Perpendicular Media

SYNTHETIC ANTIFERROMAGNETIC SOFT UNDERLAYERS

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HIGH SPEED SWITCHING

– EXPERIMENTAL
  V. G. Voznyuk and W. D. Doyle

– MODELING
  A. Misra and P. B. Visscher
Synthetic Antiferromagnetic Soft Underlayers

❖ Advantages

• Fe$_{65}$Co$_{35}$ / Ru / Fe$_{65}$Co$_{35}$ with thick ferromagnetic layer
• Better thermal stability than IrMn-based films
• Ideal soft underlayers
  – No edge demagnetization
  – Low interaction with
  – Improved efficiency for magnetic flux return
    ▪ Thinner spacer layer (~0.8 nm) than the 10 nm thick IrM
Calculation of the Expected Film Parameters

- Fe$_{65}$Co$_{35}$/Ru/Fe$_{65}$Co$_{35}$ bilayer film parameters
  - Saturation field $H_S$ (the field at which the moment has attained 80% of the saturation moment)
  - Permeability $\mu = 1 + 4\pi M_s / H_S$

- $J_{AF} = 1.6$ erg/cm$^2$ [1]
- $4\pi M_s = 23$ kG
- $H_s = 230$ Oe is required for $\mu = 100$
- Fe$_{65}$Co$_{35}$ thickness = 76 nm

Dependence of $J_{AF}$ on FeCo Thickness

![Graph showing the dependence of $J_{AF}$ on FeCo thickness. The graph plots $J_{AF}$ (erg/cm$^2$) against $t_F$ (nm). The data points indicate a sharp decrease in $J_{AF}$ as $t_F$ increases from 0 to 50 nm, followed by a plateau at higher thicknesses.](image-url)
Calculated and Experimental Hysteresis Loops for a Bilayer Structure

Glass/ Ru(2.5 nm)/ FeCo(50 nm)/ Ru(1.0 nm)/ FeCo(50 nm)/ Ru(10 nm)

![Graphs showing calculated and experimental hysteresis loops for a bilayer structure.](image_url)
Angular Dependence of the Hysteresis in a Bilayer Structure

Glass/ Ru(2.5 nm)/ FeCo(50 nm)/ Ru(1.0 nm)/ FeCo(55 nm)/ Ru(10 nm)
Thermal Stability

glass/ Ru(2.5 nm)/ FeCo(50 nm)/ Ru(1.0 nm)/ FeCo(55 nm)/ Ru(10 nm)

(a) Easy axis loop shift (Oe) vs. Temperature (°C)

(b) J_{AF} (erg/cm²) vs. Temperature (°C)

Legend:
- ■ H_p at RT
- ○ H_p at T
- ■ J at RT
- ○ J at T
Improved Characteristics in a Trilayer

Glass/ Ru(2.5 nm)/ FeCo(25 nm)/ Ru(1.0 nm)/ FeCo(45 nm)/ Ru(1.0 nm)/
FeCo(25 nm)/ Ru (10 nm)

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Negative remanence

Glass/ Ru(2.5 nm)/ FeCo(50 nm)/ Ru(1.0 nm)/ FeCo(55 nm)/ Ru(10 nm)

Observed loop

Calculated loop

Possible misalignment of the easy axes during film deposition.

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Annealing experiment

Glass/ Ru(2.5 nm)/ FeCo(50 nm)/ Ru(1.0 nm)/ FeCo(55 nm)/ Ru(10 nm)

Annealing in a 1T field for one hour aligns the easy axes.

Calculated loop

Observed loop

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Future Plans

- Optimize the design based on modeling results.
- Extend the model to include magnetization twist.
- Demonstrate improved characteristics in structures with aligned anisotropies.
- Investigate bilayer with Rh spacer layers to achieve higher $J_{AF}$ values.
Time Dependent Remanent Coercivity in Perpendicular Recording Media

❖ Motivation and challenges

• Previously, using a unique pulse field magnetometer, we have measured the time-dependent coercivity down to $10^{-9}$ s for a wide variety of longitudinal media.

