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Static and Dynamic Properties of Magnetic Mesoscopic Structures

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ABSTARCT:

- In this work we present a study of static and dynamic properties of two-dimensional arrays of permalloy(Py) $Ni_{80}Fe_{20}$ ellipsoidal nanomagnets.

- The samples were studied by dc-magnetization, broad band spectroscopy and reversible susceptibility measurements.

- The magnetization loops at room temperature showed a wasp-waisted shapes that can be correlated with the magnetic shape anisotropy contribution of these samples.

- By broadband ferromagnetic resonance (FMR), two different narrow absorption lines can be resolved due to the collective magnetic contribution between the magnetic cells, in counterpart of the single narrow line measured for the Py thin film. The field variation of the resonance lines were followed from 1 kOe to 3 kOe and can be compared with the theory of FMR for thin films.

- The critical curves were measured by the method of reversible susceptibility, where the angular variation was conducted with magnetic field in plane.

MOTIVATION

- Magnetization reversal is one of the central issues in the physics of mesoscopic magnetic systems. Its understanding is important not only for its evident fundamental interest but also due to the big impact on the information technology, more specifically on magnetic information storage.

- Magnetic recording is rapidly approaching the nanometer scale as storage densities are projected to increase beyond a terabit per square inch. High volume of data requires higher data transfer rates. These present new challenges and opportunities in nanometer scale materials engineering and in understanding the magnetic properties of nanometer scale magnetic materials.

- With the aim to study the internal magnetic trends and the interaction effects between the magnetic cells, different geometrical arrangements of permalloy ($Ni_{80}Fe_{20}$) cells were studied.

SAMPLES

The samples were prepared at National University of Singapore by deep ultraviolet lithography at 248 nm wavelength followed by the lift-off process.[1] The samples with a thickness of 30 nm and with typically dimensions of 0.8 µm x 2 µm for each magnetic cell.[2].

Sample Py C Pattern (30nm)

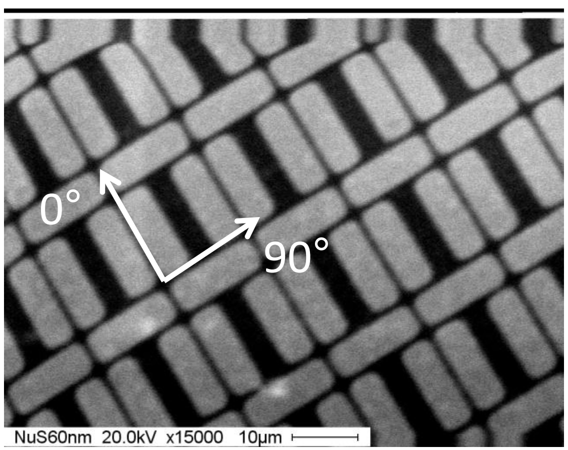


Image taken by Scanning Electron Microscopy (SEM) at AMRI-UNO.

Sample B1 (30nm)

