

Exchange Induced Magnetic Anisotropy in Fe/CoO/MnO/MgO(001) System

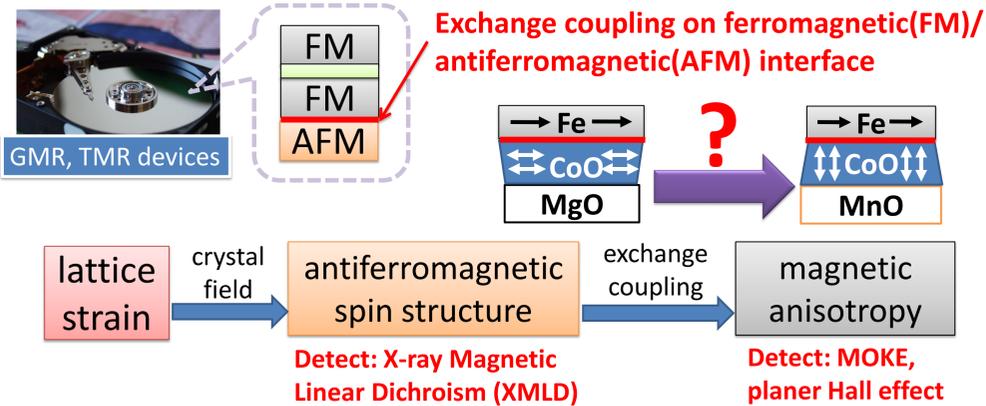


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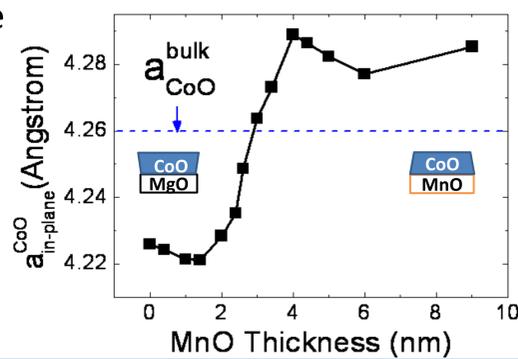
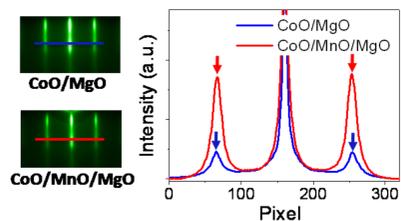
Introduction



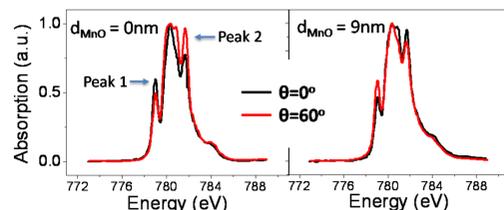
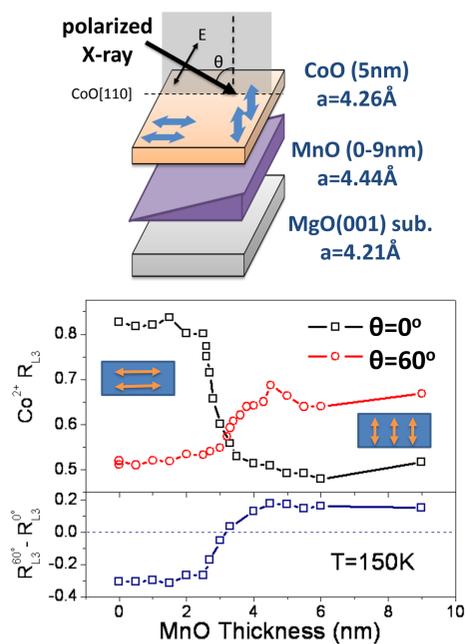
Experiments & Results

1. Lattice parameter change

RHEED patterns of CoO/MnO wedge/MgO(001)



2. X-ray Magnetic Linear Dichroism (XMLD) measurements



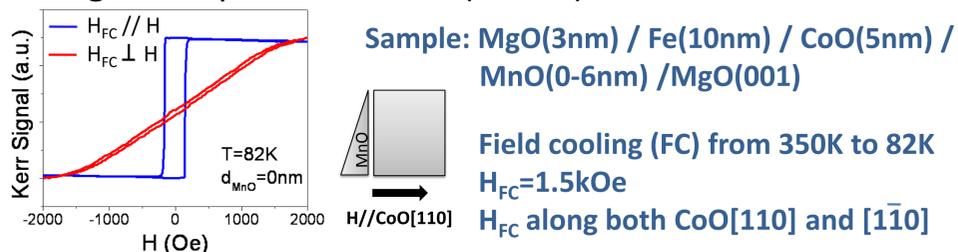
Co^{2+} L3 ratio:
 $R_{L3} = \text{Peak1/Peak2}$

