



Magneto-optical Properties of CoFeB Ultrathin Films : Effect of Ta Buffer and Capping Layer

Sajid Husain, Nanhe Kumar Gupta, Vineet Barwal, and Sujeet Chaudhary*

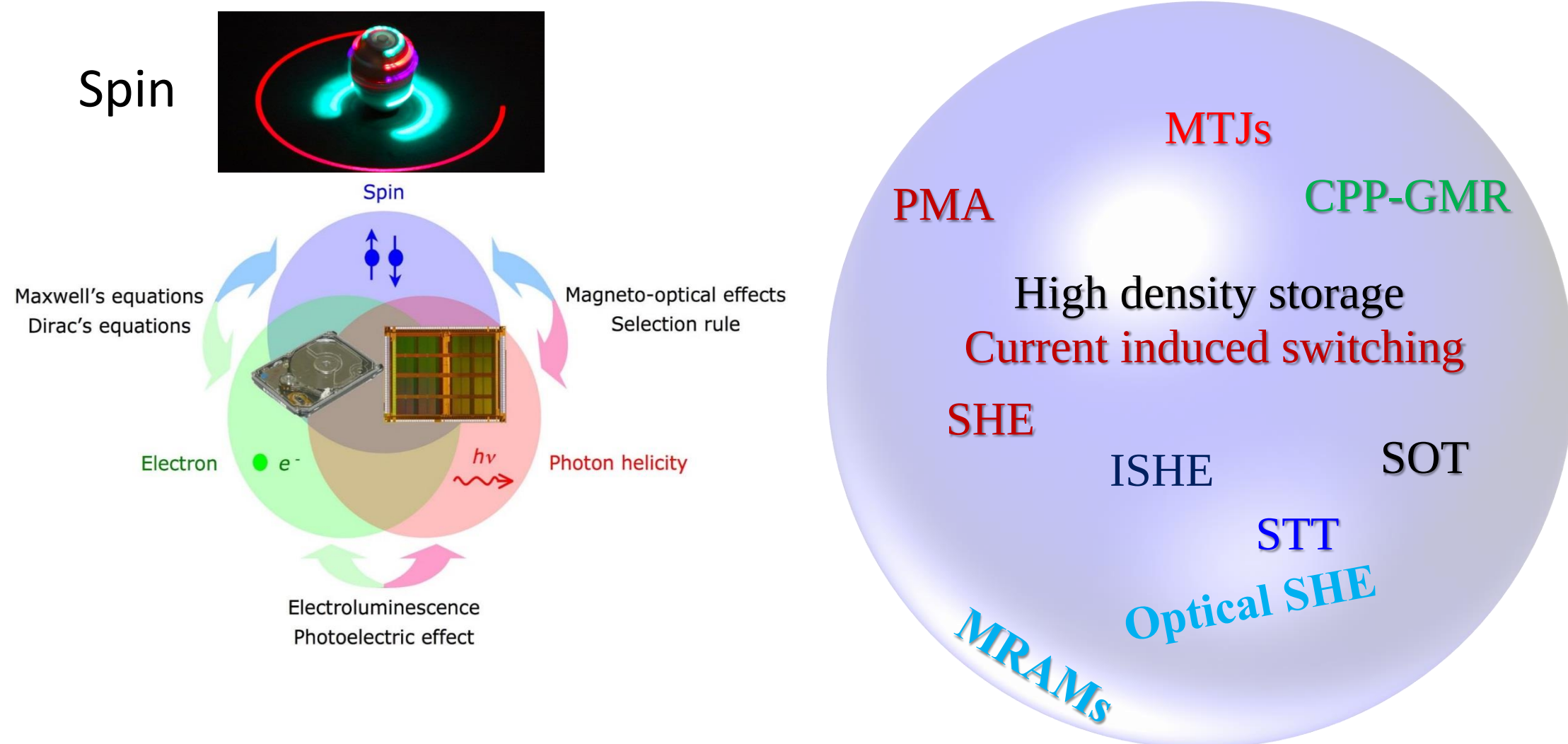
Thin Film Laboratory, Department of Physics, IIT Delhi, New Delhi 110016, India