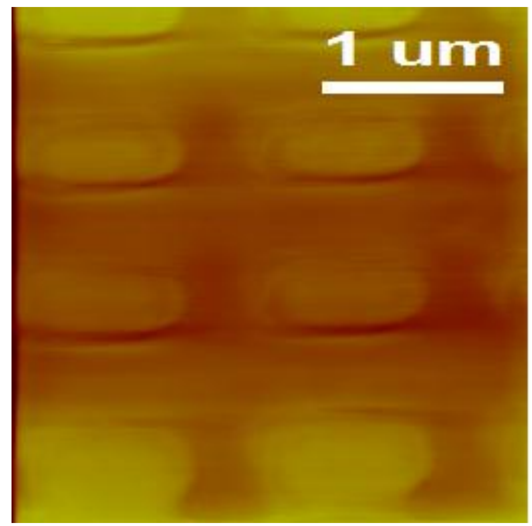
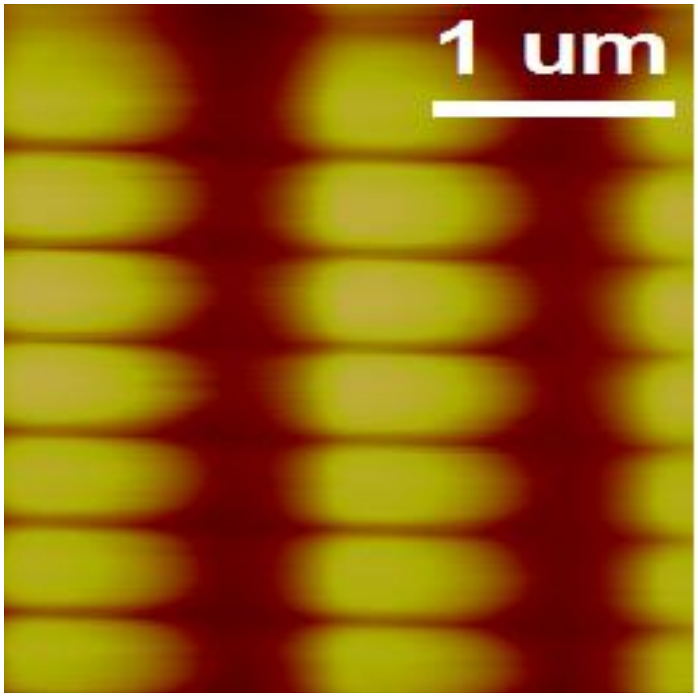
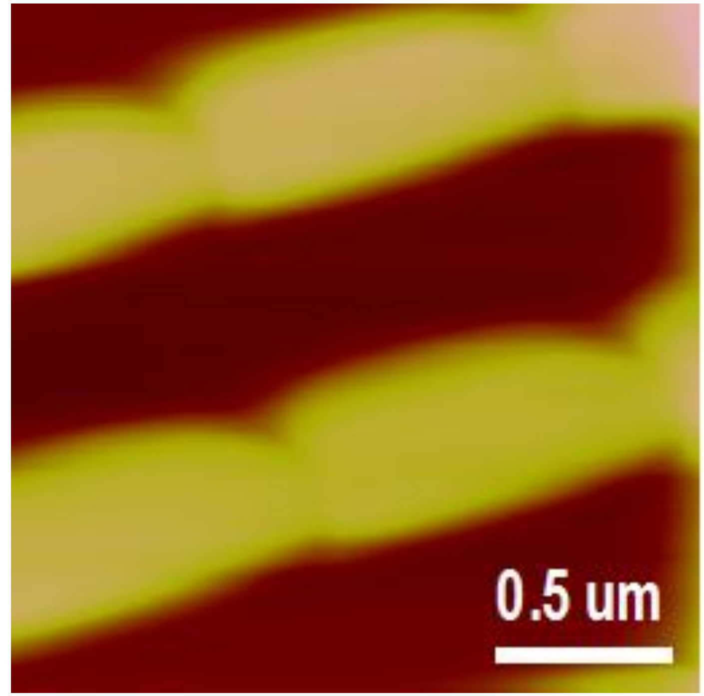


Image taken by Atomic Force Microscopy (AFM) at AMRI-UNO

Sample B2 (30nm)



Sample B3 (30nm)

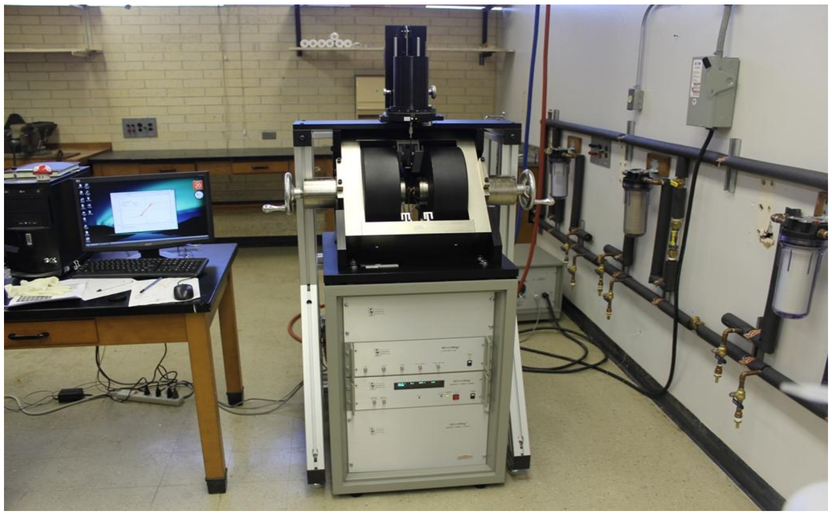


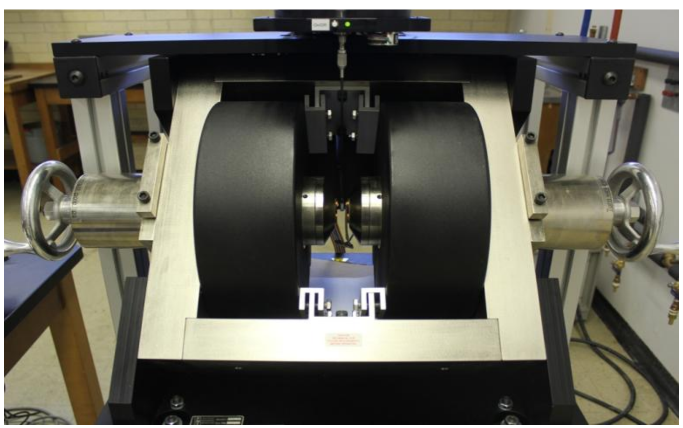
Images taken by Atomic Force Microscopy (AFM) at AMRI-UNO.

