7p-P03-29

Control of Interlayer Chiral Coupling by thermal annealing under oblique magnetic field application

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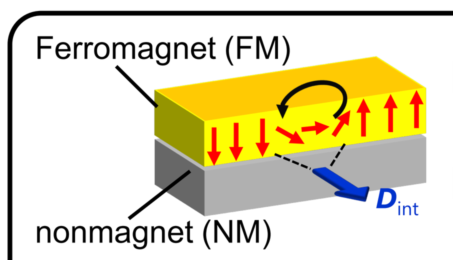
Introduction

[Intralayer Chiral Coupling]

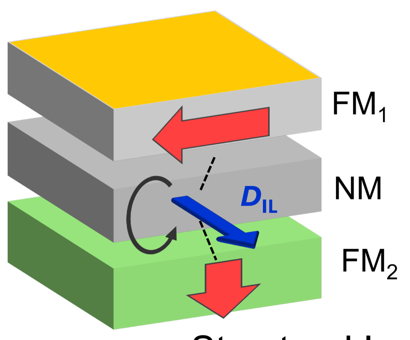


Interfacial Dzylosinski-Moriya Interaction (DMI)

Origin:
Structural Inversion Asymmetry in the **vertical axis**

Application:
Racetrack memory/ Brownian Computing [1,2]
(Formation of Chiral domain wall / Skymion)

[Interlayer Chiral Coupling (ICC)]



Interlayer-DMI [3-7]

Chiral spin texture along the **vertical axis**

Origin:
Structural Inversion Asymmetry in the **in-plane axis**
(Wedge structure, oblique sputtering, field-induced deposition etc.)

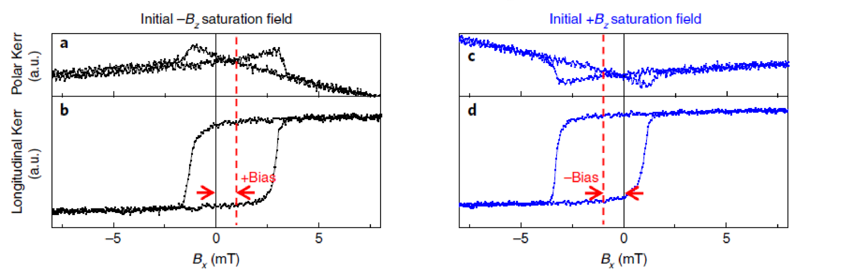
Application:
3D-magnetism[3] / Field-free SOT switching [8]

[Previous Studies on ICC]

➢**Observation of ICC in tri-layer structures [3-8]**
→ Heavy metal spacer with large spin-orbit coupling
(NM = Pt/Ru/Pt, Ir, Pt, Ru etc.)

➢**ICC (or D_{IL}) varies between devices** [5,6,7]
→ due to the polycrystalline nature / interfacial spin structure?

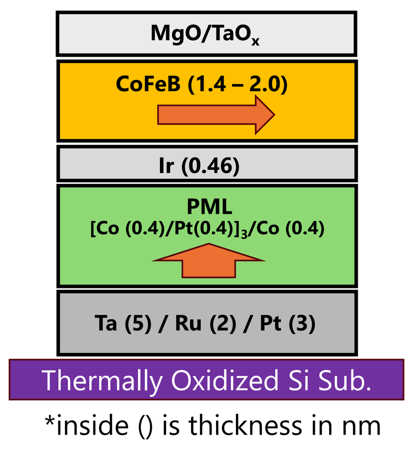
ICC detection by MOKE [3]



This work: Is there any method to control ICC?
➡ We focused on interfacial spin structure

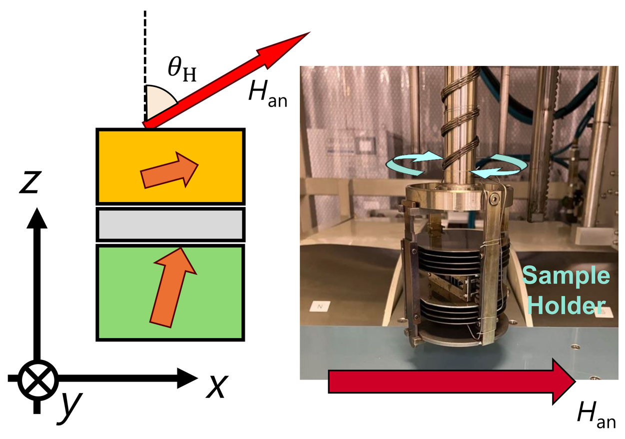
Experiment setup

[Structure]



