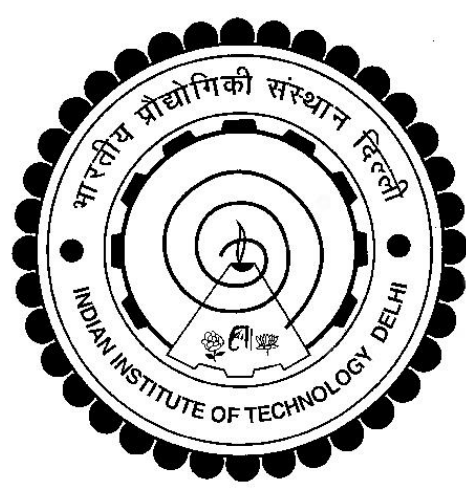




Growth and Study of Ion Beam Sputtered Heusler Alloy Thin Films For Spintronic Applications

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SRC PRESENTATION
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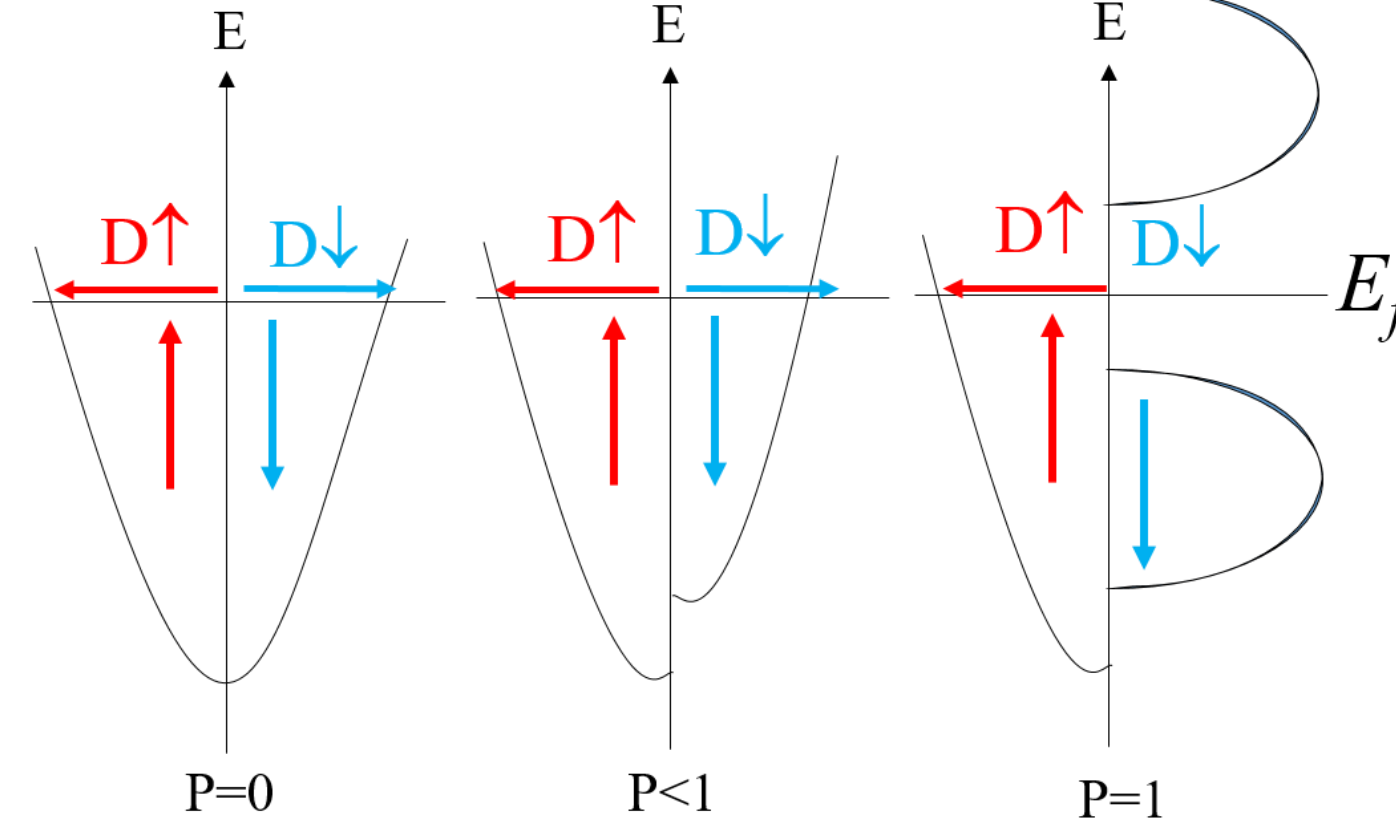
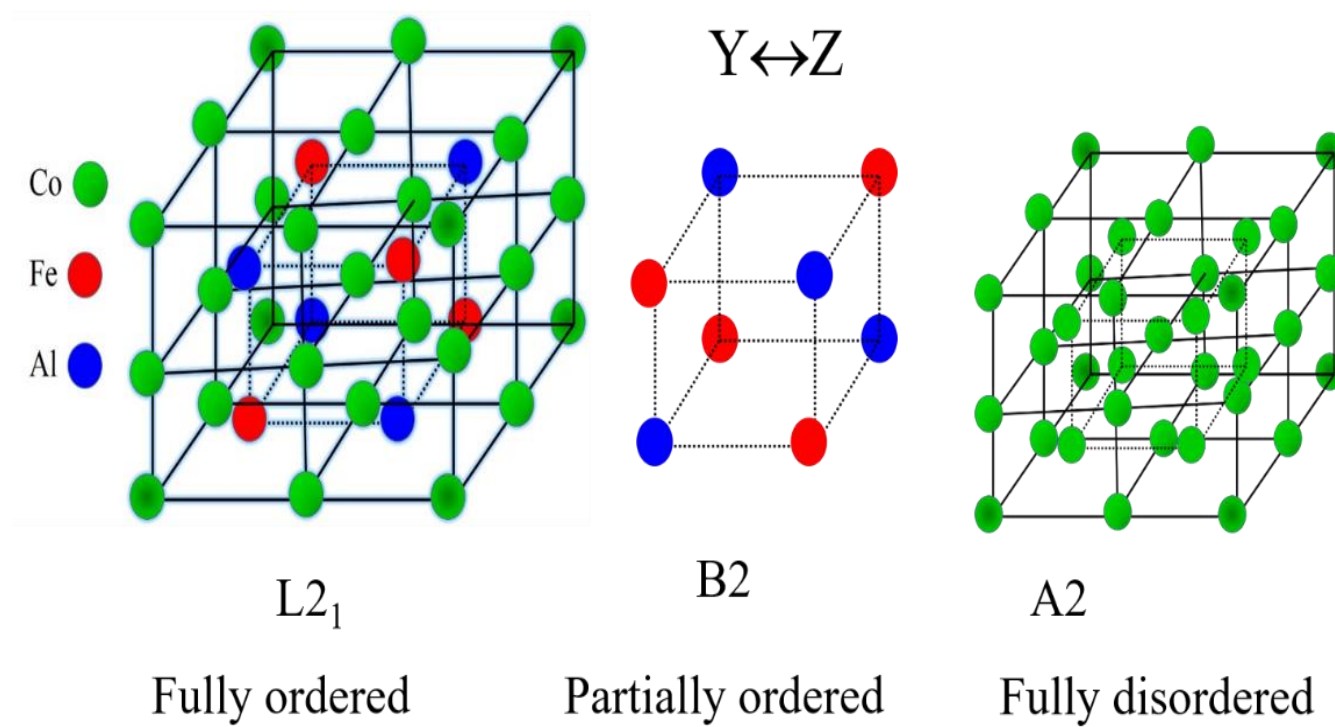
Objectives:

- Growth of ordered Co₂FeAl Heusler alloy thin films on Si(100) substrate
- Structural, static and dynamics magnetization properties

INTRODUCTION

Heusler Alloy(X₂YZ)

Half Metallicity: Spin band structure exhibits different behavior for the two spin orientations - **Metallic** for **majority spin band** and **semiconducting** for **minority spin**



Why Heusler Alloy?

- 100% spin polarization
- High Curie temperature
- Very small damping constant

Applications:

- ❖ High density memory devices with perpendicular magnetic anisotropy
- ❖ In MRAMs due to high sensitivity using CPP GMR at room temperature
- ❖ In STT devices owing to very low damping constant

LLG Equation:

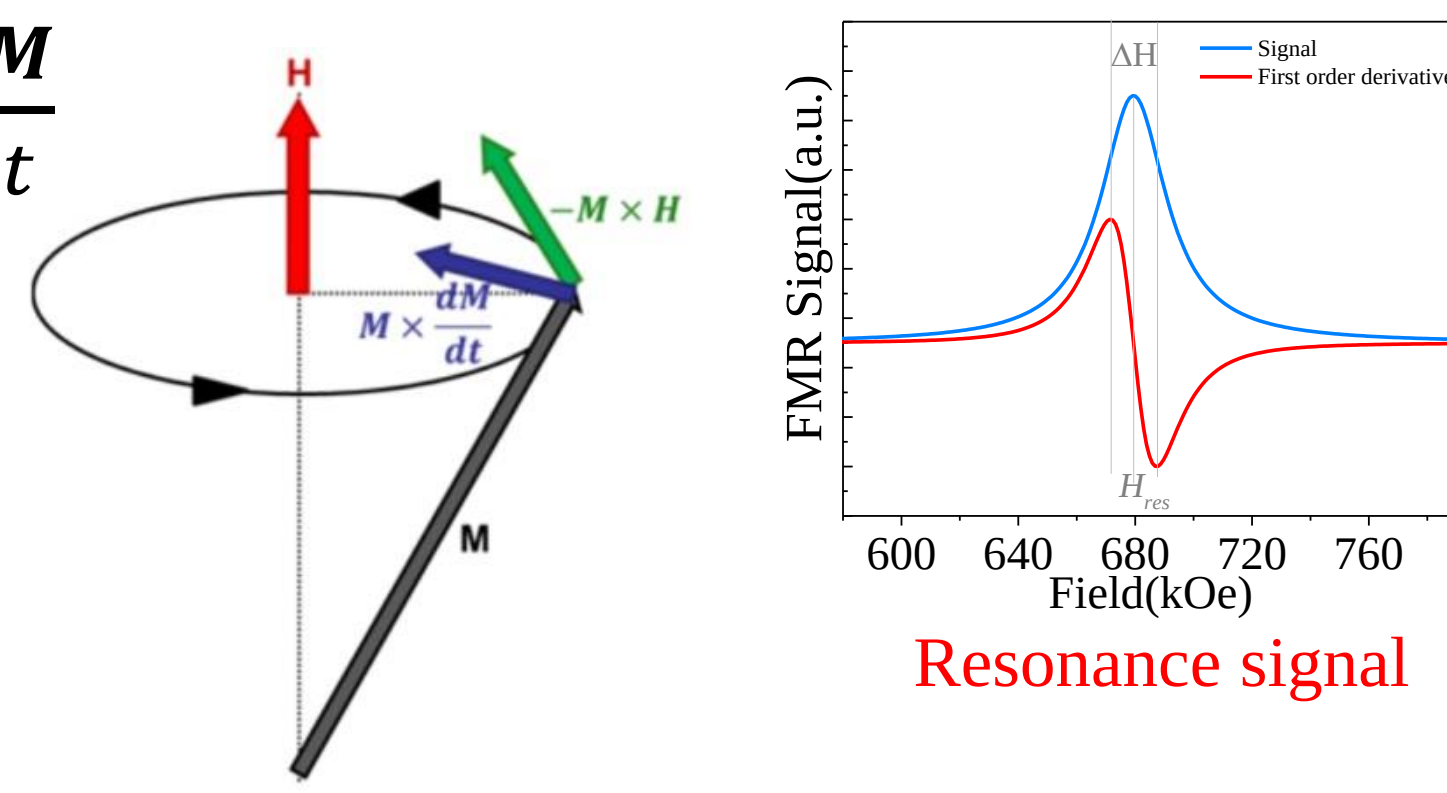
$$\frac{d\mathbf{M}}{dt} = -\gamma \mathbf{M} \times \mathbf{H} + \frac{\alpha}{M} \mathbf{M} \times \frac{d\mathbf{M}}{dt}$$