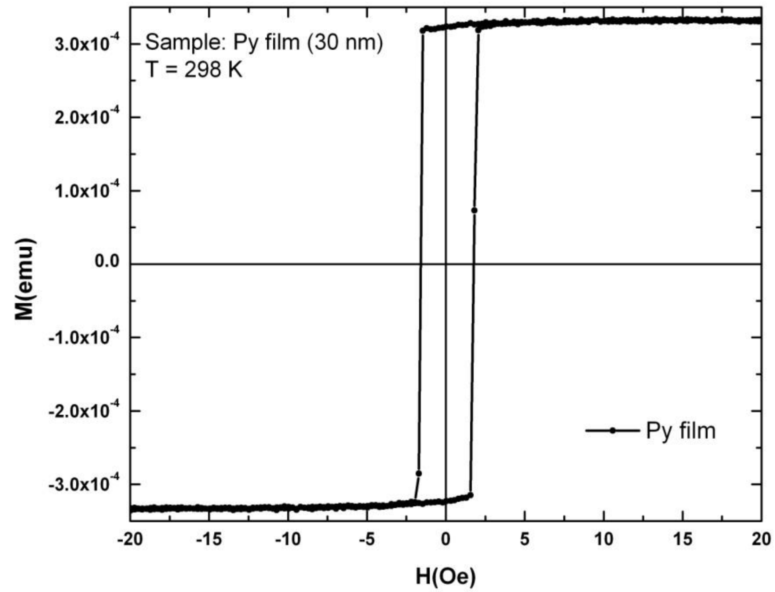
RESULTS

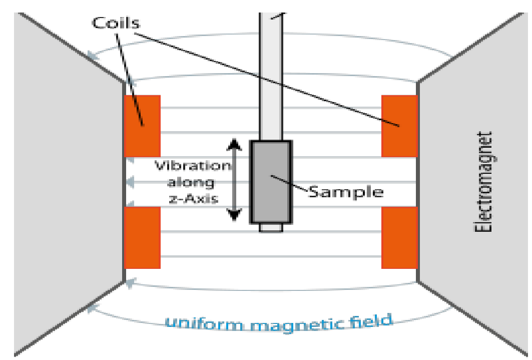
VIBRATING SAMPLE MAGNETOMETER (VSM)

The magnetization loops of the samples C, B1,B2,B3 and control Py samples were measured at room temperature (RT)



