Temperature-dependent Magnetic Anisotropies in Epitaxial Fe/CoO/MgO(001) System Studied by the Planar Hall Effect

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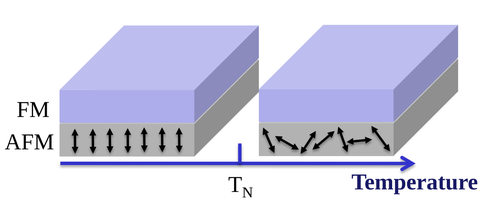
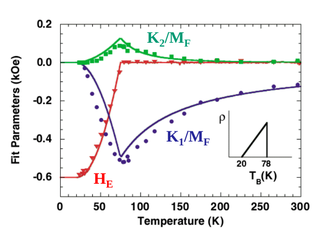
Introduction

Ferromagnetic (FM)/antiferromagnetic (AFM) exchange coupling has been intensively explored due to fundamental physical interest and its technological applications. One of the important issue is to study the magnetic anisotropy modulated by FM/AFM coupling.

Ferromagnetic/antiferromagnetic coupling ➡ Magnetic anisotropy





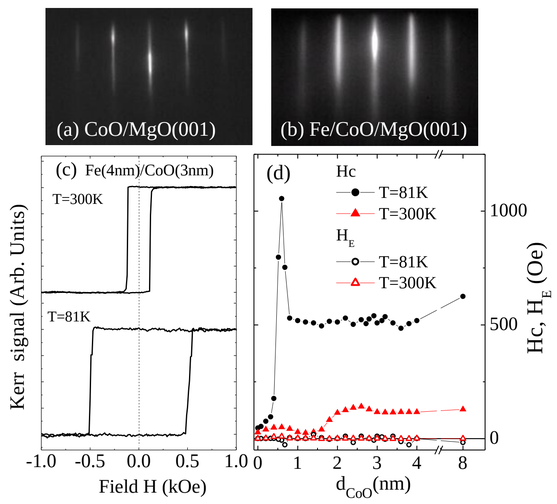
Co/FeF_2
Uniaxial anisotropy changes with temperature.
M. Grimsditch, PRL 90, 257201(2003)

Other FM/AFM system?

Experiment

1. Sample

MgO(3nm)/Fe(4nm)/CoO(5nm)/MgO(001)



No exchange bias observed ➡ no unidirectional anisotropy

2. Measurement

Planer Hall effect (PHE) in rotational in-plane H field

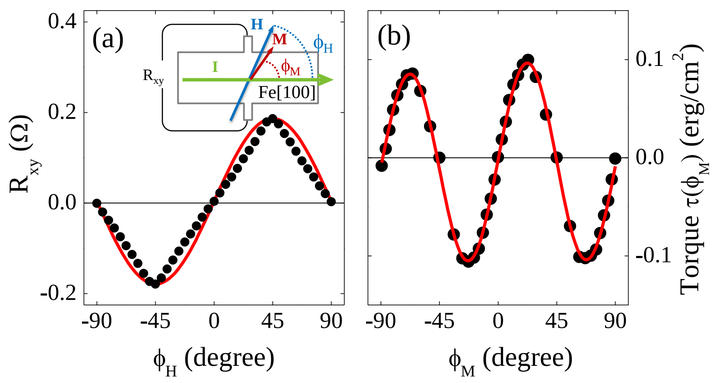
Planer Hall resistance $R_{xy} \sim \sin 2\Phi_M$

Energy per unit area:

$$E = \underbrace{-M_{Fe} d_{Fe} H_{ap} \cos(\phi_H - \phi_M)}_{\text{Zeeman energy}} + \underbrace{K_u \sin^2(\phi_M - \phi_{Ku})}_{\text{uniaxial anisotropy energy}} + \underbrace{K_4 \sin^2(\phi_M)\cos^2(\phi_M)}_{\text{4-fold anisotropy energy}}$$

Minimize E ➡ torque per area:

