Giant anisotropic Gilbert damping in single crystal CoFeB(001) films

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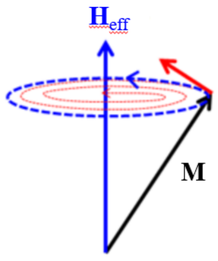
WU GROUP

Introduction

1. Gilbert damping

Damping ⇨ a key parameter for spin dynamics



Landau-Lifshits-Gilbert equation:

$$\frac{d\mathbf{M}}{dt} = -\gamma \mathbf{M} \times \mu_0 \mathbf{H}_{eff} + \frac{\alpha}{|\mathbf{M}|} \mathbf{M} \times \frac{d\mathbf{M}}{dt}$$

α- Gilbert damping

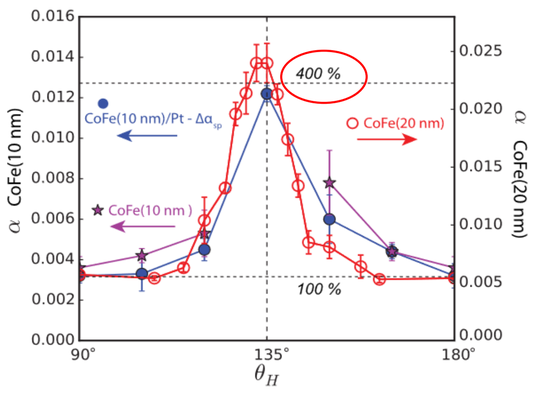
- ✓ Magnetization switching
- ✓ Domain wall motion
- ✓ Spin wave propagation

2. Anisotropic Gilbert damping

BCC-structure single crystal CoFe(001)

◆**Giant damping anisotropy**

$\alpha_{\langle 100\rangle}/\alpha_{\langle 110\rangle}$ = 440%



Calculation: *Interface Rashba effect*

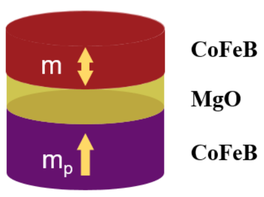
Y. Li, *et al.* PRL 122, 117203 (2019)

➢More magnetic systems with anisotropic damping

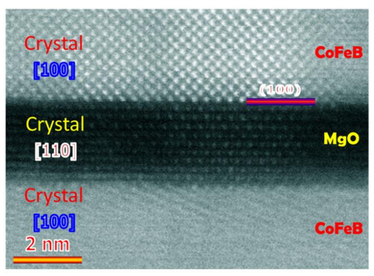
3. CoFeB

CoFeB ⇨ a promising ferromagnetic material

■Magnetic tunnel junction



■STEM image:



Z. C. Wang *et al.*, Nano Lett. 16, 1530 (2016)

CoFeB Structure after annealing:

Textured or Single Crystal

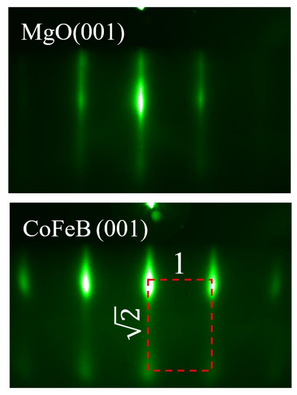
➢Anisotropic damping in CoFeB?

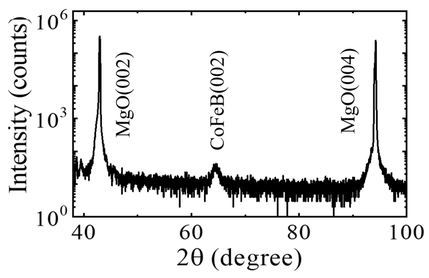
Experiment

1. Films growth

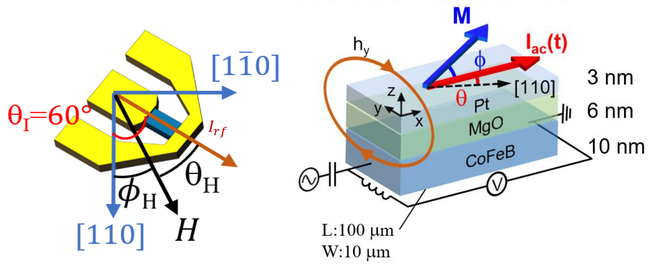
$Co_{40}Fe_{40}B_{20}$ (10 nm)/MgO(001)

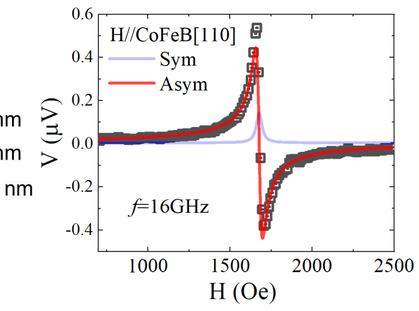
BCC CoFeB (001) film





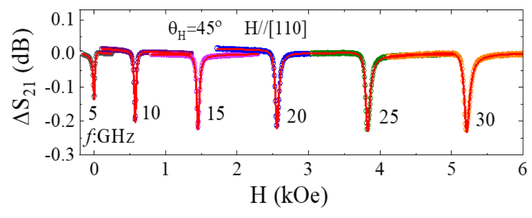
2. STFMR measurements

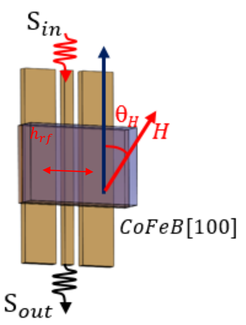




$$U = A_{sym}\frac{\Delta H^2}{(H-H_r)^2+\Delta H^2} + A_{asym}\frac{\Delta H(H-H_r)}{(H-H_r)^2+\Delta H^2} \qquad \Delta H = \Delta H_0 + \frac{\alpha_G \omega}{\gamma}$$