*inside () is thickness in nm

[Thermal Annealing process]



◆Multilayer deposition: UHV magnetron sputtering (Canon Anelva Ltd., C-7100)

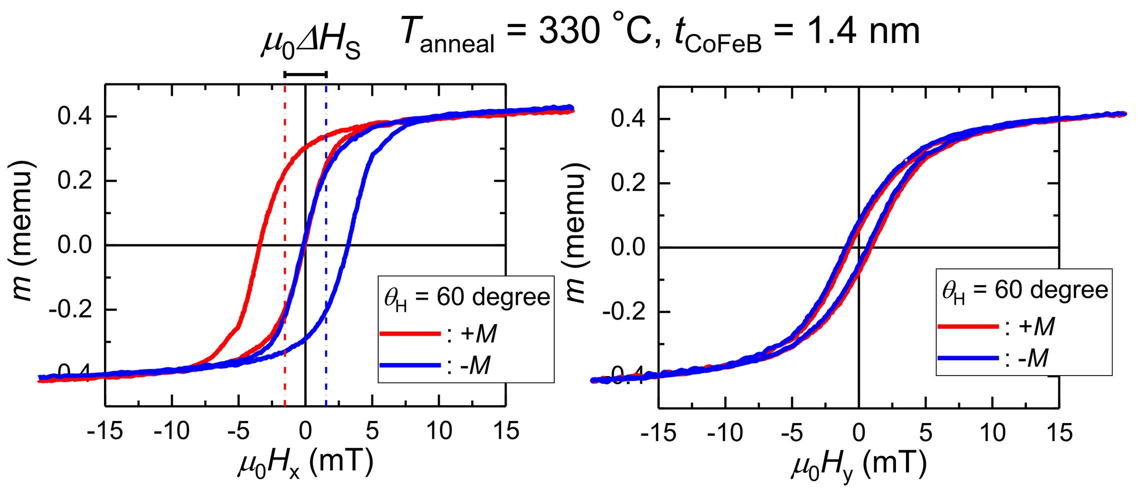
◆Thermal annealing procedure:
- Annealing temperature T_{anneal} = 200 ~ 380 °C
- Duration time: 1 hour
- Magnetic field amplitude H_{an}: 1T

◆Microfabrication: optical lithography

◆Characterization of ICC
- Vibrating sample magnetometer (VSM)
- Longitudinal/Polar MOKE system

Result ①: Interlayer Chiral coupling control by thermal annealing under magnetic field

[Magnetization curve]