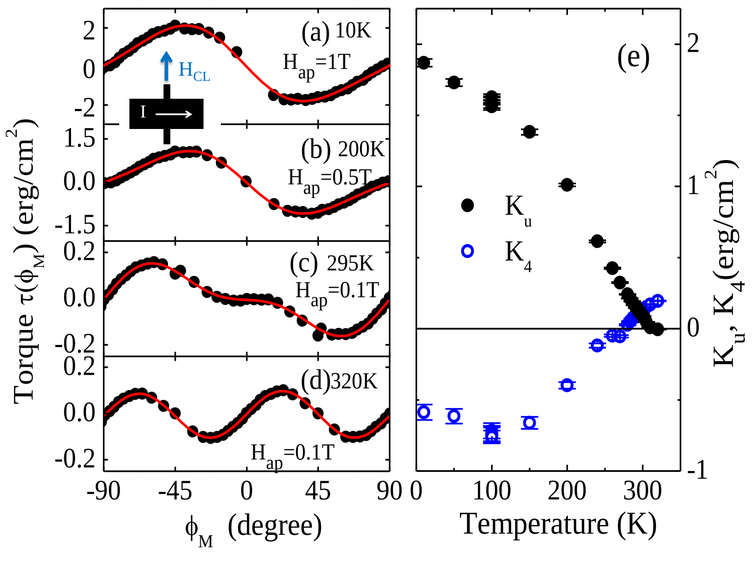
$$\tau(\phi_M) = M_{Fe} d_{Fe} H_{ap} \sin(\phi_H - \phi_M) = K_u \sin(2(\phi_M - \phi_{Ku})) + \frac{1}{2} K_4 \sin(4\phi_M)$$



fitting ➡ Uniaxial anisotropy ~ K_U
4-fold anisotropy ~ K_4

Result

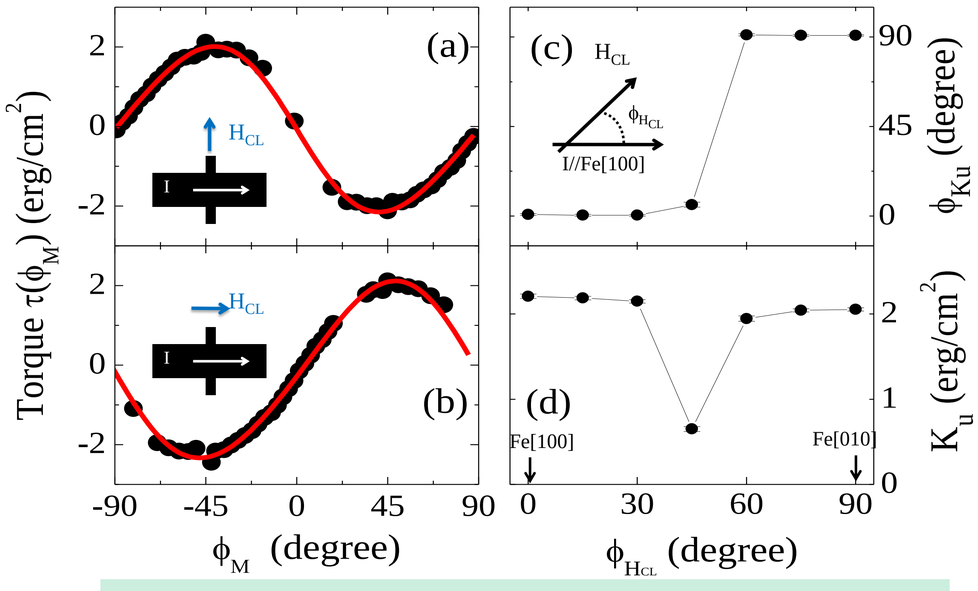
Temperature dependence of anisotropy

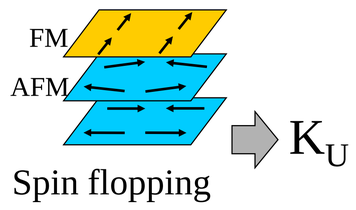


CoO: antiferromagnetc➔paramagnetic
4-fold easy axis: Fe<110> ➔ <100>
Uniaxial easy axis: always // Fe<110>

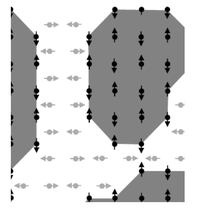
Temperature

CoO Lattice symmetry dependence of anisotropy





Spin flopping ➡ K_U



Spin frustration ➡ K_4

Uniaxial easy axis always // cooling field

Due to FM/AFM exchange coupling, the formation of CoO AFM order switch the 4-fold eaasy axis from Fe<100> to <110>, and induce a strong uniaxial anisotropy along Fe<100>.