*sujetc@physics.iitd.ac.in

About the work

- The effect of adding Ta as a **capping and seed** layer with ultrathin CFB(Co₆₀Fe₂₀B₂₀) thin films has been investigated **by magneto-optical Kerr effect**
- A **large difference in the coercivity and saturation field** is observed between the **single layer CFB(2nm)** and **Ta(5nm)/CFB(2nm)/Ta(2nm) trilayer** structure
- In particular, the **in-plane anisotropy energy is found to be 90.00 kJ/m³** on CFB(2nm) and **2.22 kJ/m³** for **Ta(5nm)/CFB(2nm)/Ta(2nm)** thin films
- Anisotropy energy reduced to 0.93 kJ/m³** on increasing the CFB thickness in the trilayer structure, i.e., Ta(5nm)/CFB(4nm)/Ta(2nm)
- Low coercivity and anisotropy energy in capped and buffer** layer thin films envisage the potential of employing CFB for **low field switching applications of the spintronic devices**

INTRODUCTION

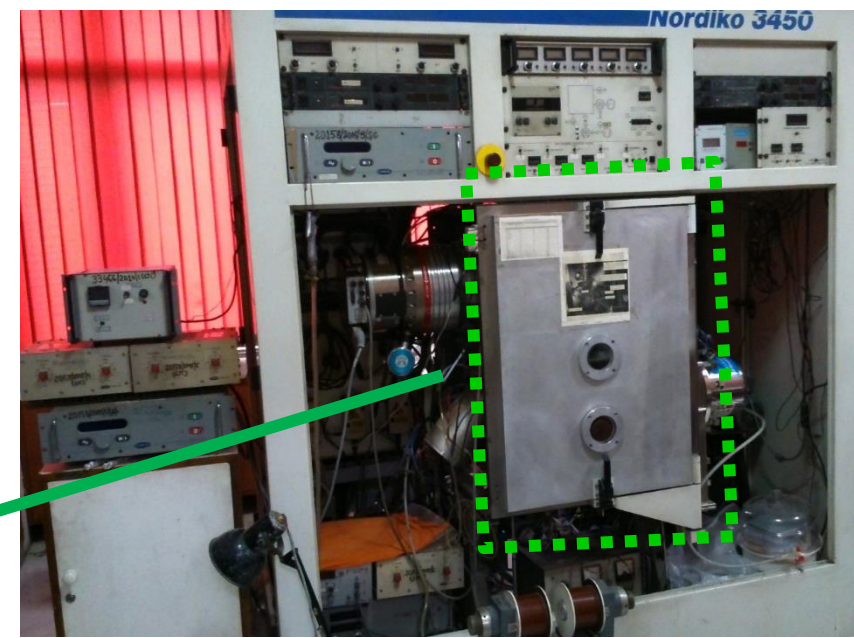
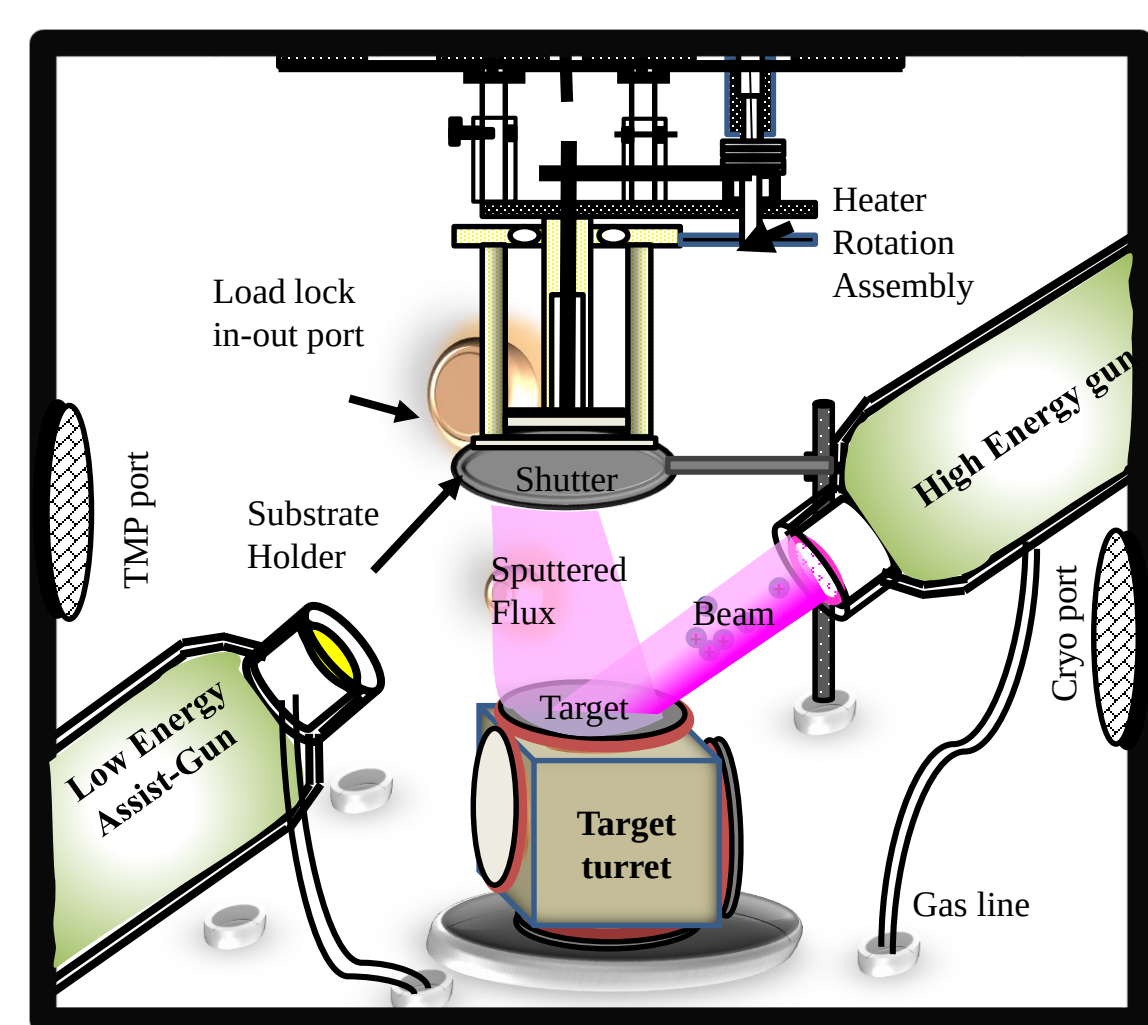


