In-plane magnetic anisotropy in Fe/MgO/GaAs(001) system

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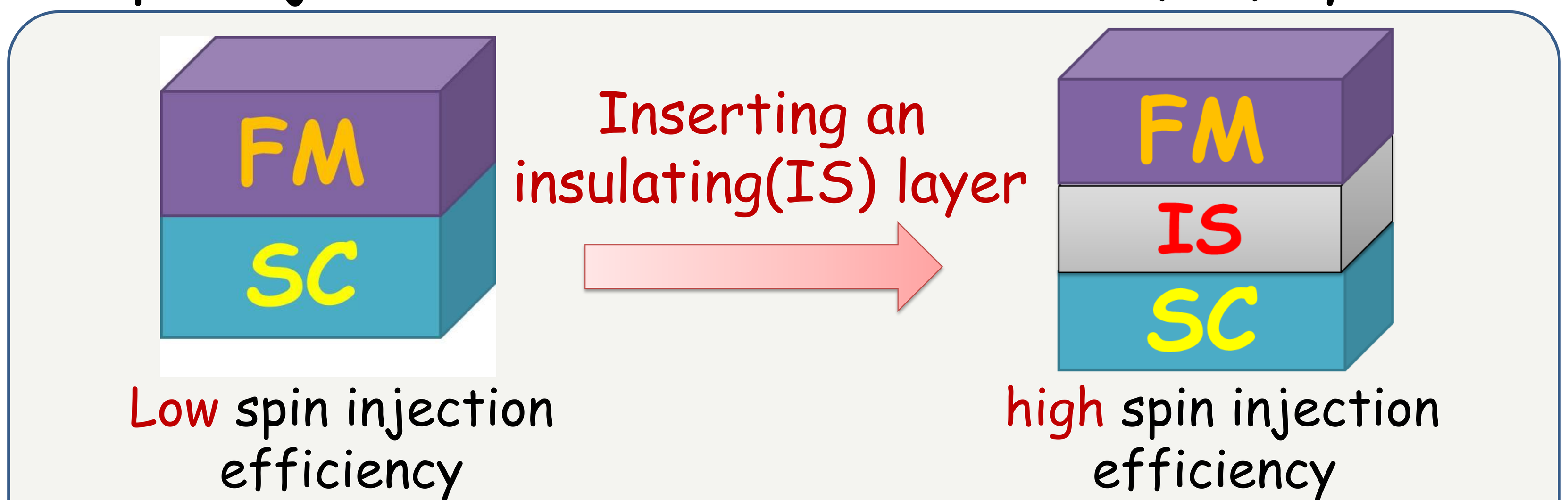
Introduction

Spin injection in FM/Semiconductor(SC) system



Example: CoFe/MgO/GaAs(001) X.Jiang, *et.al*, Phys. Rev. Lett. **94**, 056601 (2005)

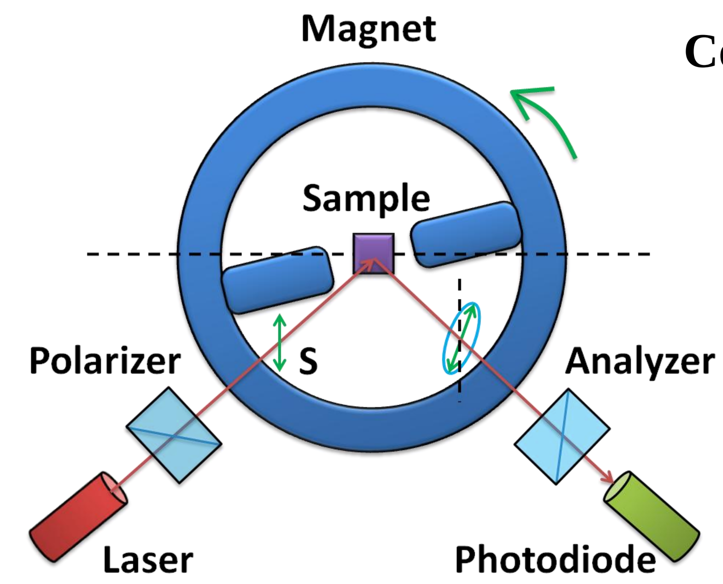
Fe/MgO/GaAs(001) ~ **a promising future spintronic devices**

