Antiferromagnetic domain nucleation and motion energy barrier directly determined in Fe/CoO System

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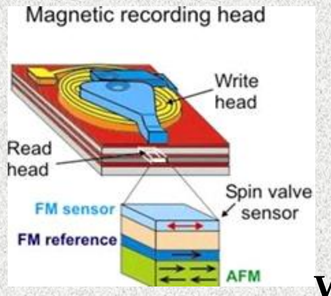
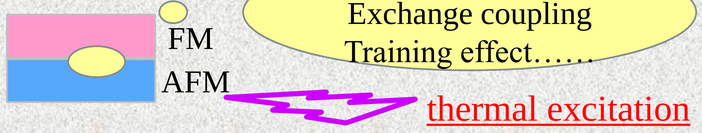
Ⅰ Introduction

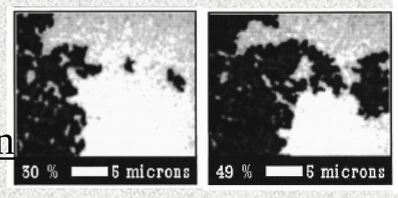




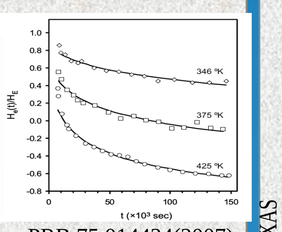
AFM domain structure is important!

What is AFM domain dynamics under thermal excitation?

Magnetization reversal
- Domain nucleation
- Domain wall motion



PRB 57,1085(1998)
Co/Pd multilayer

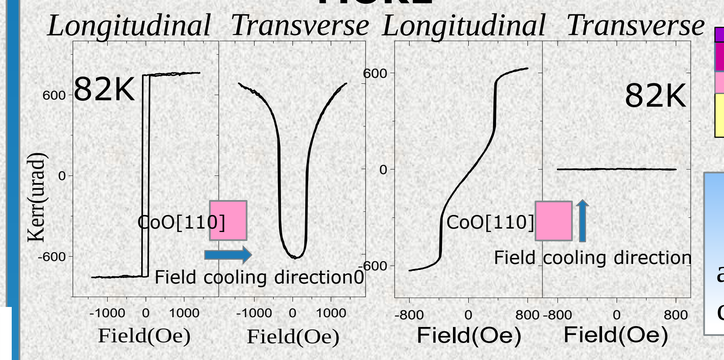


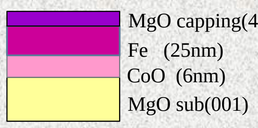
PRB 75,014434(2007)
NiO/NiCoFe

How to determine AFM domain nucleation and wall motion energy barrier more directly?

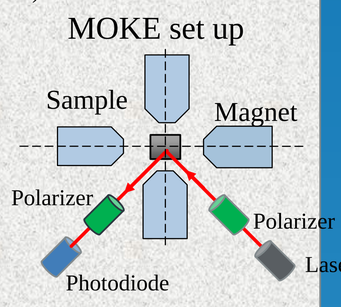
Ⅱ Fe/CoO coupling characterization

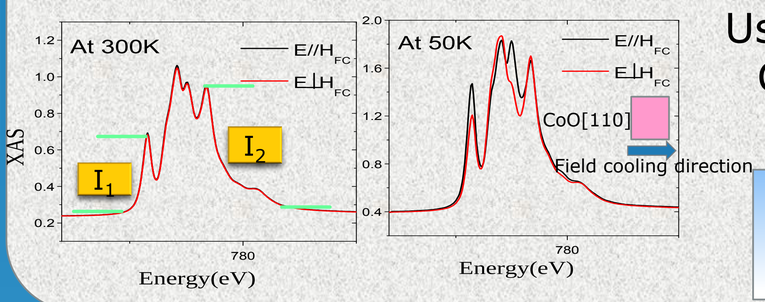
MOKE





Uniaxial anisotropy easy axis is along field cooling direction.





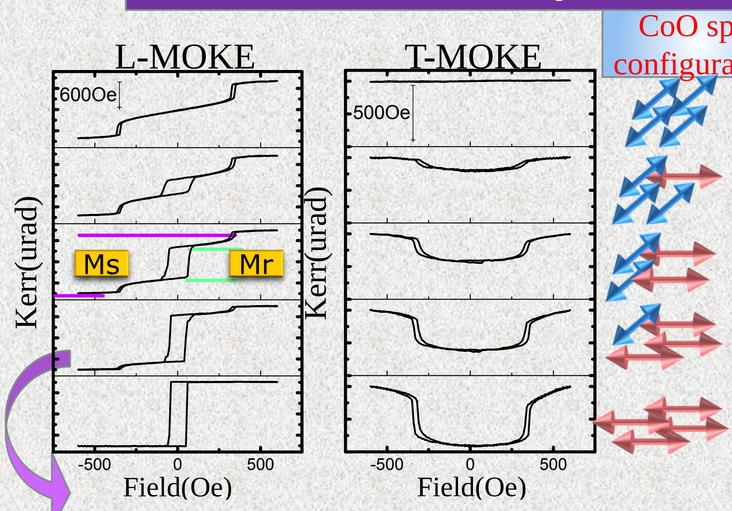
Use XMLD to determine CoO spin orientation