Why CoFeB?

- ☐ **Large TMR ratio** (800% at 5K)
- ☐ **Amorphous** in nature: No issues related to phase stability
- ☐ **Low uniaxial anisotropy** due to amorphous nature

FABRICATION PROCESS

Dual ion-beam sputtering



Schematic illustration of dual ion beam sputtering system. The process for the ion-beam sputter deposition of metal/alloy is shown (without using the assist-gun).

Deposition Conditions:

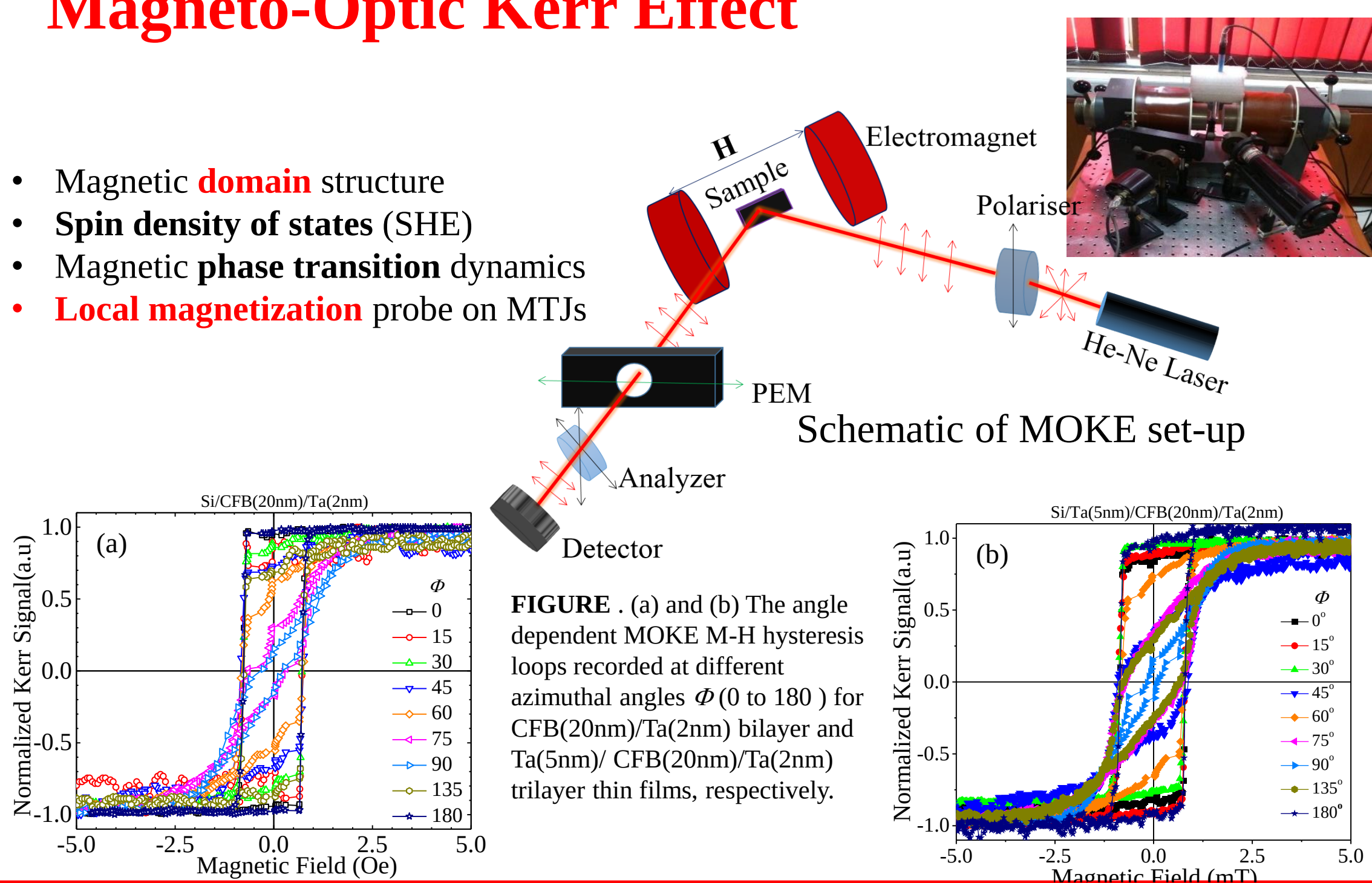
Base pressure	: $\sim 1 \times 10^{-7}$ Torr
Working pressure	: $\sim 8.4 \times 10^{-5}$ Torr
Ar ion energy	: 500 eV
Target-substrate gap	: 27 cm
Substrate Temperature	: 300K