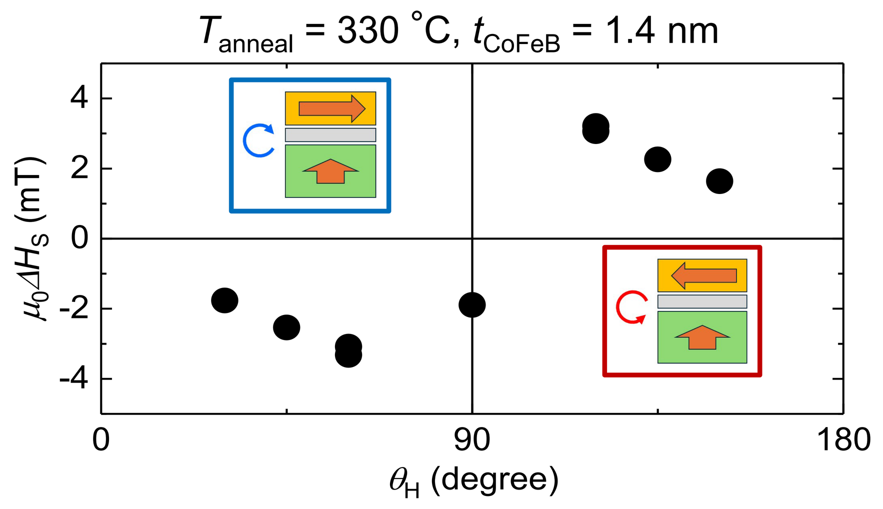


$$\mu_0\Delta H_S \equiv \mu_0 H_S(+M) - \mu_0 H_S(-M)$$

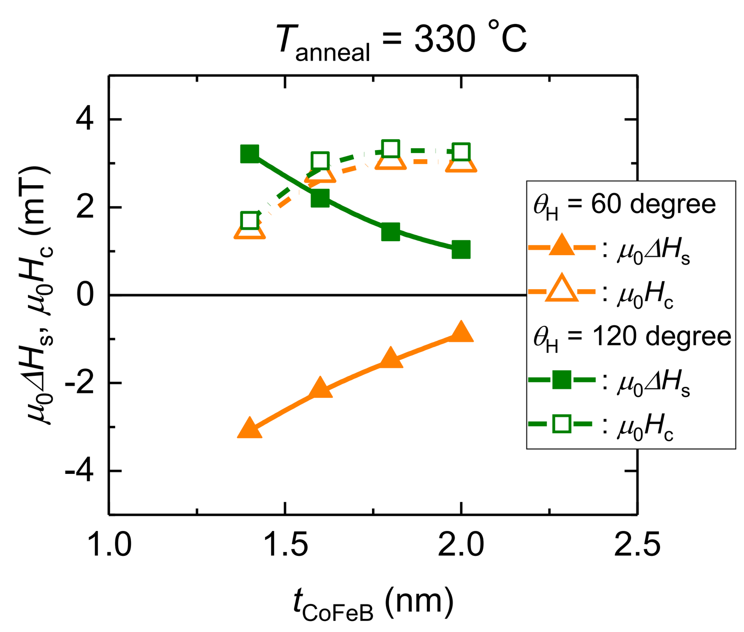
◆+(-)M state: $m_z^{PML} \parallel +(-)\boldsymbol{z}$
◆+(-)M state was fixed by applying $\mu_0 H_z$ = +(-)1T before VSM measurement

◆H_x- M curve: PML dependent bias field was observed ($\mu_0\Delta H_S \approx -3$ mT)
◆ H_y- M curve: no bias field was observed ($\mu_0\Delta H_S \approx 0$ mT)
➡ **interlayer DMI vector along –y direction** (**clockwise chirality**)

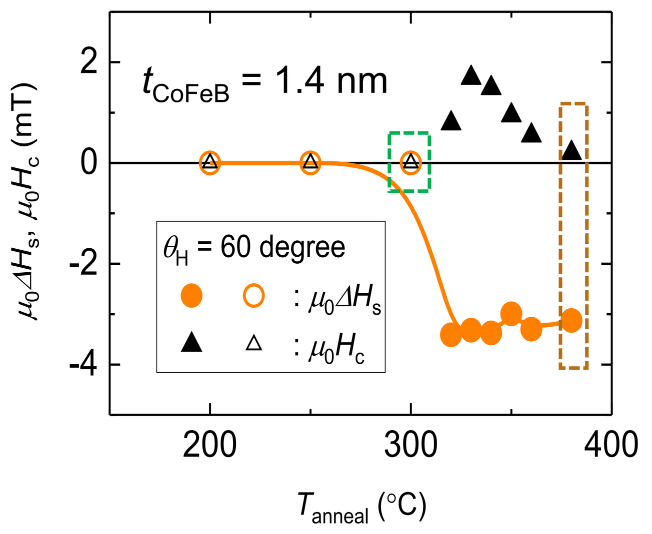
[ΔH_s under various θ_H]

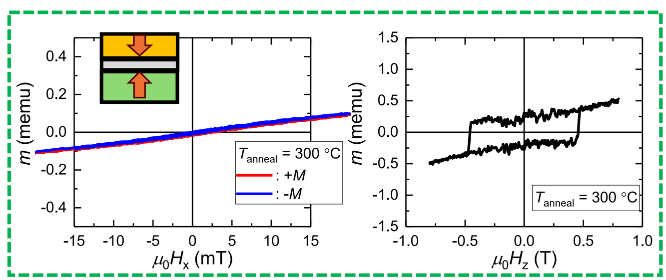


[CoFeB thickness dependence]

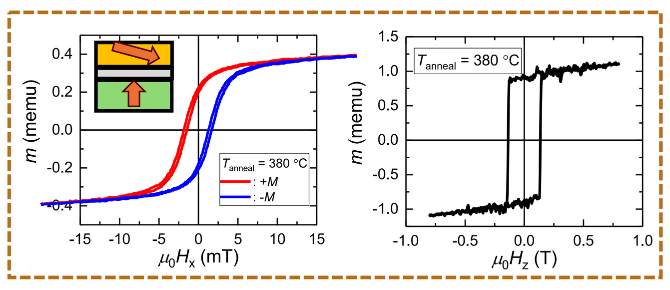


[Effect of annealing temperature]