Motivation:

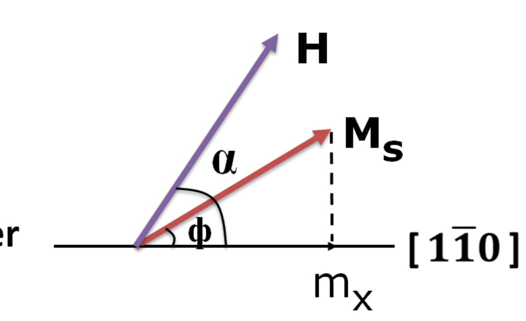
The structure and magnetic properties of Fe/MgO/GaAs(001) with ultrathin MgO interlayer?

Experimental method

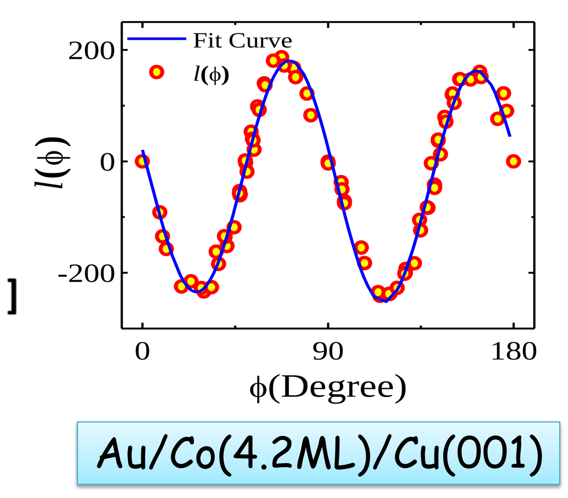
Rot-MOKE (Rotating-of-Field longitudinal Magneto-Optic Kerr Effect)



Coherent Rotation Model



A typical torque curve



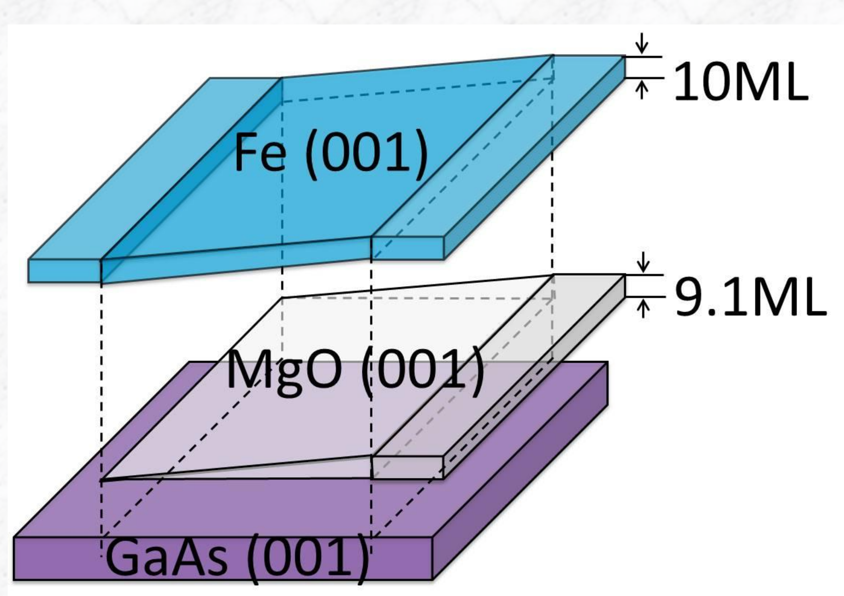
Energy density $e = -M_s H\cos(\alpha-\phi) + K_u \sin^2(\phi) + K_4 \sin^2(\phi+45^o)\cos^2(\phi+45^o)$