Ta(0,2nm)
CoFeB(2-4nm)
Ta(0,5nm)
Si(substrate)

Thin Film Heterostructure

Magneto-Optic Kerr Effect

- Magnetic **domain** structure
- Spin density of states (SHE)**
- Magnetic **phase transition** dynamics
- Local magnetization** probe on MTJs



ACKNOWLEDGMENTS

One of the authors SH acknowledges the Department of Science and Technology, Govt. of India for providing the INSPIRE Fellowship. We also acknowledge the Ministry of Communication and Information Technology, Government of India for providing the financial grants to carry out this work.

RESULTS AND DISCUSSION

Structural Analysis

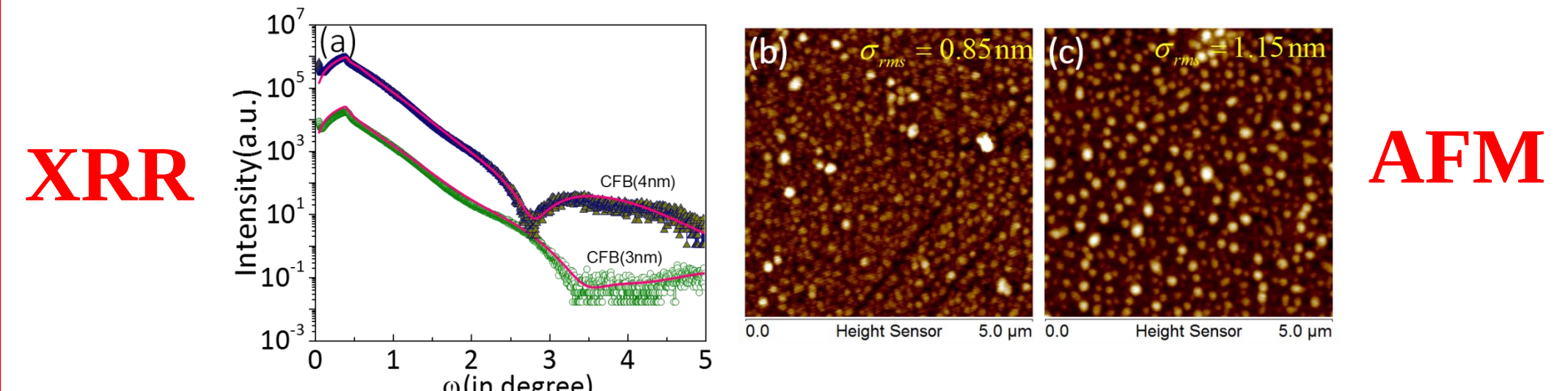


FIGURE . (a) XRR spectra, experimental and simulated, of a Si/SiO₂/CFB (3,4 nm) single thin films. Symbols represent the experimental data points, and the red lines represent the simulated spectra. (b) and (c) present the AFM images of CFB(3 nm) and CFB(4 nm) thin films, respectively.

