axis Coercivity as the Ru seed layer thickness increases.]
Magnetostriction Data

Ru(50nm)/FeCo(150nm)

Output (V)

Field (Oe)

Ru(100nm)/FeCo(150nm)

Output (V)

Field (Oe)
XPS Data Showing Interface Mixing Between Ru and FeCo
Summary of Results

- Magnetostriction and stress are both significantly reduced as a function of increasing seed layer thickness.

- Coercivity and moment are not significantly affected as a function of seed layer thickness.

- Stress is significantly reduced as a function of number of laminations, but magnetostriction does not change significantly.

- The films become magnetically harder as the deposition pressure is increased. This is explained by XPS data showing significant interface mixing that increases sharply at higher pressures. At high pressures, this intermixing may result in the Ru seed layer becoming discontinuous, so that the resulting magnetic layer has high coercivity.
Future Plans

• Effect of low deposition rates to keep the interface between FeCo and Ru sharp.
• X-ray diffraction studies of a range of depositions to relate orientation and texture to observed film properties as a function of deposition parameters, seed layer thickness, and number of laminations.
• Micromagnetic model calculations relating stress and magnetostriction to film microstructure.
• Comparison of similar structures deposited on production systems at Veeco Instruments (NSF GOALI proposal submitted).
References

Magnetization in Exchange-Coupled FM/Gd Bilayers

A. Pogorily, E. Shypil, Institute of Magnetism, Kyiv, Ukraine; Chester Alexander UA

Previous Work

Several series of exchange-coupled bilayered FM/Gd films with different FM layers were studied experimentally by ferromagnetic resonance (FMR), vibration sample magnetometer (VSM) and polar magneto-optical Kerr effect (PMOKE). It is shown that combination of ‘interlayer’ and RKKY (‘intralayer’) exchanges with the Zeeman energy can explain the observed oscillations and enhancement of the total magnetization at room temperature (RT).

See Poster Entitled:
A Study of Magnetization in Exchange-Coupled FM/Gd Bilayers
Magnetic properties of Transition and RE metals

<table>
<thead>
<tr>
<th>Transition Metal</th>
<th>( T_C ) (K)</th>
<th>( \mu_B ) (0K)</th>
<th>( 4\pi M_s ) (G) 20°C</th>
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<tbody>
<tr>
<td>Fe</td>
<td>1044</td>
<td>2.2</td>
<td>21352</td>
</tr>
<tr>
<td>Co</td>
<td>1360 - 1388</td>
<td>1.7</td>
<td>17584</td>
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<tr>
<td>Ni</td>
<td>627</td>
<td>0.6</td>
<td>6154</td>
</tr>
<tr>
<td>Py(Ni\textsubscript{80}Fe\textsubscript{20})</td>
<td>850</td>
<td>1.0 - 1.2</td>
<td>9700</td>
</tr>
<tr>
<td>Fe\textsubscript{50}Co\textsubscript{50}</td>
<td></td>
<td></td>
<td>23000</td>
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<table>
<thead>
<tr>
<th>RE Metal</th>
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<tr>
<td>Tb</td>
<td>230</td>
<td>19.7</td>
<td>30000(T=0)</td>
</tr>
<tr>
<td>Gd</td>
<td>293</td>
<td>7.6</td>
<td>26600 (T=0)</td>
</tr>
</tbody>
</table>

Three kinds of exchange interactions:

1. **TM- TM** (3d-3d) - direct interaction

2. **RE-RE** 4f (5f) – indirect interaction (via cond. electrons)

3. **TM-RE** – direct interaction via 5d - 3d hybridization

The aim: to hybridize the properties for certain applications
Dependence of 4pMs on Gd thickness for different FM/Gd samples

Magnetization oscillations are consistent with indirect (RKKY) exchange
Py/Gd

SQUID, $H_{ii}$, RT:
- Q/40Å Py/30Å SiO (NM13)
- Q/40Å Py/50Å Gd/30Å SiO (NM17)