Antiparallel(AP) configuration

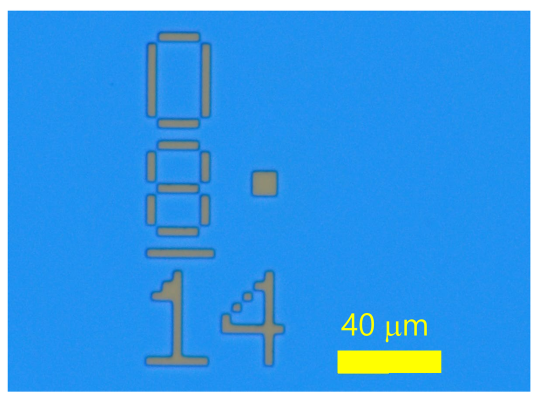


Orthogonal configuration

◆ The sign of ICC induced chirality changed at θ_H = 90 degree.
◆ ΔH_s is inversely proportional to t_{CoFeB}
➡ indicating ΔH_s is interfacial effect (consistent with ICC)
◆ T_{anneal} < 320 C behavior
➡ negligible ΔH_s + no in-plane m component (AP configuration)
◆ $T_{anneal} \geq$ 320 C behavior
➡ significant ΔH_s + in-plane m component (Canted configuration)
Reconfiguration of interfacial spin structure by crystallization of CoFeB (or diffusion of Ir and CoFeB)?

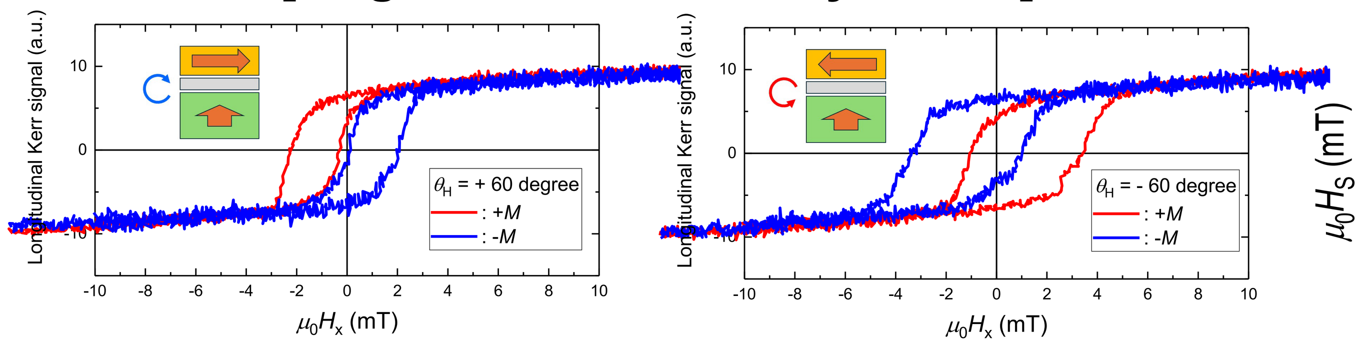
Result ②: Observation of Chirality control in micro-size device

[Optical Image of device]



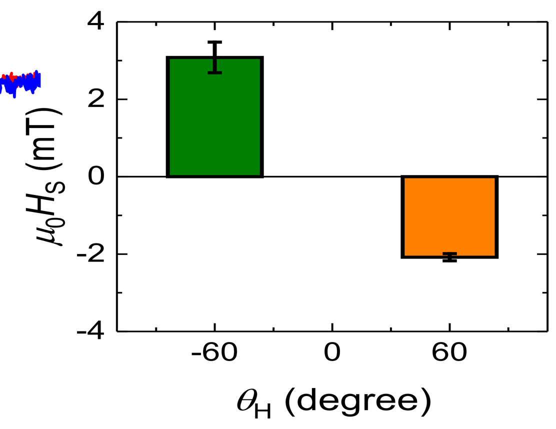
◆Device: 10x10 µm square dot
◆Thermal annealing procedure was held after the device fabrication. (θ_H = ±60 degree)
◆T_{anneal} = 330 °C
◆t_{CoFeB} = 1.4 nm

[Magnetization curve by MOKE]



Clockwise Chirality **Anti-clockwise Chirality**

[Average ΔH_s upon multiple devices]



Conclusion/Future perspective

◆ We have studied the effect of interlayer chiral coupling in PML/Ir/CoFeB structure under thermal annealing with oblique magnetic field application.
◆ ICC-induced bias field shows significant dependence on the magnetic field angle during annealing, which even changes the sign of the chirality.
◆ Thermal annealing under an oblique magnetic field is effective even in micro-scale devices.
◆ Although the direction of ICC can be controlled, its magnitude is still small. Single-crystal growth of the tri-layer system could be one of the solutions.

Acknowledgments & Reference

We thank Ms. Y. Sato for technical support. This work was partly supported by Grant-in-Aid for JSPS KAKENHI (No. 23H01477), Japan.

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産総研
ともに挑む。つぎを創る。

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