TABLE I. The XRR simulated parameters, i.e., ρ , t , and σ for the single Si/SiO₂/CoFeB(3,4nm) thin films. Here ρ , t , and σ respectively refer to the density, thickness, and surface roughness of CoFeB single layer.

Layer	CFB (3 nm)			CFB (4 nm)		
	Density ρ (gm/cc) ± 0.03	Thickness t (nm) ± 0.02	Roughness σ (nm) ± 0.01	Density ρ (gm/cc) ± 0.04	Thickness t (nm) ± 0.01	Roughness σ (nm) ± 0.02
SiO ₂	3.52	3.50	0.74	3.45	2.49	0.64
CFB	7.00	2.50	0.54	7.23	3.25	0.35
MOx	4.13	1.19	0.25	2.41	1.94	0.9

Magneto-Optic Kerr effect M-H (MOKE-MH) in Ultrathin films

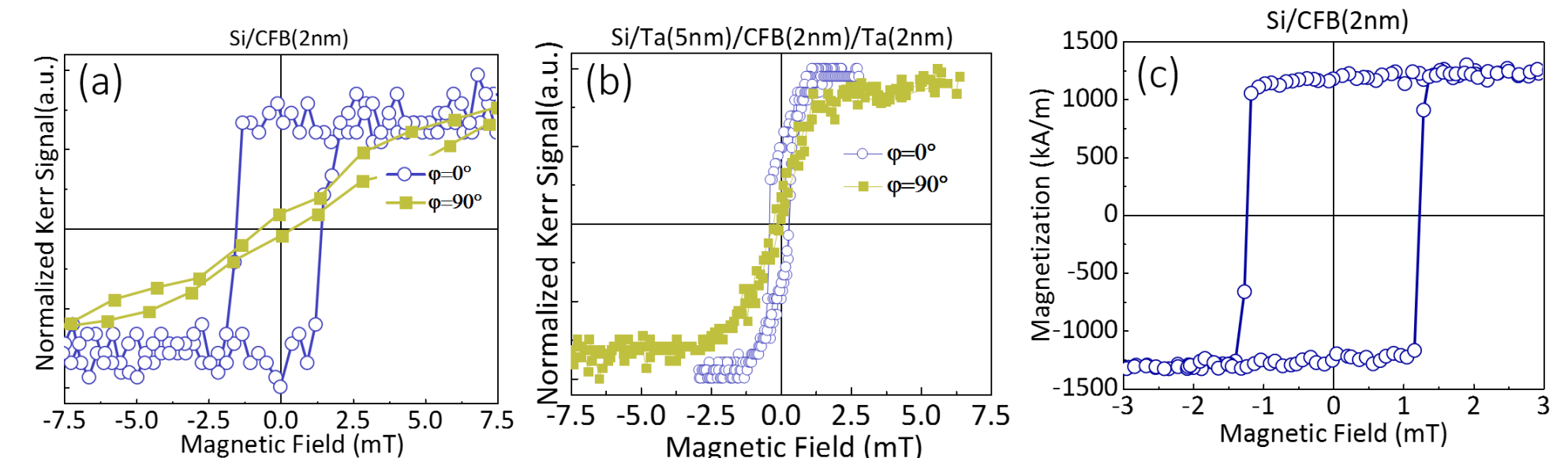


Figure : (a) & (b) The angle dependent hysteresis loops recorded using MOKE at different azimuthal angles $\phi = 0$ and 90° for CFB(2nm) single layer and Ta(5nm)/CFB(2nm)/Ta(2nm) trilayer films, respectively. (c) Magnetization hysteresis of CFB(2nm) thin film at room temperature.

Effective uniaxial anisotropy constant K_{eff} can be written in terms of volume contribution (K_u^V) and an interface contribution (K_u^S)-

$$K_u^{eff} = K_u^V + 2K_u^S/t$$

Since the thickness of FM layer is large, therefore mainly contribution comes from the volumetric term.

The anisotropy constant can be evaluated

$$K_u^{eff} = 1/2 M_s H_K$$

Where M_s is the saturation magnetization measured from PPMS-VSM and H_K is the anisotropy field extracted from MOKE hysteresis loops.