Kittel equation:

$$f = \frac{\gamma}{2\pi} \sqrt{(H_r + H_K)(H_r + H_K + 4\pi M_{eff})}$$

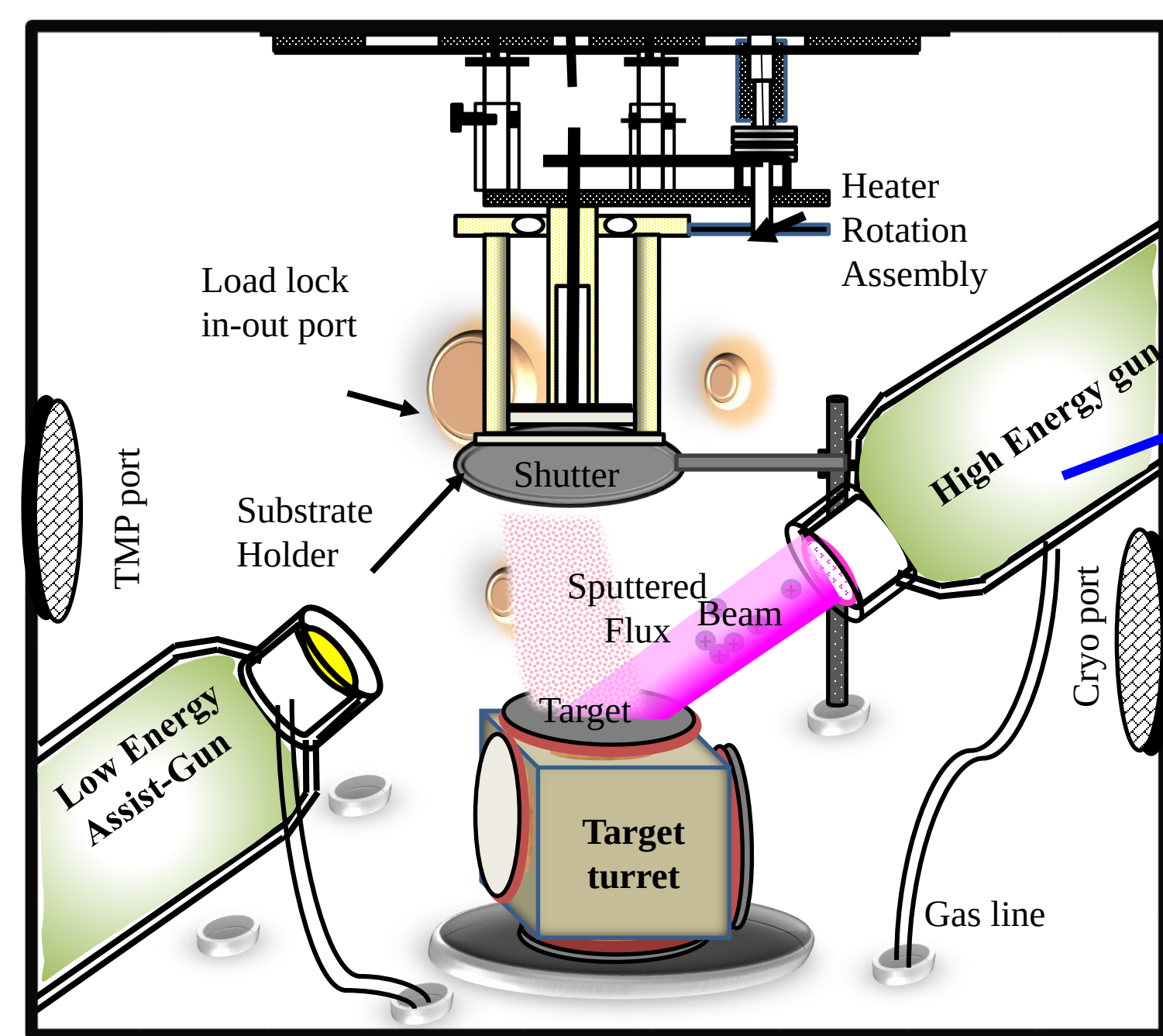
Linewidth:

$$\Delta H = \Delta H_0 + \frac{4\pi\alpha f}{\gamma}$$



FABRICATION PROCESS

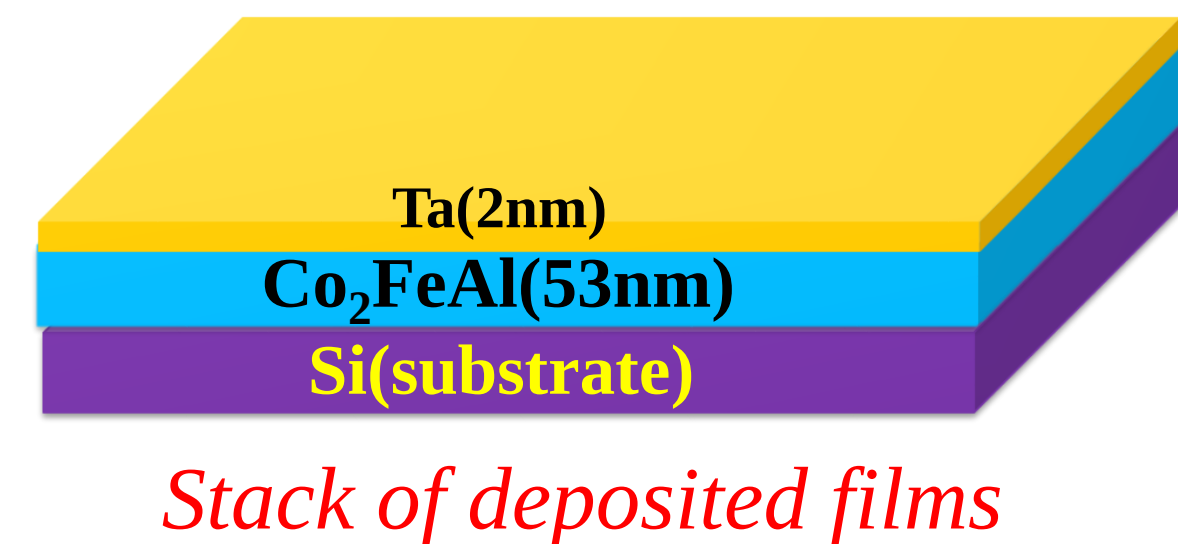
Dual ion-beam sputtering



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 : 8×10^{-7} Torr
Working pressure : 2.5×10^{-4} Torr
Ar ion energy : 500 eV
Target substrate gap : 27 cm
Substrate Temperature: RT-773K



Stack of deposited films

Structural Analysis (XRD and AFM)

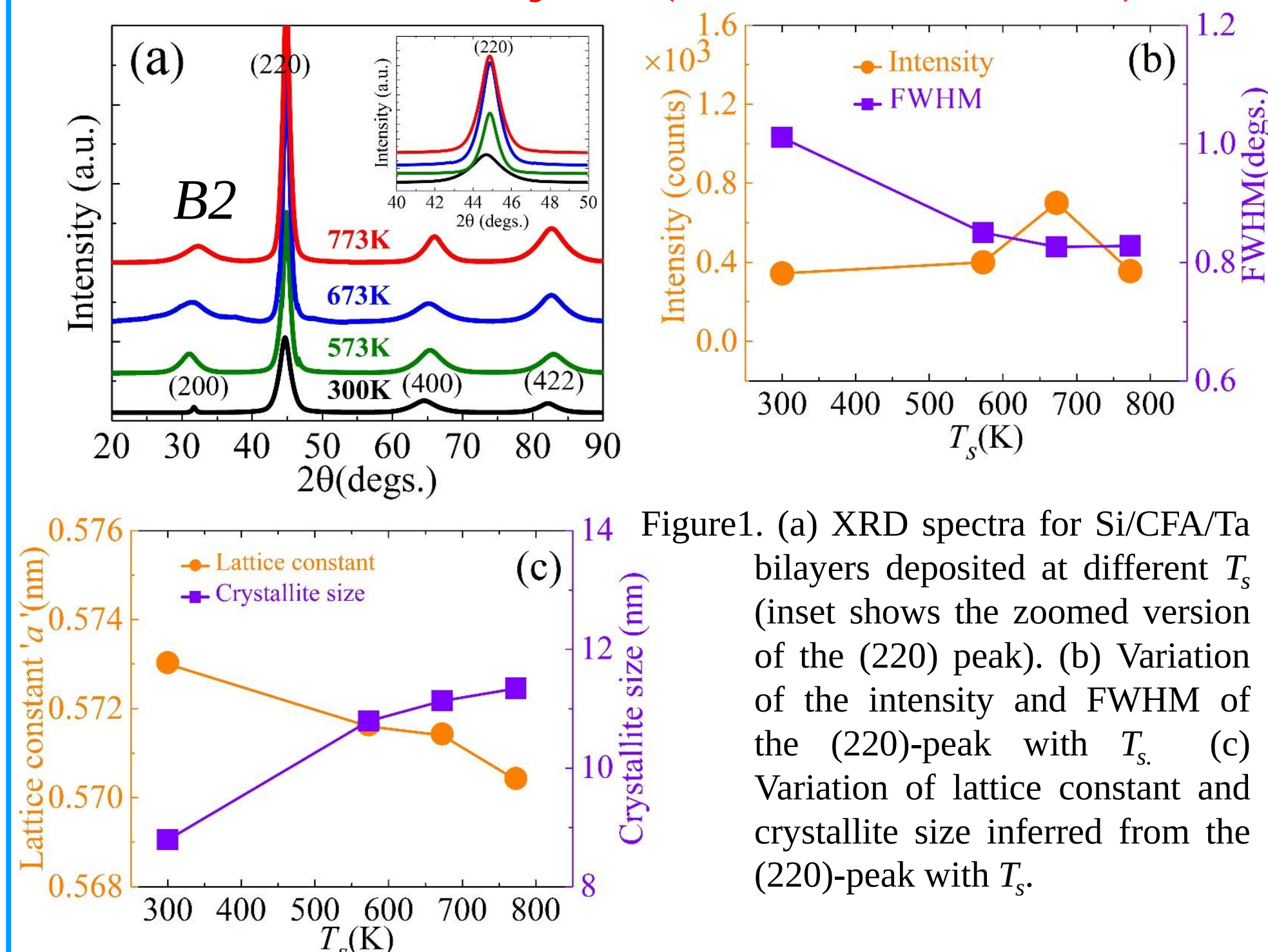


Figure1. (a) XRD spectra for Si/CFA/Ta bilayers deposited at different T_s (inset shows the zoomed version of the (220) peak). (b) Variation of the intensity and FWHM of the (220)-peak with T_s . (c) Variation of lattice constant and crystallite size inferred from the (220)-peak with T_s .