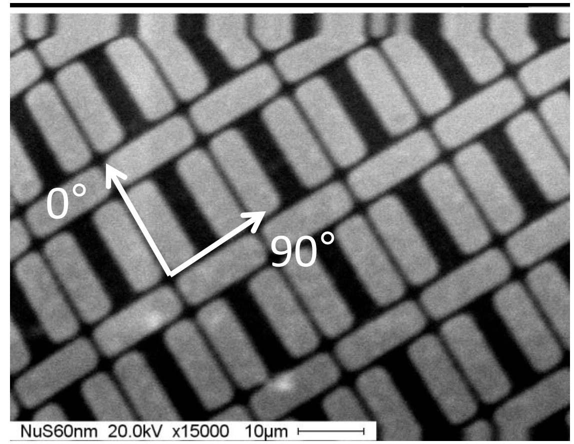


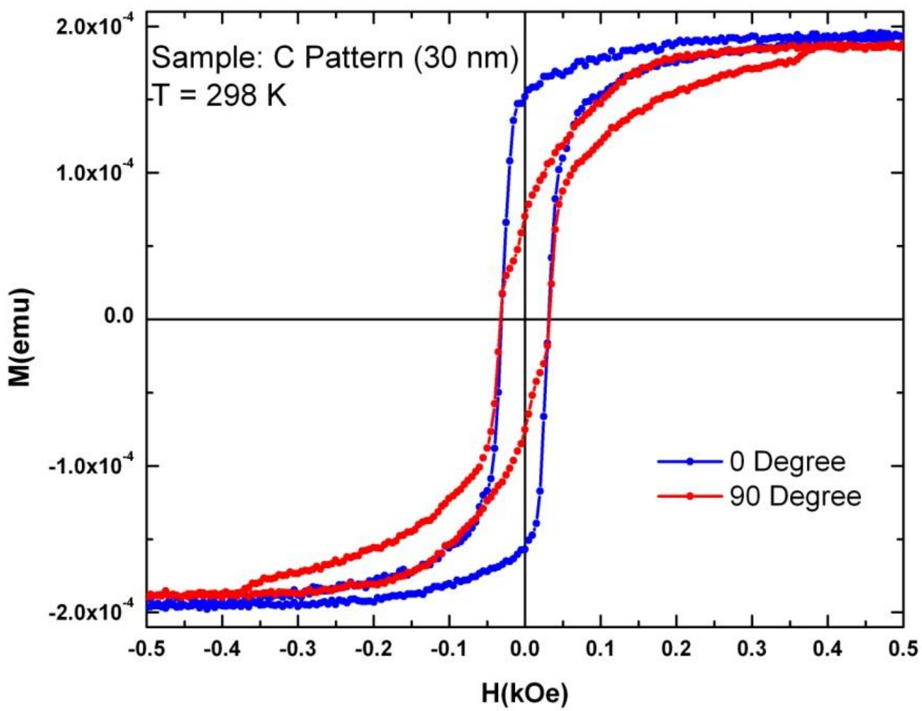


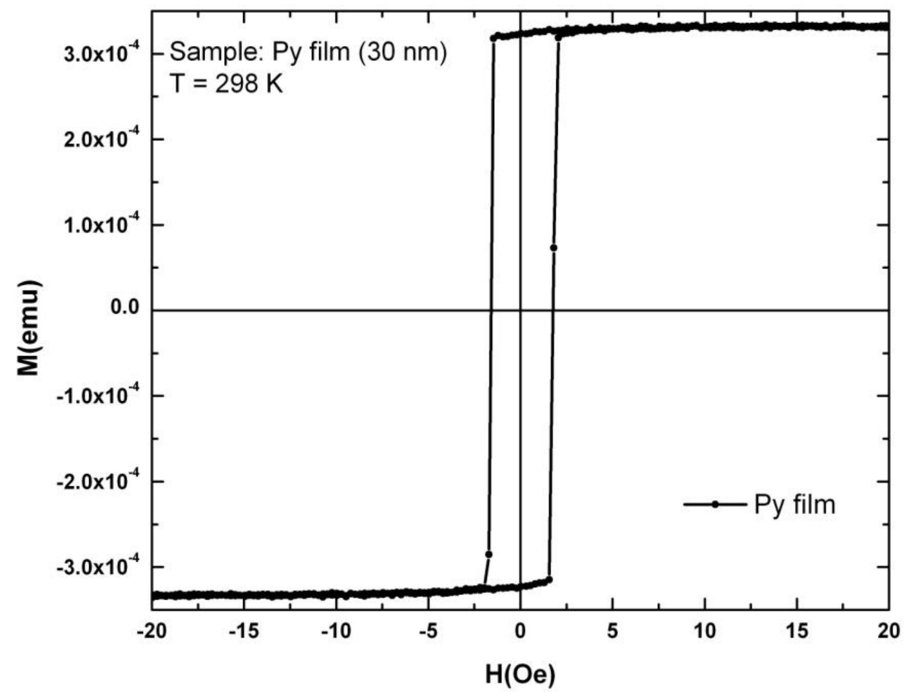


Magnetization loops for C patterned sample

Magnetic field in-plane for 0 and 90 degree orientations:

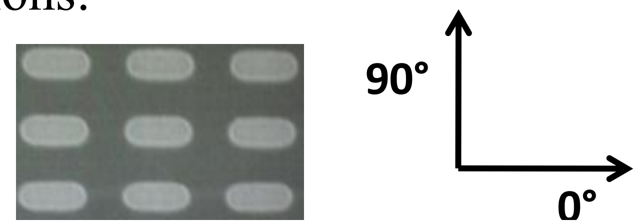


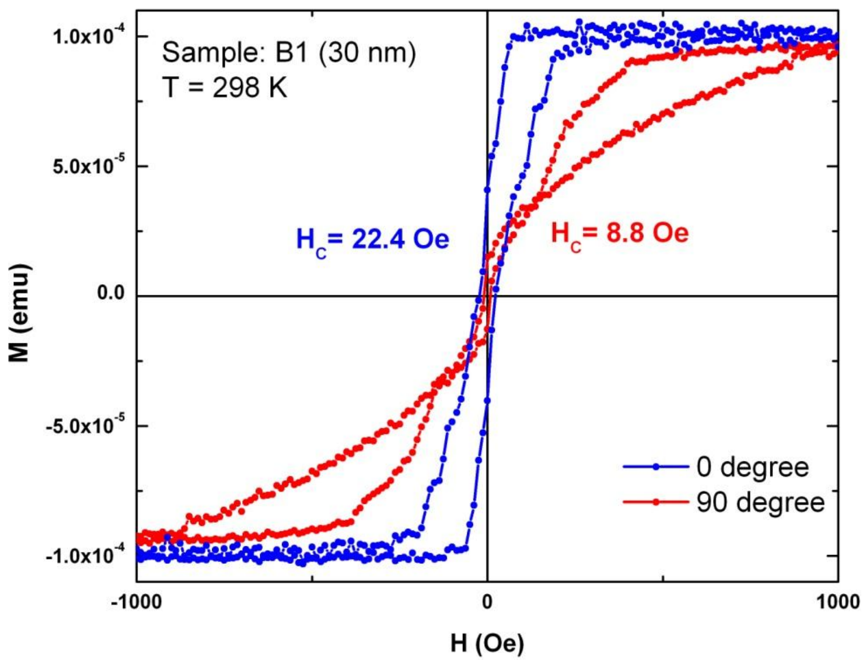


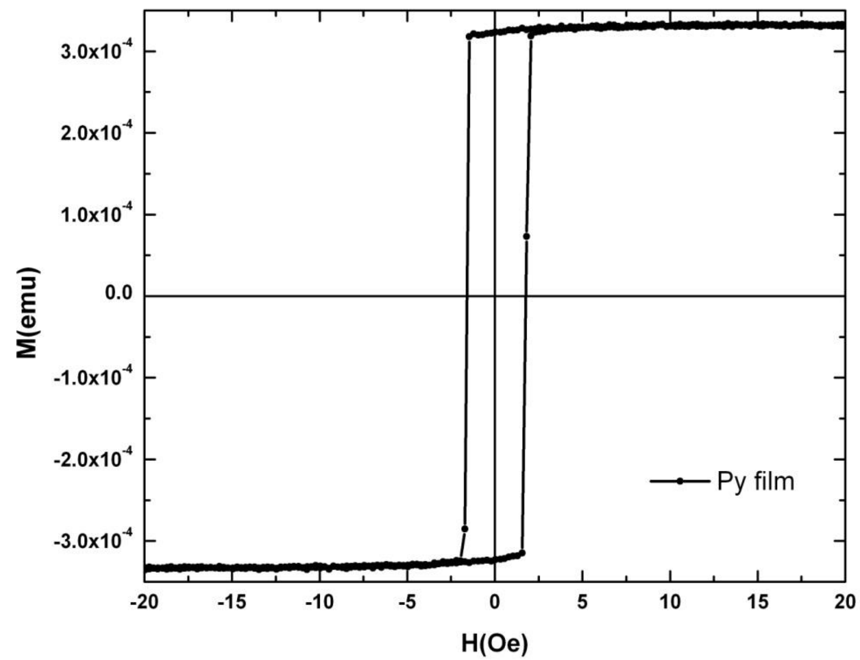


Magnetization loops for B1 patterned sample

Magnetic field in-plane for 0 and 90 degree orientations:

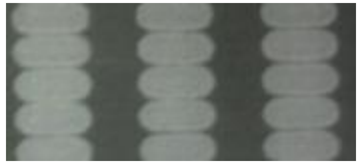


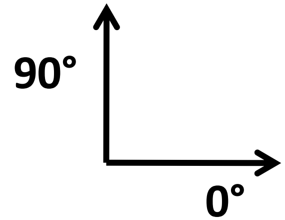


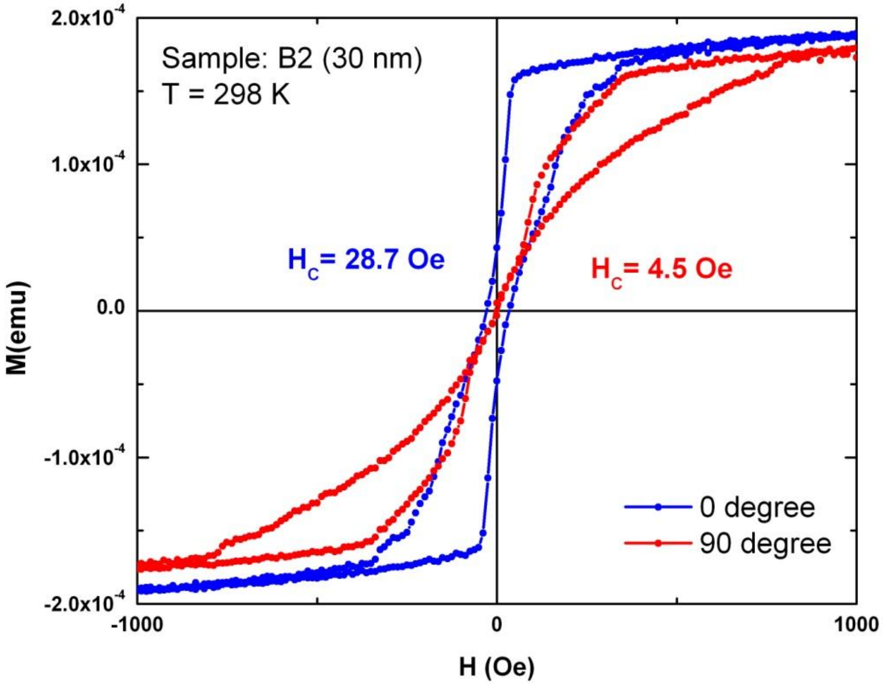


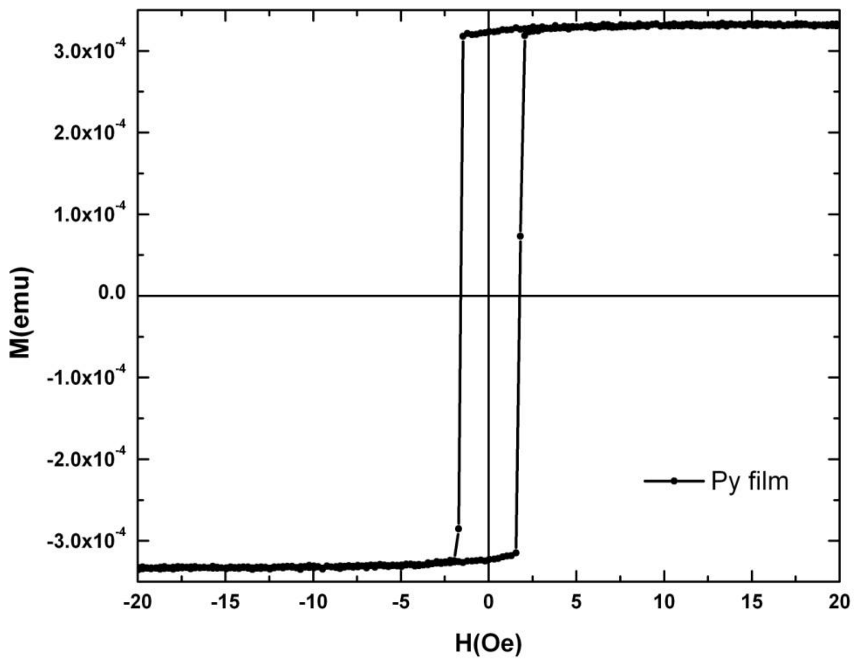
Magnetization loops for B2 patterned sample

Magnetic field in-plane for 0 and 90 degree orientations:



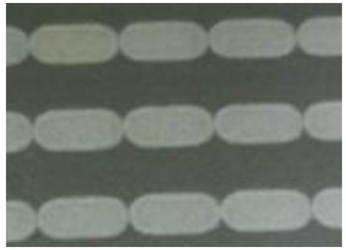


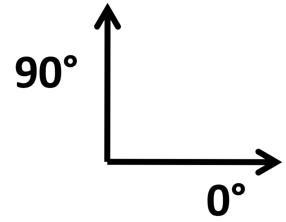


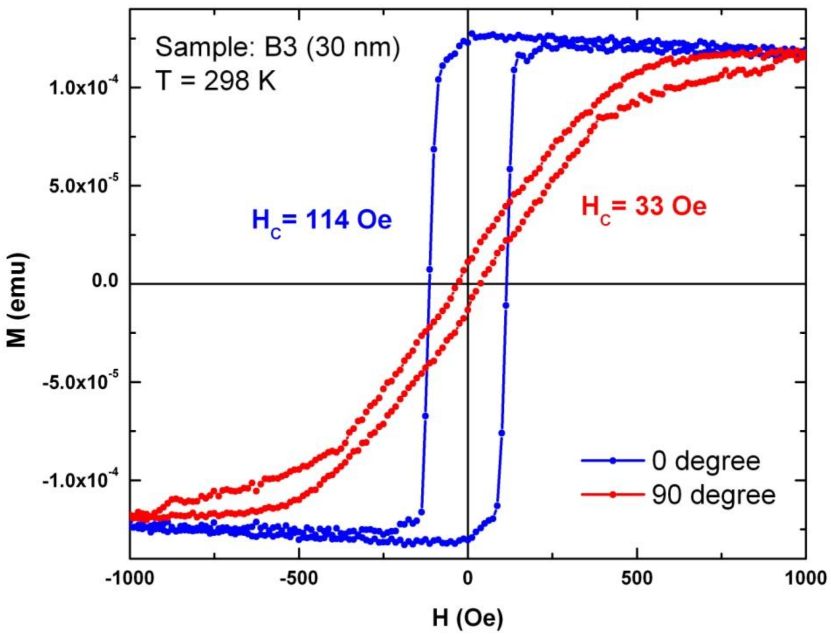


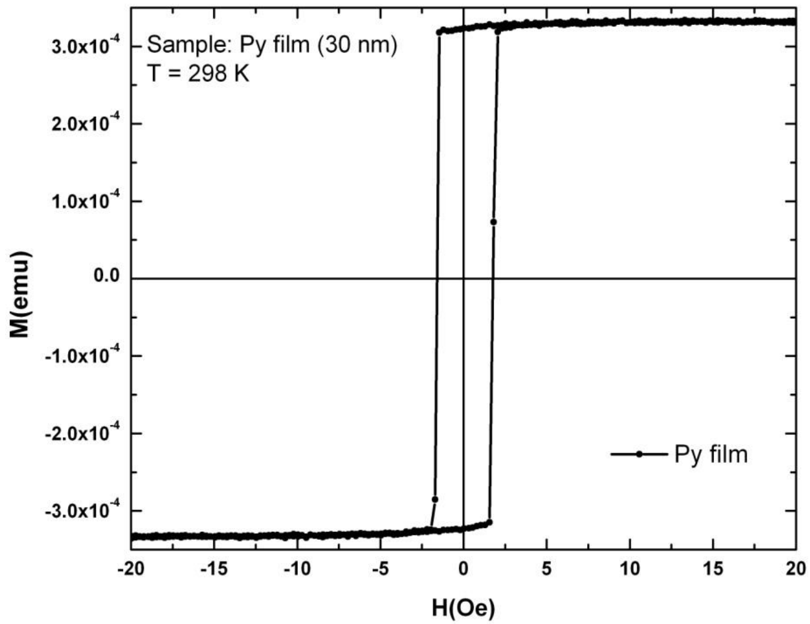
Magnetization loops for B3 patterned sample

Magnetic field in-plane for 0 and 90 degree orientations:



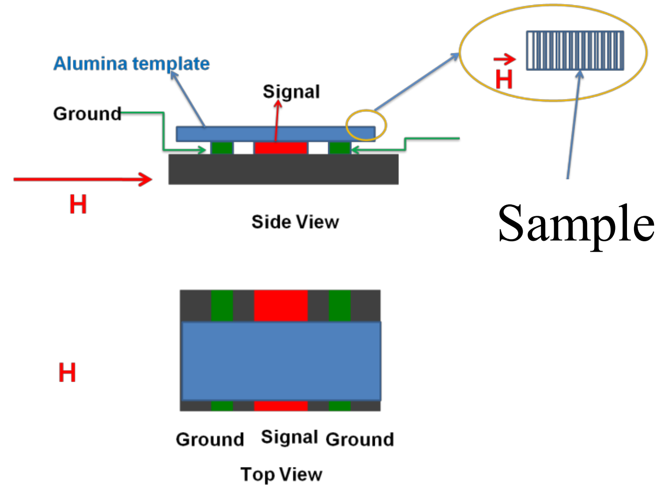




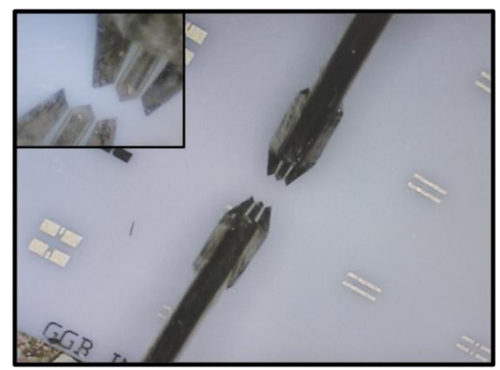


Broadband Ferromagnetic Resonance (FMR)