• Perpendicular media presents several challenges to us:
  - high intrinsic switching fields;
  - less compatible geometry for microstripline measurements;
  - smaller stray fields;
  - strong signal from the soft underlayer.
Experimental Setup
Pulse Generation and Sample Magnetization State Detection

High Voltage DC Power Supply -> R
-> Coaxial Cable RG-213
-> Trigger Unit
-> Switch Unit (Spark Gap)
-> Transient Digitizer SCD 1000

Hall Probe + F.W.Bell Gaussmeter 9900

Saturating Permanent Magnet

Ground Plane

Microstripline
Conductor: Copper 120 x 15 µm
Insulator: Kapton, 50 µm

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Microstripline Configuration

Sample preparation

1. Substrate
2. 90° Magnetic film
3. Magnetic film
4. Cross-sectional view

Cross-sectional view

- Copper strip conductor: 120 x 15 μm
- Insulator Kapton: 50 μm
- Sample substrate
- Ground plane
- Epoxy
- Magnetic layer: 18 μm x 3 mm x t

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Differential detection

Peak position determination

Signal measured at peak position is proportional to the remanent magnetization

Sample: Ta (5nm) / Ti$_8$Zr$_2$ (40nm) / CoCrPtB (16nm) (from Seagate)

$^1$ P.J. Flanders (private communication)
9 kOe field pulse!

Sample: Ta (5nm) / Ti$_8$Zr$_2$ (40nm) / CoCrPtB (16nm) (from Seagate)
Perpendicular Media with Soft Underlayer

Glass / NiAl / CoNb₈Zr₅ / NiAl/CrTa / CoPt₁₂Cr₁₈ / C
7 nm 400 nm 4 nm 1 nm 20 nm 5 nm

Sample is provided through INSIC–EHDRM by Yoshihiro Ikeda, IBM Almaden Research Center

Recording layer (RL)
Ms ≈ 0.75 memu/cm²

Soft Underlayer (SUL)
Ms ≈ 34 memu/cm²
Hc < 0.1 Oe (10 Hz)
Suppression of the SUL Signal

Helmholtz coils
\[ H_x = 32 \text{ Oe}, 200 \text{ Hz} \]

Microstrip Line
Moving stage with Vibrator
19.5 Hz

Audio Amplifier

Coaxial Cable RG-213
Charging Resistor
300 M\(\Omega\)-300 G\(\Omega\)

High Voltage DC Power Supply

High-Voltage Connectors:
THT.20 series (Radiall)
Attenuator: 2237- HFNFP (Barth Electronics)

Function Generator

Low-Voltage Connectors:
Analog output

Switch Unit (Spark Gap)

Gaussmeter
F.W.Bell 9900
int. osc. 5 kHz

Lock-in Amplifier
SR 830

X-position Pulse
PC
Start/ Stop/ Settings

Audio Amplifier
Resistor

Transient Digitizer
SCD 1000

Hall Probe

Resistor

Motor

Function Generator

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**Hcr(t) Data**

- **Pulse data**
- **MOKE long time data**
- **Sharrock's fit**

**Equations:**

- $n = 2/3$ (Sharrock's fit)
- $H_0 = 6.0 \pm 0.2$ kOe
- $KV/kT = 170 \pm 20$
Dependence of Switching on the Initial Remanent State

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Dependence of Switching on the Initial Remanent State. Simulation.

(by A. Misra and P. B. Visscher)

States with remanent magnetization $M_i < M_{rs}$ obtained by:

(a) reversing the grains with lowest $H_k$, to mimic the effect of a long-duration external field $H < H_c$;

(b) 2.3 ns pulsed field of amplitude 5.3 kOe.
Future Plans

- Measure remanence dependence vs. pulse width.
- Measure $H_{cr}(t)$ after pulse demagnetization.
- Study the role of low-coercivity grains – nucleate switching. (May lower coercivity without thermal instability).