M, emu/mm$^3$

T, K
Py/Gd

D:MINT_SQUIDNM13&17_PyGd_M-T&M-H_RT

SQUID, $H_i$, RT:
- $Q/40\,\text{Å} \, \text{Py/30\,Å SiO (NM13)}$
- $Q/40\,\text{Å} \, \text{Py/50\,Å Gd/30\,Å SiO (NM17)}$
CoGd

SQUID, $H_\parallel = 0.1T$:

- $Q/40\AA\ Co/30\AA\ SiO$ (NM4)
- $Q/40\AA\ Co/80Gd/30\AA\ SiO$ (NM39)
CoGd

SQUID, $H_{||}$, RT:

- Q/40Å Co/30Å SiO (NM4)
- Q/40Å Co/80Gd/30Å SiO (NM39)
Co/Gd With Different Barriers

\[ M, \text{emu/mm}^3 \]

SQUID, \( H_{||} = 0.1 \text{T} \);
- Q/30Å Co/30Å SiO
- Q/30Å Co-3.5min/30Å Gd/30Å SiO
- Q/30Å Co-80 min/30Å Gd/30Å SiO
Co/Gd With Different Barriers

SQUID, H_{II}, RT

- Q/30Å Co/30Å SiO (NM3)
- Q/30Å Co/3.5min/30Å Gd/30Å SiO (NM32)
- Q/30Å Co/80min/30Å Gd)/30Å SiO (NM36)

M, emu/mm³

H, Oe

D:\MINT_SQUID\NM3&32&36_M-H_SQUID
Results of VSM, SQUID, AGM and FMR of pure FM layers and bilayers with Gd
Measurements on base of Py and Co

<table>
<thead>
<tr>
<th></th>
<th>VSM/SQUID/AGM</th>
<th>FMR</th>
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<tr>
<td></td>
<td>M (emu/mm³)</td>
<td>4πM (kG)</td>
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<tr>
<td>Py/Gd:</td>
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</tr>
<tr>
<td>SQUID: NM13 40Å Py</td>
<td>0.66</td>
<td>8.290</td>
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<tr>
<td>SQUID: NM17 40Å Py/50Å Gd</td>
<td>1.38</td>
<td>17.333</td>
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<tr>
<td>Co/Gd:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VSM NM5 100Å Co</td>
<td>1.26</td>
<td>15.826</td>
</tr>
<tr>
<td>AGM 100Å Co</td>
<td>1.24</td>
<td>15.574</td>
</tr>
<tr>
<td>VSM NM4 40Å Co</td>
<td>0.95</td>
<td>11.932</td>
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<tr>
<td>AGM 40Å Co</td>
<td>1.31</td>
<td>16.453</td>
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<tr>
<td>SQUID 40Å Co/80Å Gd</td>
<td>1.95</td>
<td>19.534</td>
</tr>
<tr>
<td></td>
<td>1.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.15</td>
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</tr>
<tr>
<td>Co/Gd with different barriers:</td>
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<td></td>
</tr>
<tr>
<td>NM3 30Å Co VSM</td>
<td>0.88</td>
<td>11.053</td>
</tr>
<tr>
<td>SQUID</td>
<td>1.11</td>
<td>13.942</td>
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<tr>
<td>NM32 30Å Co/3.5min/30Å Gd</td>
<td>0.68</td>
<td>8.540</td>
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<tr>
<td>VSM</td>
<td>1.11</td>
<td>13.942</td>
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<tr>
<td>SQUID</td>
<td>1.11</td>
<td>13.942</td>
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<tr>
<td>NM36 30Å Co/80min/30Å Gd</td>
<td>1.14</td>
<td>14318</td>
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<tr>
<td>VSM</td>
<td>1.62</td>
<td>20.347</td>
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<tr>
<td>SQUID</td>
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Future Work

The orientation of the RE and FM spins in an external field will be investigated by polarized neutron reflectometry experiments at Argonne National Pulsed Neutron Source Facility.
Future Work

XPS depth-profile experiments will be used to confirm the existence and nature of the buffer layer formed as a function of FM-Gd deposition wait time.

We will extend these experiments with higher moment films such as FeXN/Gd and FeCo/Gd. Initial experiments with FeCo have not shown the same effects as with NiFe and Co.