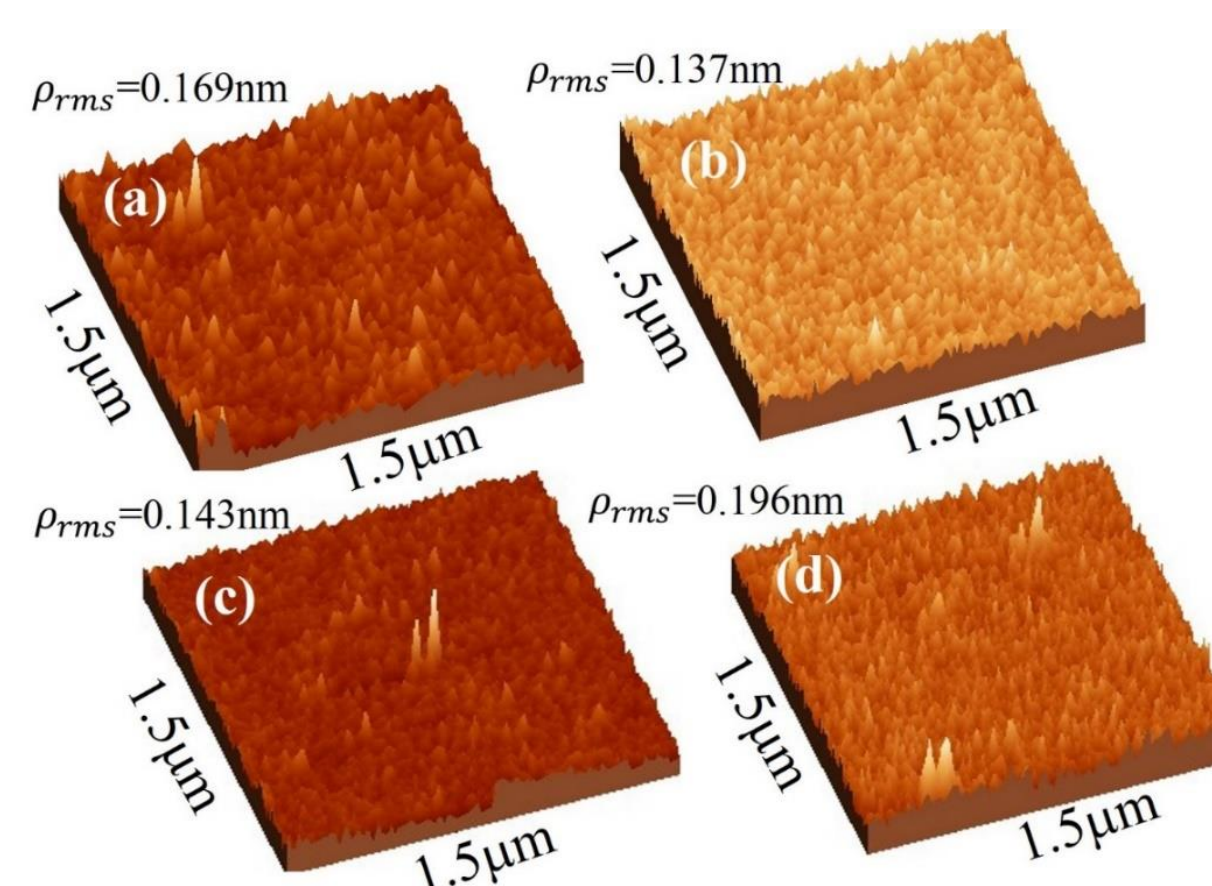


Figure 2. Topographical images of bilayer Si/CFA/Ta deposited at different T_s : (a) 300K, (b) 573K, (c) 673K and (d) 773K

Structural Analysis(XRR)