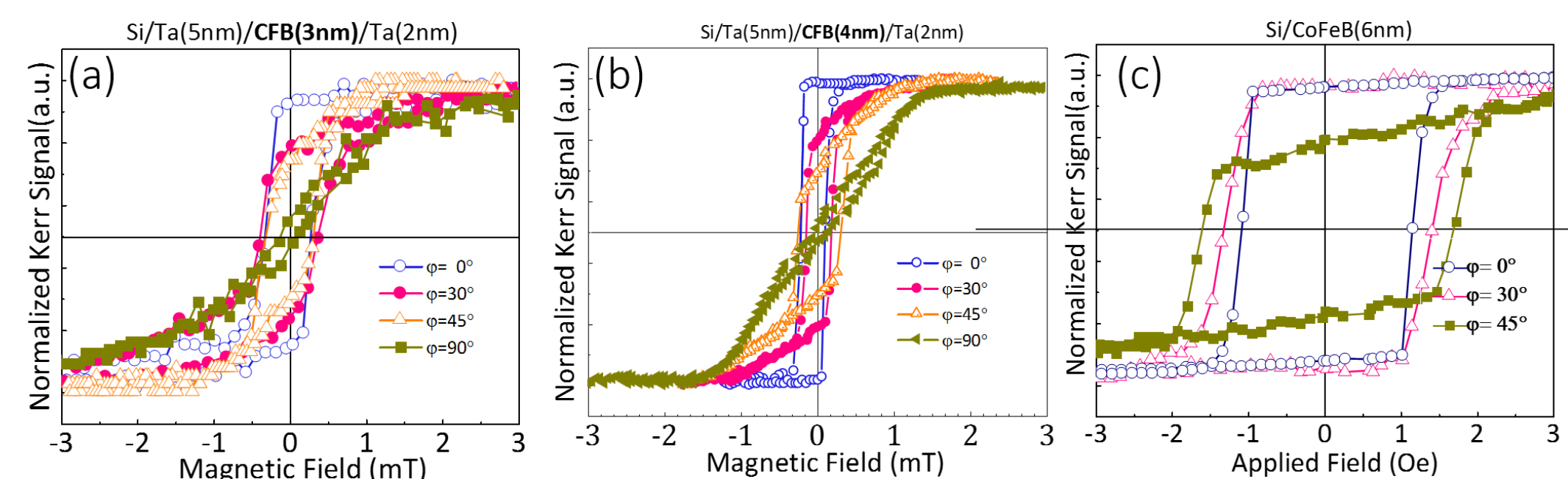


FIGURE . (a) and (b) The angle dependent MOKE M-H hysteresis loops recorded at different azimuthal angles ϕ (0 to 90°) for Ta(5nm)/CFB(3nm)/Ta(2nm) and Ta(5nm)/CFB(4nm)/Ta(2nm) trilayer thin films, respectively. (c) MOKE-MH signals for single layer CoFeB(6nm)

CONCLUSIONS

- The dc-magnetization behaviour of single layer CFB(2nm) and Ta(5)/CFB(2nm)/Ta(2nm) trilayer **ultrathin films** has been compared employing magneto-optical Kerr effect
- It is **established** that with Ta as buffer and capping layers with CFB, **low H_c** (~ 0.1 - 0.2 mT) and **low K_u** (~ 0.93 - 1.54 kJ/m³) result.
- X-ray Reflectivity** studies revealed that the buffer and capping layer favors the **smoothing of the film/substrate interface** as well as the protection of the surface from oxidation.
- Low anisotropic and low defect concentration** in these Co₆₀Fe₂₀B₂₀ thin films grown on Si make them superior candidates for **low field switching applications** in spintronic devices.

REFERENCES

- I. Žutić, J. Fabian, and S. Das Sarma, Rev. Mod. Phys. 76, 323 (2004).
- A.T. Hindmarch, A.W. Rushforth, R.P. Campion, C.H. Marrows, and B.L. Gallagher, Phys. Rev. B 83, 212404 (2011).
- S. Husain, A. Kumar, S. Chaudhary, and P. Svedlindh, AIP Conf. Proc. 20072, 20072 (2016).
- L. Kippen, H. Fulara, M. Raju, and S. Chaudhary, J. Magn. Magn. Mater. 324, 3118 (2012).
- C. Stamm et al, Phy. Rev. Lett. 119, 087203 (2017)