AFM spin orientation in CoO

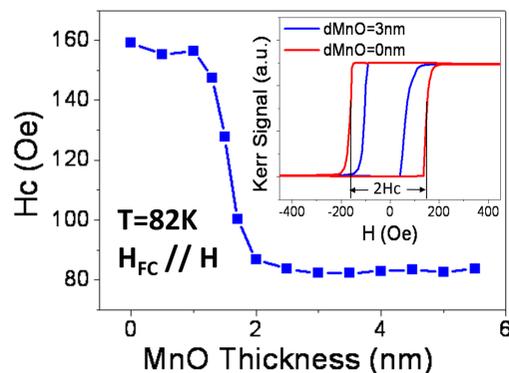
$R_{L3}^{60^\circ} - R_{L3}^{0^\circ} < 0 \rightarrow S_{\text{CoO}}$ in plane
 $R_{L3}^{60^\circ} - R_{L3}^{0^\circ} > 0 \rightarrow S_{\text{CoO}}$ out of plane

CoO antiferromagnetic spin reorientation transition

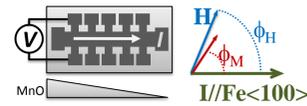
3. Magneto-Optic Kerr Effect (MOKE) measurements



→ Very small exchange bias
→ field cooling induced easy axis along CoO[110]
→ A drop in coercivity (H_c) with increasing d_{MnO}
anisotropy?



4. Transpot measurements of magnetic anisotropy



Planar Hall Effect(PHE) in rotating field
→ Magnetic anisotropy

Sample: MgO(3nm) / Fe(5nm) / CoO(5nm) / MnO wedge(0-5nm) / MgO(001)

Hall resistance: $R_{xy} = \Delta R \sin^2 \phi_M$

Energy per unit area: $E = -M_{\text{Fe}} d_{\text{Fe}} H_{\text{ap}} \cos(\phi_H - \phi_M) + K_u \sin^2(\phi_M - \phi_{Ku}) + K_4 \sin^2(\phi_M) \cos^2(\phi_M)$

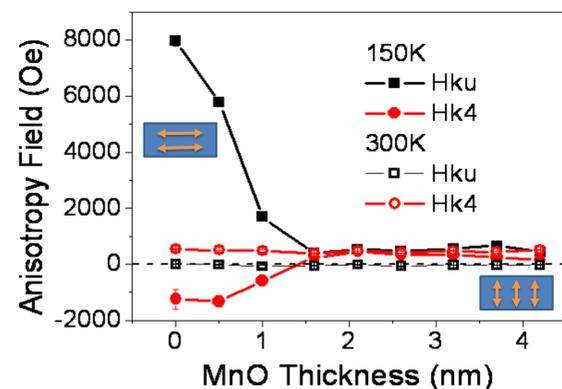
Zeeman energy
Uniaxial anisotropy energy 4-fold anisotropy energy

Minimize E → torque:

$$\tau(\phi_M) = M_{\text{Fe}} d_{\text{Fe}} H_{\text{ap}} \sin(\phi_H - \phi_M) = K_u \sin(2(\phi_M - \phi_{Ku})) + \frac{1}{2} K_4 \sin(4\phi_M)$$

Fitting → K_u, K_4

$+K_4 \rightarrow$ 4-fold EA // Fe<100>
 $-K_4 \rightarrow$ 4-fold EA // Fe<110>



Exchange induced anisotropy decreases as MnO thickness increases.

Discussions

Fe/CoO → spin flop coupling

On spin compensated interface
 $S_{\text{CoO}} \perp S_{\text{Fe}}$

Field cooling → CoO spin alignment → Fe uniaxial anisotropy
 $H_{\text{FC}} // \text{Fe}[100]$ $S_{\text{CoO}} // \text{Fe}[010]$ easy axis // Fe[100]

Fe/CoO/MgO: $S_{\text{CoO}} //$ plane

S_{Fe} has a uniaxial anisotropy with easy axis $\perp S_{\text{CoO}}$

Fe/CoO/MnO/MgO: $S_{\text{CoO}} \perp$ plane

S_{Fe} always $\perp S_{\text{CoO}}$, no additional anisotropy in plane

Summary:

When d_{MnO} increases, the changing strain makes the CoO spin rotates from in-plane to out-of plane

➤ Uniaxial anisotropy with the easy axis along Fe<100> decreased by nearly an order.

➤ The easy axis of 4-fold anisotropy switches from Fe<110> to <100>.