RESULTS

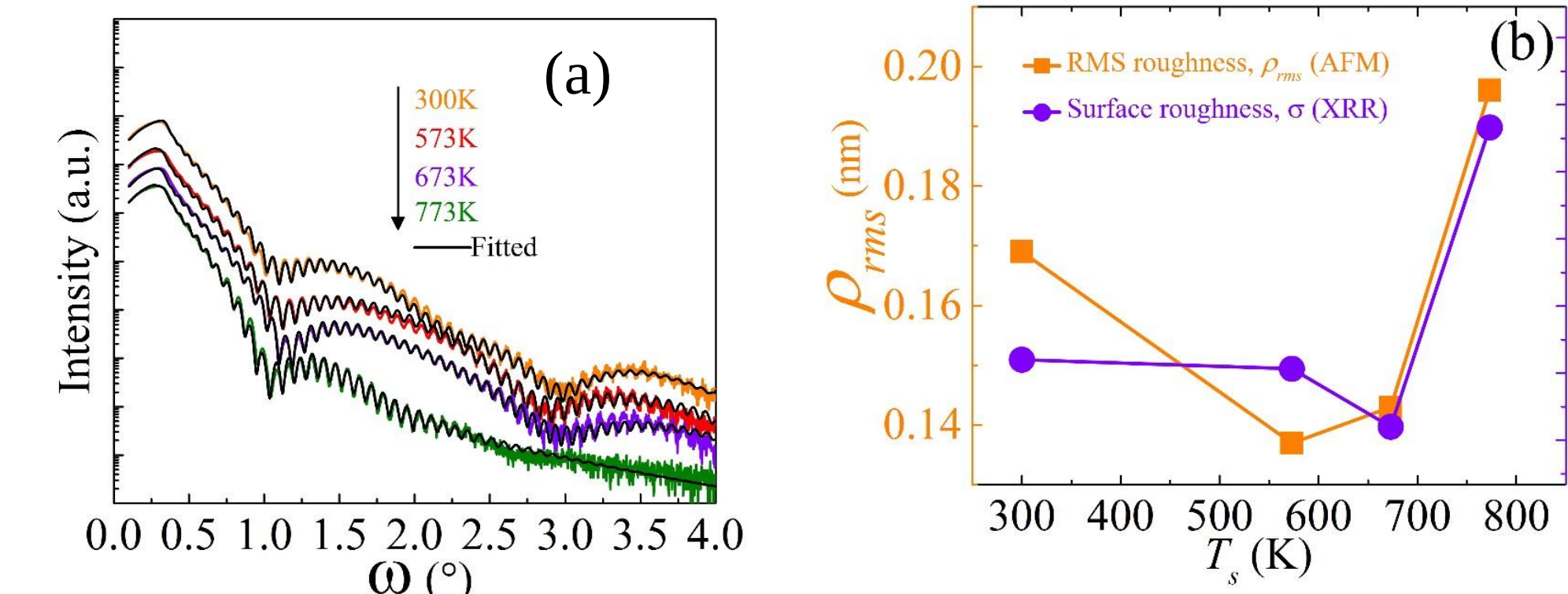


Figure 3. (a) X-ray reflectivity spectra recorded for bilayer Si/Co₂FeAl/Ta thin films deposited at various T_s . (b) Effect of T_s on the surface roughness determined from AFM and XRR measurements

Static and Dynamic Magnetization Analysis

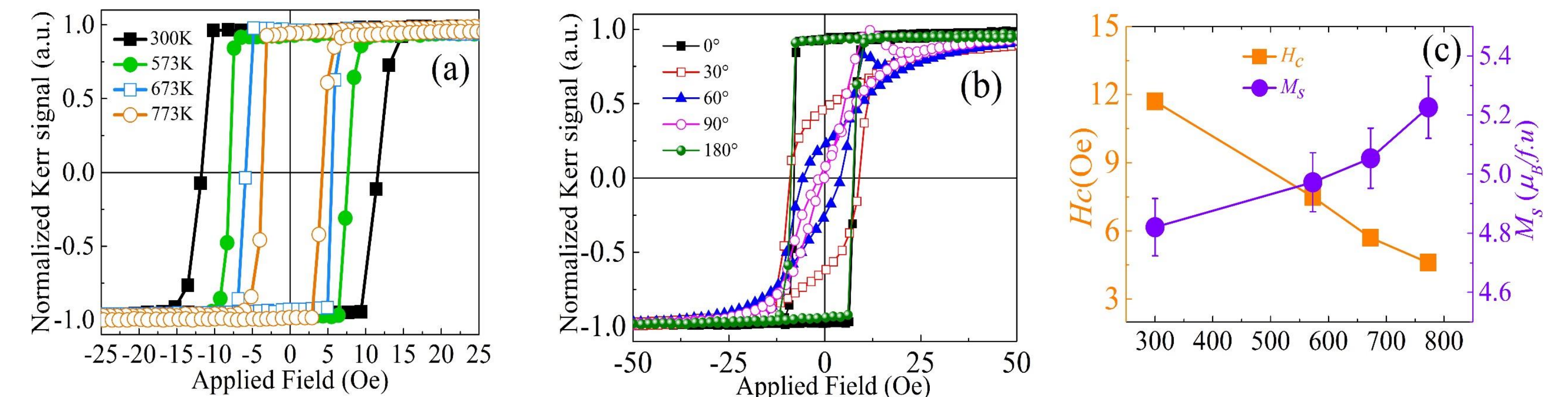


Figure 4. (a) MOKE hysteresis loops recorded at room temperature along the easy axis of magnetization for the CFA films deposited at different T_s . (b) Angle dependent MOKE hysteresis curves recorded at different azimuthal angles on the Si/CFA(53nm)/Ta(2nm) thin film deposited at $T_s \sim 573$ K. (c) Dependence of H_c and M_s on T_s .