4-fold anisotropy: $K_4>0$, ea//<100> $K_4<0$, ea//<110>

At equilibrium $\frac{\partial e}{\partial \phi} = 0$ ⇒ $I(\phi) = H\sin(\alpha-\phi) = \frac{K_u}{M_s}\sin(2\phi) - \frac{K_4}{2M_s}\sin(4\phi)$

Growth and Structure

Sample structure

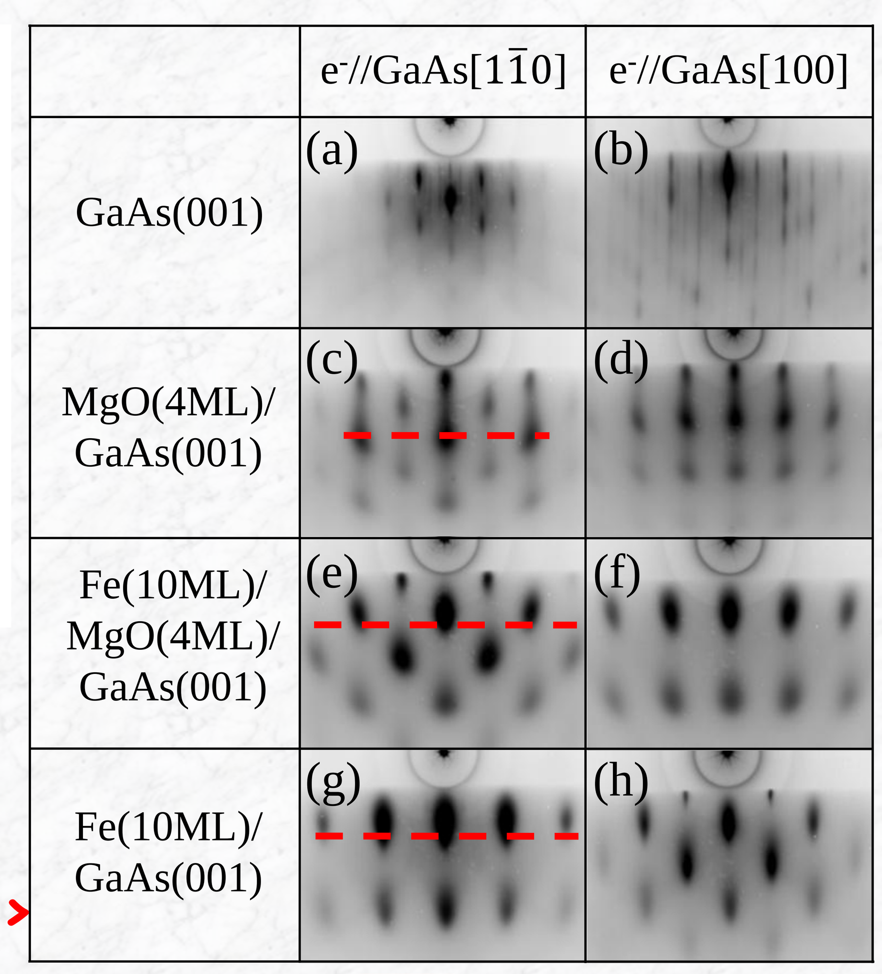


The epitaxial relationship

Fe<100>//GaAs<100>

Fe<100>//MgO<110>//GaAs<110>

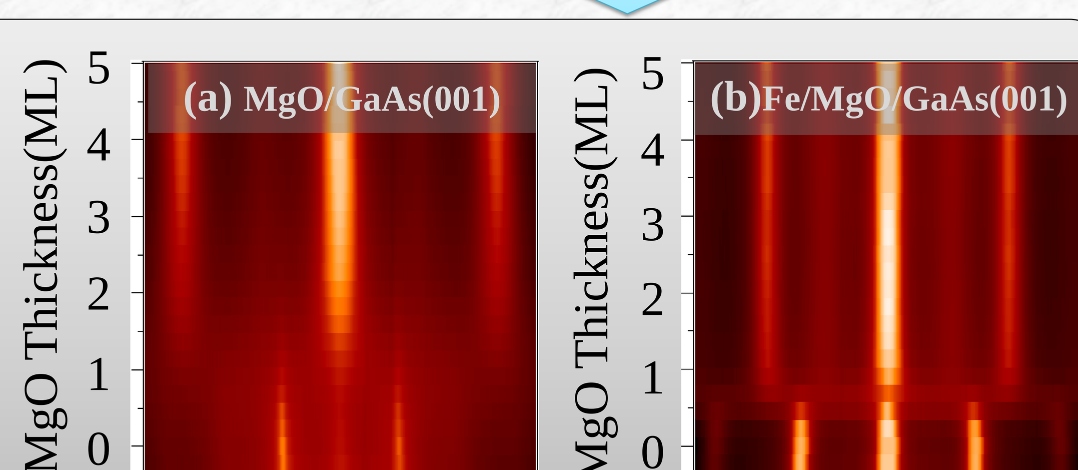