3. VNA-FMR measurements

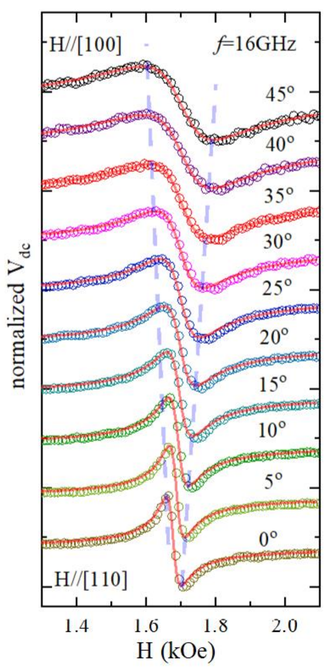




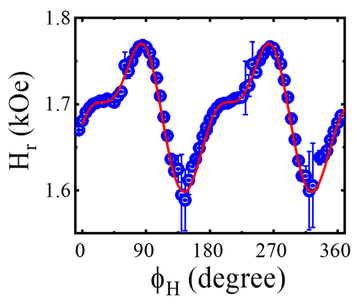
Anisotropic Damping

1. STFMR Measurement

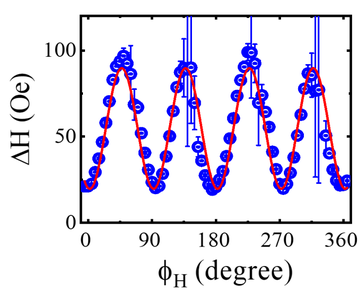
■FMR spectra



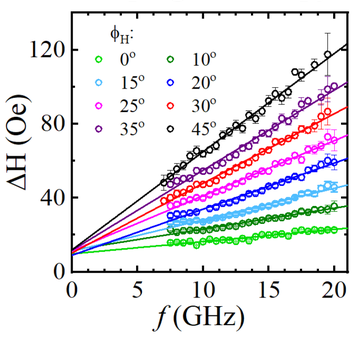
■Resonance field H_r

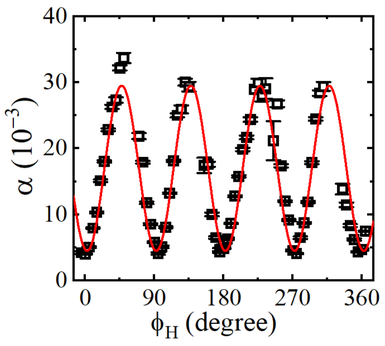


■Linewidth ΔH



■Damping anisotropy





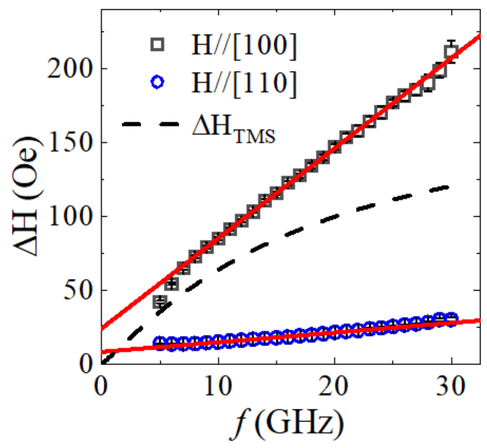
$\alpha_{[100]} = 0.0322 \pm 0.0004$
$\alpha_{[110]} = 0.0040 \pm 0.0001$

$\alpha_{\langle 100\rangle}/\alpha_{\langle 110\rangle}$ = 800%

2. VNA-FMR Measurement

$\alpha_{[100]} = 0.0368 \pm 0.0001$
$\alpha_{[110]} = 0.0039 \pm 0.0002$

$\alpha_{\langle 100\rangle}/\alpha_{\langle 110\rangle}$ = 940%

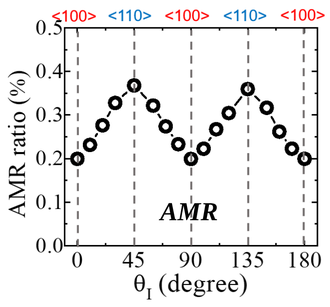


Discussion

◆CoFe(001): $\alpha_{\langle 100\rangle}/\alpha_{\langle 110\rangle}$ = 4.4 $AMR_{\langle 100\rangle}/AMR_{\langle 110\rangle}$ = 23

Strong damping anisotropy ⇔ Strong AMR anisotropy

◆CoFeB(001): $\alpha_{\langle 100\rangle}/\alpha_{\langle 110\rangle}$ = 9.4 $AMR_{\langle 100\rangle}/AMR_{\langle 110\rangle}$ = 1.8



Strong damping anisotropy

⇕

Weak AMR anisotropy

➢Anisotropic damping mechism in CoFeB?

Conclusion

- ➢BCC-structure single-crystal CoFeB(001) prepared.
- ➢ 900% anisotropic Gilbert damping observed.
- ➢ Damping anisotropy has weak correlation with AMR.