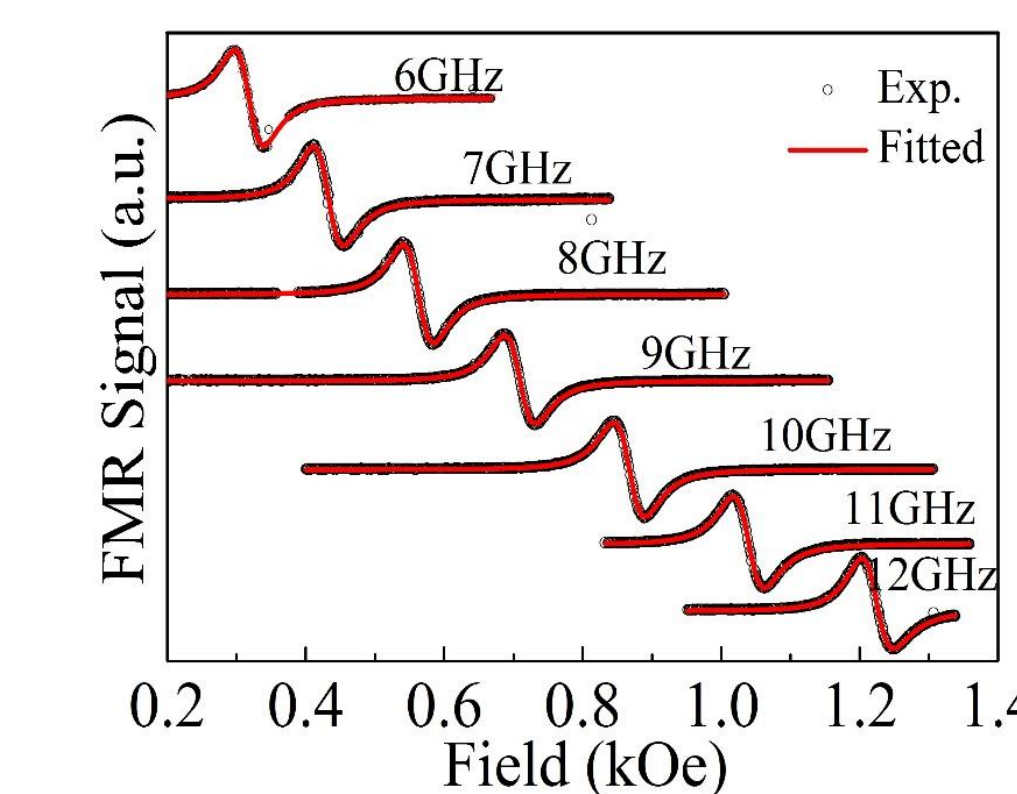


Figure 5. Frequency dependence of FMR spectra for the 573K deposited CFA film

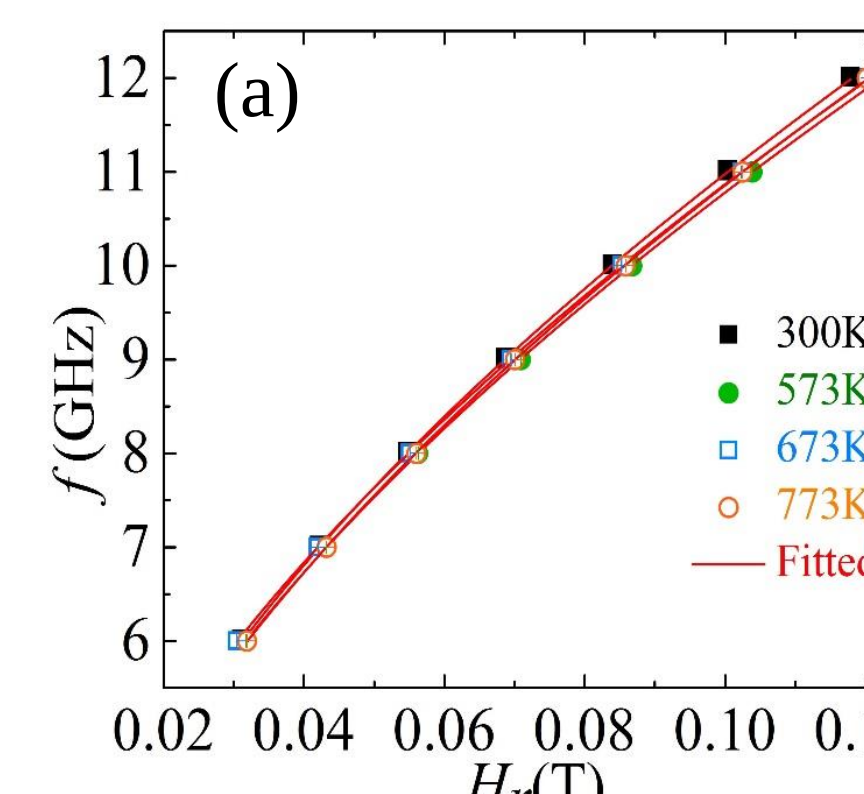


Figure 6. (a) f vs. H_c plot for the different films (b) T_s dependence of $4\pi M_{eff}$ together with $4\pi M_s$ vs. T_s .