RHEED pattern



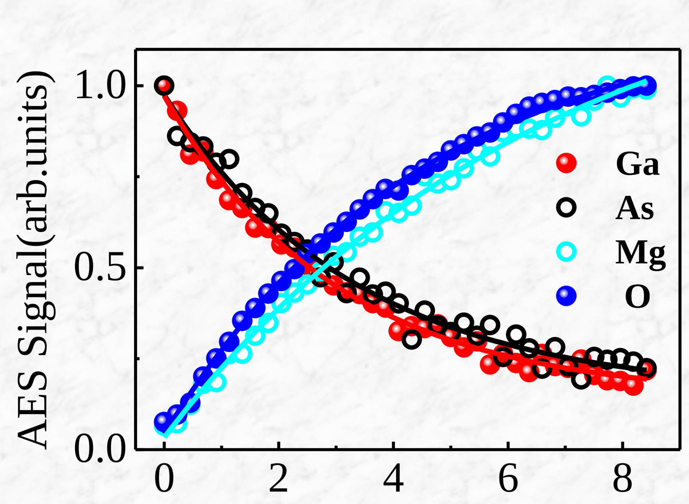
d_{MgO}-dependent structure evolution

MgO/GaAs(001)
MgO Pattern is fully developed ~ d_{MgO}>2ML

Fe/MgO/GaAs(001)
Fe Pattern is fully developed ~ d_{MgO}>1ML



d_{MgO}-dependent AES Signal



The AES Signal can be fitted by an exponential function:

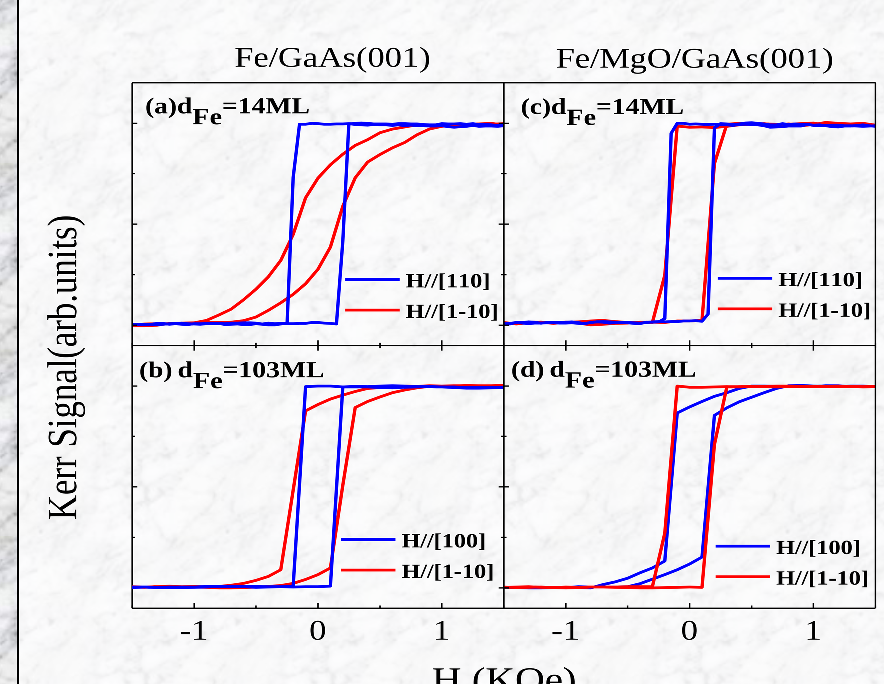
$$I(d_{MgO}) = I_{d\to\infty} + Ae^{-d/\lambda}$$