$RL3=I_1/I_2$

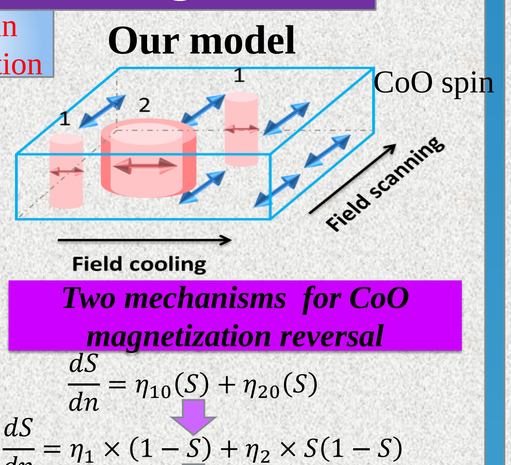
$RL3(E \parallel H_{FC}) > RL3(E \perp H_{FC})$

Perpendicular coupling between Fe/CoO

Ⅲ AFM domain dynamics-'training' effect



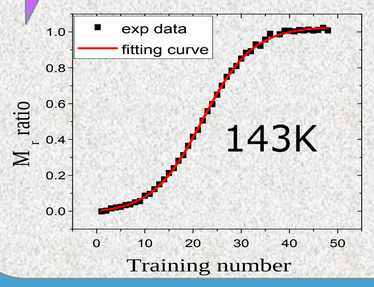
CoO spin configuration



Two mechanisms for CoO magnetization reversal

$$\frac{dS}{dn} = \eta_{10}(S) + \eta_{20}(S)$$

$$\frac{dS}{dn} = \eta_1 \times (1-S) + \eta_2 \times S(1-S)$$



Mr ratio=Mr/Ms

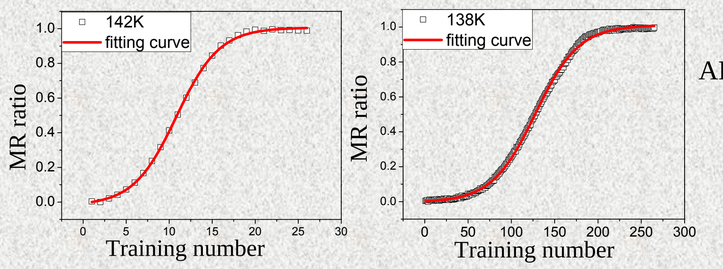
Fitting formula

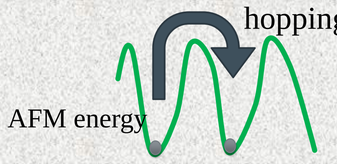
$$S = A\frac{1-e^{-n(\eta_1+\eta_2)}}{1+\frac{\eta_2}{\eta_1}e^{-n(\eta_1+\eta_2)}} + S_0$$

n——field switching times
S——AFM flipped spin domain area
η_1——coefficient of domain nucleation possibility per field switching
η_2——coefficient of domain motion possibility per field switching

Ⅳ AFM energy barrier determined by temperature dependence measurement

142K Training field:600Oe 138K

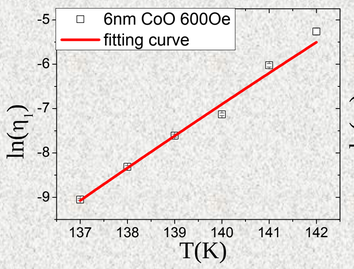




Fitting formula

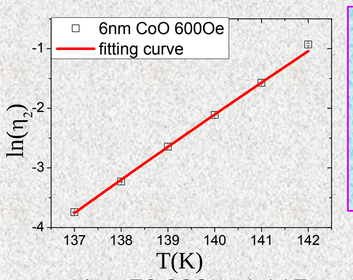
$$S = A\frac{1-e^{-n(\eta_1+\eta_2)}}{1+\frac{\eta_2}{\eta_1}e^{-n(\eta_1+\eta_2)}} + S_0$$

