Effect of the Kinds of Ferromagnetic Layers on Exchange Coupling Strength in IrMn/FM Films

H.S. Jung, O. Traistaru, and H. Fujiwara

MINT Center and Department of Physics and Astronomy, The University of Alabama

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Introduction: Non-linear Relationship between $J_{ex}$ and $M_s$

Previously Reported Data

Experiment

<table>
<thead>
<tr>
<th>Ferromagnetic and Antiferromagnetic Materials Used</th>
<th>$M_s$ (emu/cm$^3$) $T_c$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeCoFe$<em>{30}$Co$</em>{70}$</td>
<td>1910</td>
</tr>
<tr>
<td>CoFeCo</td>
<td>1430</td>
</tr>
<tr>
<td>NiFe</td>
<td>800</td>
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<td>(NiFe)$<em>{71}$Cu$</em>{29}$</td>
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Assume that $t_{FM}$ is very thick, from the plot of $H_p$ versus $1/t_{FM}$ Slope = $J_{ex}/M_s$ Intercept = average $H_k$ $J_{ex}$

$J_{ex} = \beta \frac{H_k}{M_s}$

$J_{ex}$ and $J_{er}$ for IrMn/(Co$_{90}$Fe$_{10}$, Ni$_{80}$Fe$_{20}$, Ni, or (NiFe)$_{100-x}$Cu$_x$) films were measured.

Effect of IrMn on In-plane M-H Curves

G/Ta(20)/Cu(20)/IrMn(10)/FeCo(10-50 nm)/Cu(2)/Ta(5)

- As-deposited state
  $H_k = 27 + 1211 \times 1/t_{FeCo}$
  $H_k = 866 \times 1/t_{FeCo}$
- Annealed state
  $H_k = 38 + 1641 \times 1/t_{FeCo}$
  $H_k = 1518 \times 1/t_{FeCo}$

Both $J_{ex}$ and $J_{er}$ for IrMn/(Co$_{90}$Fe$_{10}$, Ni$_{80}$Fe$_{20}$, Ni, or (NiFe)$_{100-x}$Cu$_x$) films were measured.

Without IrMn

- As-deposited state
  $H_k = 27 + 1211 \times 1/t_{FeCo}$
  $H_k = 866 \times 1/t_{FeCo}$

- Annealed state
  $H_k = 38 + 1641 \times 1/t_{FeCo}$
  $H_k = 1518 \times 1/t_{FeCo}$

Field Strength at the HA

$H_{HA} = H_{FM} + \left( J_{ex} / M_s \right) (1/t_{FeCo})$

Confirmation of Non-linear Relationship at the Reported Data

$J_{ex} = \alpha (M_s - M_{constr})$

- Non-linear relationship between $J_{ex}$ and $M_s$

Conclusion

- Non-linear relationship between $J_{ex}$ and $M_s$
  in IrMn/FM films was observed and fit well to a formula $J_{ex} = \alpha (M_s - M_{constr})$.

- This non-linear relationship also holds for various AFM/FM films such as CoO, FeMn, and PdPmMn.

- The contribution of $\Delta H_c$ to the non-linear relationship is negligible.

- Existence of $M_{constr}$ is due to in-plane isotropic reversible M-H curves with zero remanence.

For more information and reprints contact:

H.S. Jung, MINT Center.

Tel: 205-348-0449, e-mail: jung001@bama.ua.edu