λ : Mean free path

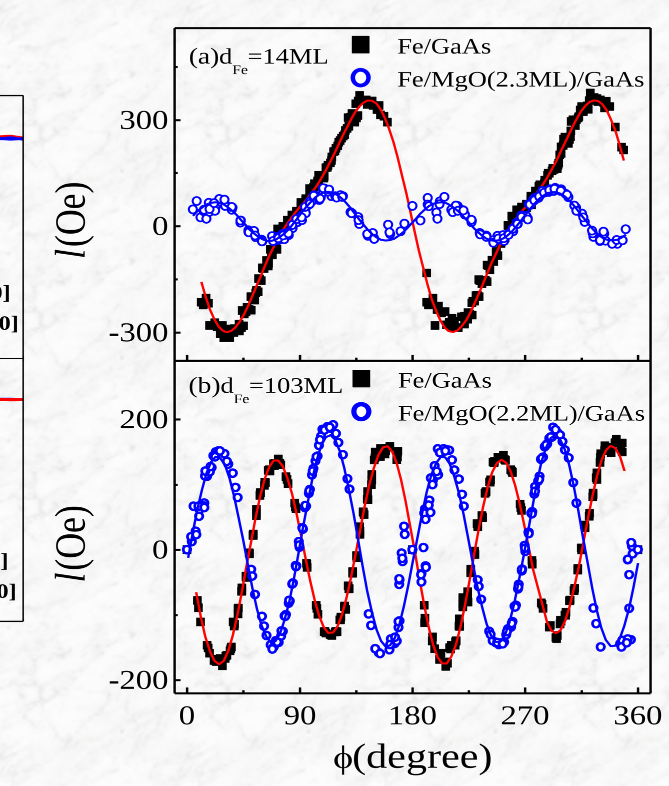
Uniform MgO layer is formed

Magnetic Anisotropy

Longitudinal-MOKE loops



Torque curves



K_u= -5 Fe/GaAs, -0.2 Fe/MgO/GaAs

K_4= +2.9 Fe/GaAs, -2.1 Fe/MgO/GaAs

K_u= -0.4 Fe/GaAs, -0.3 Fe/MgO/GaAs

K_4= +5.1 Fe/GaAs, -5.2 Fe/MgO/GaAs

(10^5 erg/cm^3)

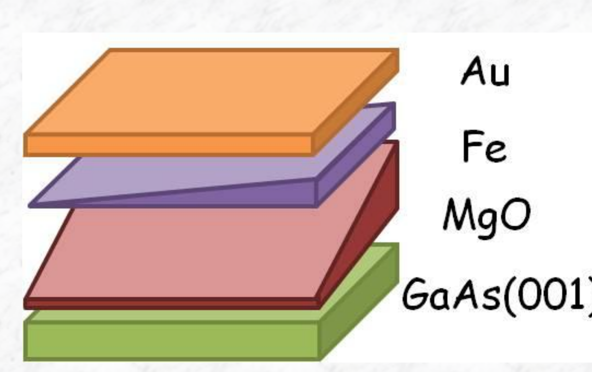
MgO interlayer:

Thin Fe suppresses K_u significantly

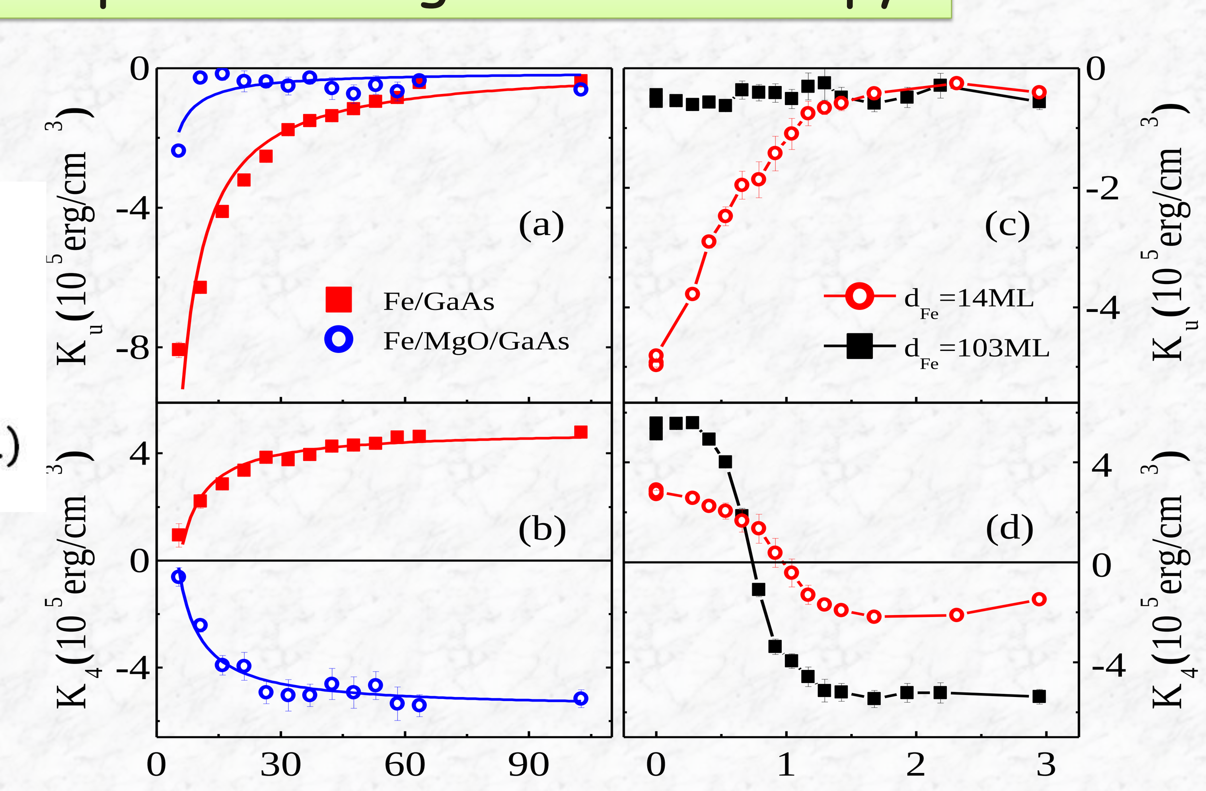
Thick Fe K_4 switches (ea//GaAs<100> ⇒ ea//GaAs<110>)

K_4>0~Fe/GaAs K_4<0~Fe/MgO/GaAs

Thickness dependent magnetic anisotropy



Double wedge



(a): K_u ~ weak dependent on d_{Fe} (Fe/MgO/GaAs)

(b): K_4 ~ good $1/d_{Fe}$ dependence $K = K^V + K^S/d_{Fe}$

(c): K_u dramatically decrease with d_{MgO} (saturate ~1.2ML MgO)

(d): K_4 switch from positive to negative ~ d_{MgO}~1.2ML

Conclusion

- Structure ~ The Fe<100> crystalline axis switches from the GaAs<100> to the GaAs<110> with d_{MgO} <1ML
- Magnetic anisotropy ~ K_u dramatically decrease and K_4 change sign ~ d_{MgO}<1.2ML