Domain nucleation



$A = 92.217 \pm 5.508$
$E = 1.197 \pm 0.066eV$

Domain wall motion



$A = 73.339 \pm 1.117$
$E = 0.911 \pm 0.013eV$

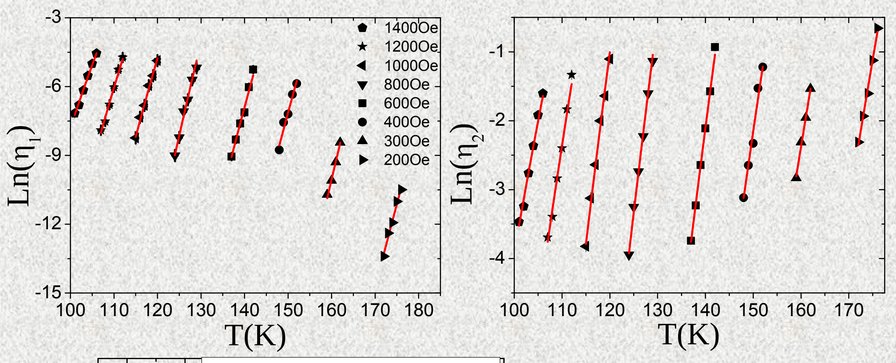
Arrhenius law

$$f = f_0 \exp\left(-\frac{E(H)}{kT}\right)$$

$$lnf = lnf_0 - \frac{E(H)}{kT} \approx A - \frac{1}{T}\cdot\frac{E(eV)}{8.629\times10^{-5}}$$

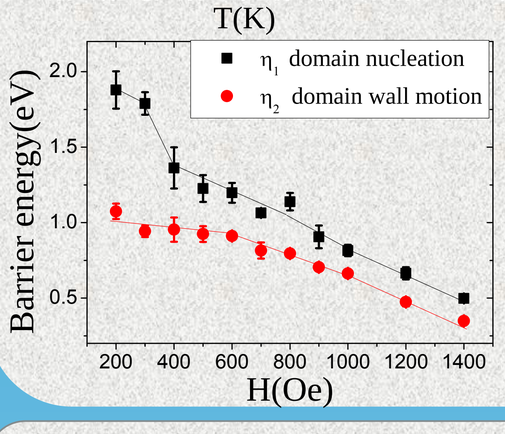
f_0 —attempt frequency
$E(H)$ —energy barrier

Ⅳ Field dependence of energy barrier



Fitting Curve

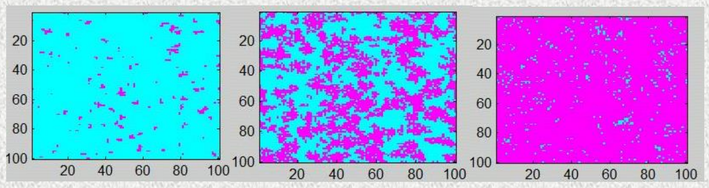
$$Ln\eta = A - \frac{1}{T}\cdot\frac{E(eV)}{8.629\times10^{-5}}$$



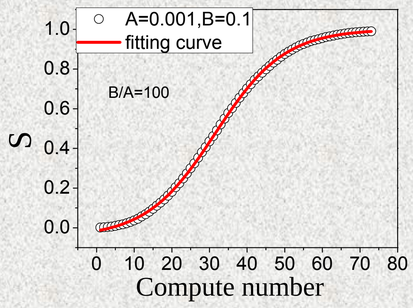
1. In high field, both barrier energy increases with field increases.
2. In the low field, the domain nucleation barrier energy increases sharply while the domain motion barrier energy saturates.

Ⅴ Discussion

Monte Carlo simulation

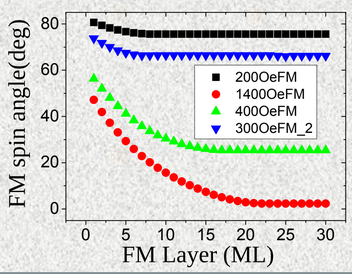


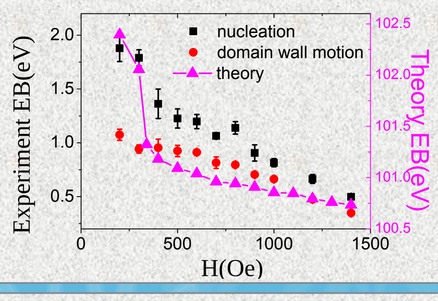
Domain nucleation possibility-A
Domain wall motion possibility-B



$\eta_1 = 0.00339 \pm 5.52E-5$
$\eta_2 = 0.106 \pm 6.90E-4$

Exchange-spring model





Ⅵ Conclusion

1. AFM magnetization reversal process are clearly revealed in Fe/CoO system.
2. AFM domain nucleation and wall motion energy barrier is directly determined from T depedence of CoO training process.