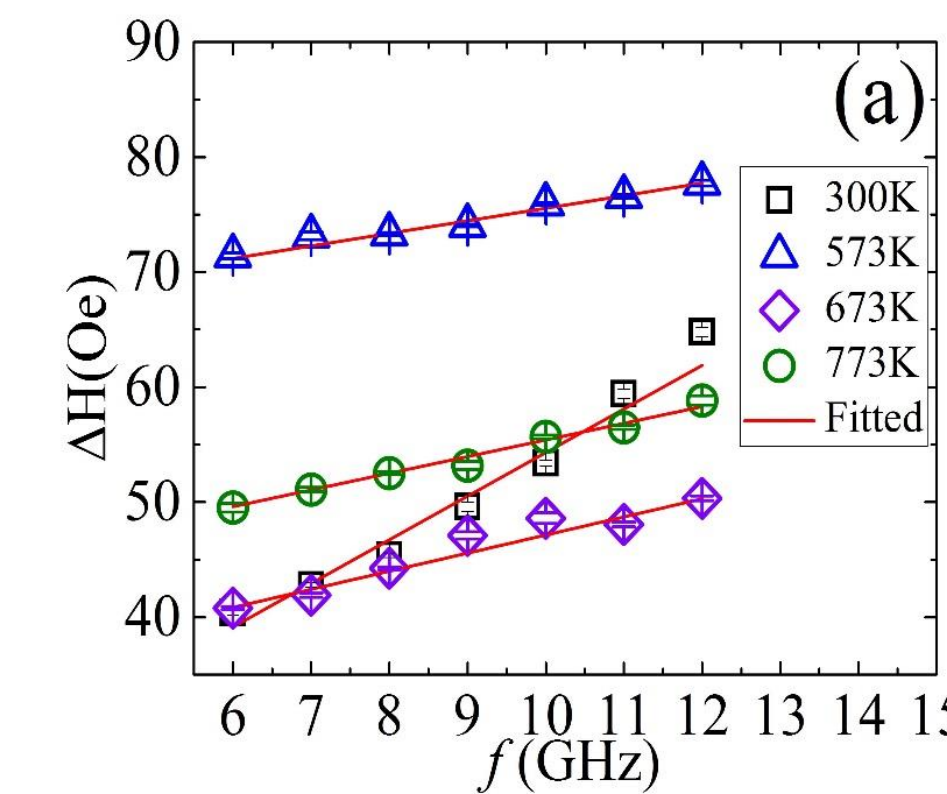


Figure 7. (a) ΔH vs. f plot for CFA films grown at different T_s , (b) Plot of Gilbert damping constant α vs. T_s .

CONCLUSIONS

- ✓ The Co₂FeAl Heusler alloy thin films grown at different substrate temperatures on Si(100) by employing ion-beam sputtering deposition technique
- ✓ B2 ordered phase was found at all temperature.
- ✓ A very low surface roughness (<3Å) and minimal anti-site disorder consistent with the observed higher saturation magnetization was found.
- ✓ Most importantly, a record low Gilbert damping constant of 0.0015 ± 0.0001 is obtained at the optimum substrate temperature of ~ 573 K.

ACKNOWLEDGEMENT

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Publication :

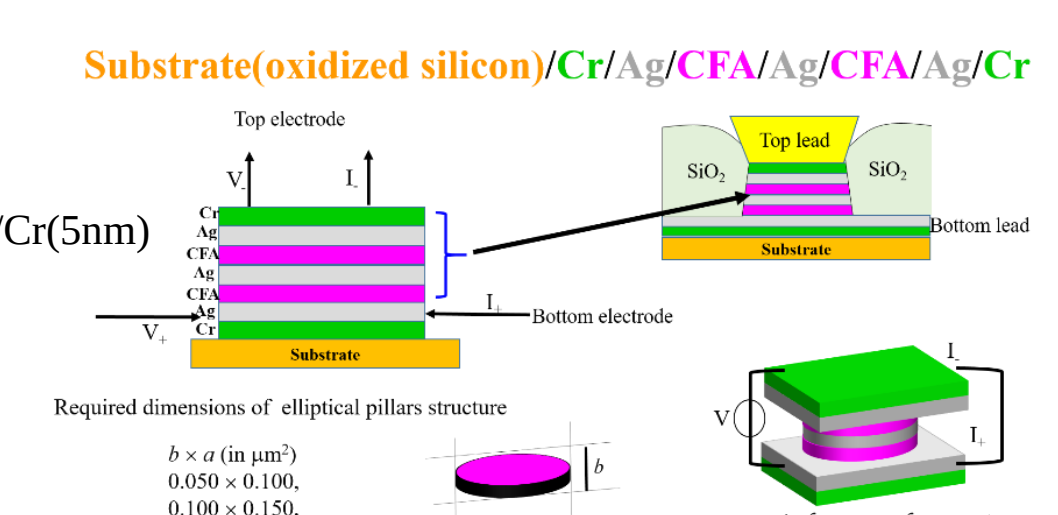
1. Sajid Husain, Serkan Akansel, Ankit Kumar, Peter Svedlindh and Sujeet Chaudhary, "Growth of Co₂FeAl Heusler alloy thin films on Si(100) having very small Gilbert damping by ion beam sputtering" (Communicated).
2. Sajid Husain, Ankit Kumar, Peter Svedlindh and Sujeet Chaudhary, "Structural and Magnetic Properties of Ion Beam Sputtered Co₂FeAl Full Heusler Alloy Thin Films" AIP conference proceeding in press.

Conferences:

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2. Sajid Husain, Ankit Kumar, Peter Svedlindh and Sujeet Chaudhary, "Skyrmions in Co₂FeAl Heusler Alloy Thin Films with Perpendicular Magnetic Anisotropy" presented at International Conference on Magnetism and Magnetic Material Application (ICMAGMA-2015) Vellore, India.
3. Sajid Husain, Ankit Kumar, Peter Svedlindh and Sujeet Chaudhary, "Structural and Magnetic Properties of Ion Beam Sputtered Co₂FeAl Full Heusler Alloy Thin Films" presented at International Conference in Condensed Matter and Applied Physics (ICC-2015) Bikaner, India.
4. Serkan Akansel, Ankit Kumar, Sajid Husain, Sujeet Chaudhary, and Peter Svedlindh, "Thickness dependent dynamic study of ion-beam sputtered Co₂FeAl thin films" presented at International Conference on Magnetism (ICM-2015) Spain.
5. Sajid Husain, Ankit Kumar, Peter Svedlindh and Sujeet Chaudhary, "Growth and Magnetization Study of Ordered Co₂FeAl Heusler Alloy Thin Films" presented at Open House event (2015), Indian Institute of Technology Delhi, India.

Future Plan:

The multilayer stack for CPP - GMR geometry
Si(thermally oxidize)/Cr(20nm)/Ag(100nm)/CFA(t_{bottom} =5nm & 10nm)/Ag(t_{top})/Ag(20nm)/Cr(5nm)
 t_{Ag} = 5 and 10 nm and
 t_{top} = 5, 10, 15, 20 nm for each t_{bottom}
The nano-pillar dimensions for CPP-GMR are 50×100, 100×200, 200×300, and 300×400 nm².
Study to be performed:
CPP-GMR will be measured using four-probe geometry at various temperatures (2-300K).



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