Experimental Setup: Frequency Range 1GHz – 24 GHz; H upto 3.5 kOe

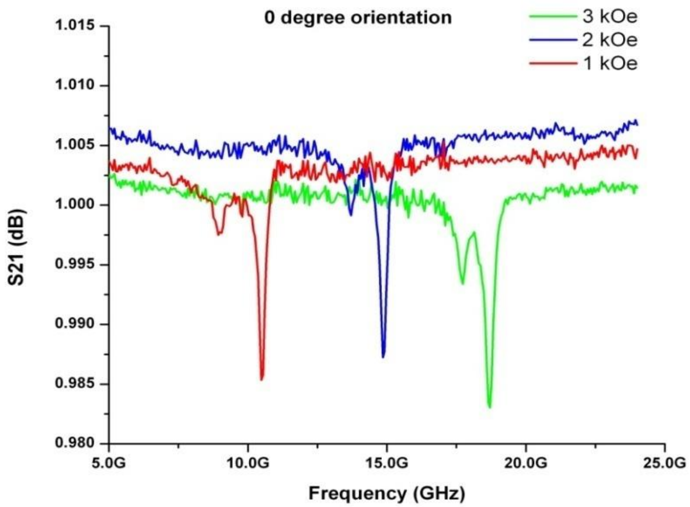


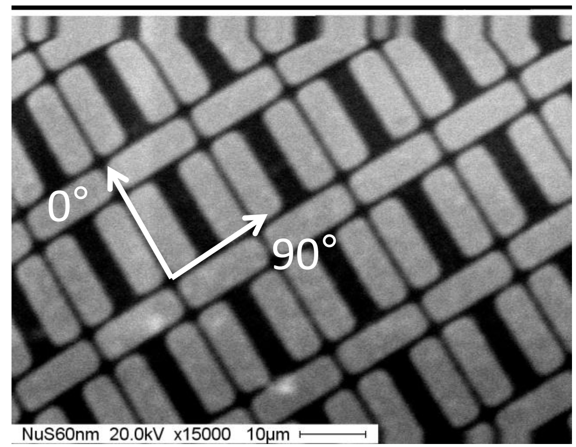
Coplanar Waveguide

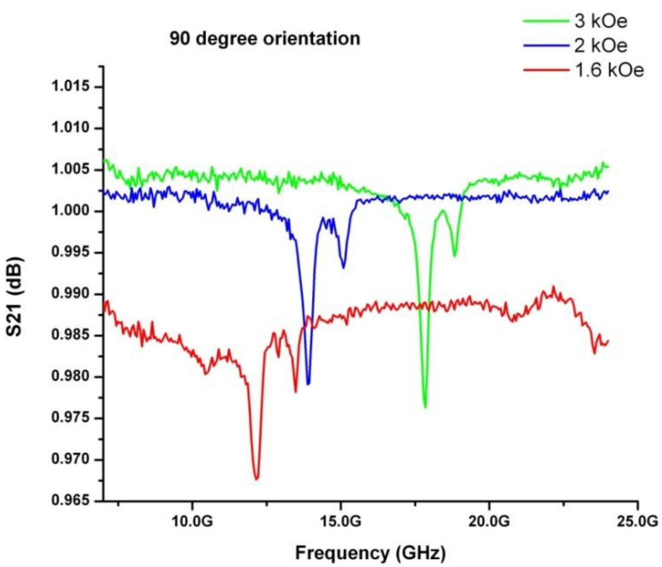


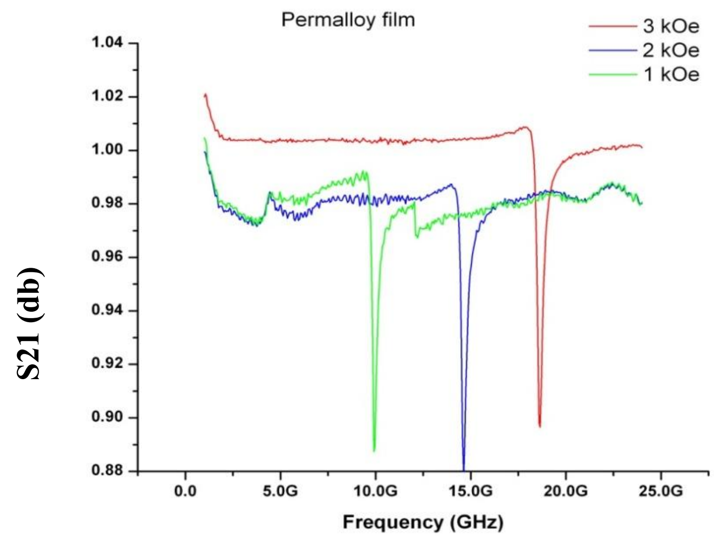
Microwave probe

FMR spectra of control sample and C-pattern of Py

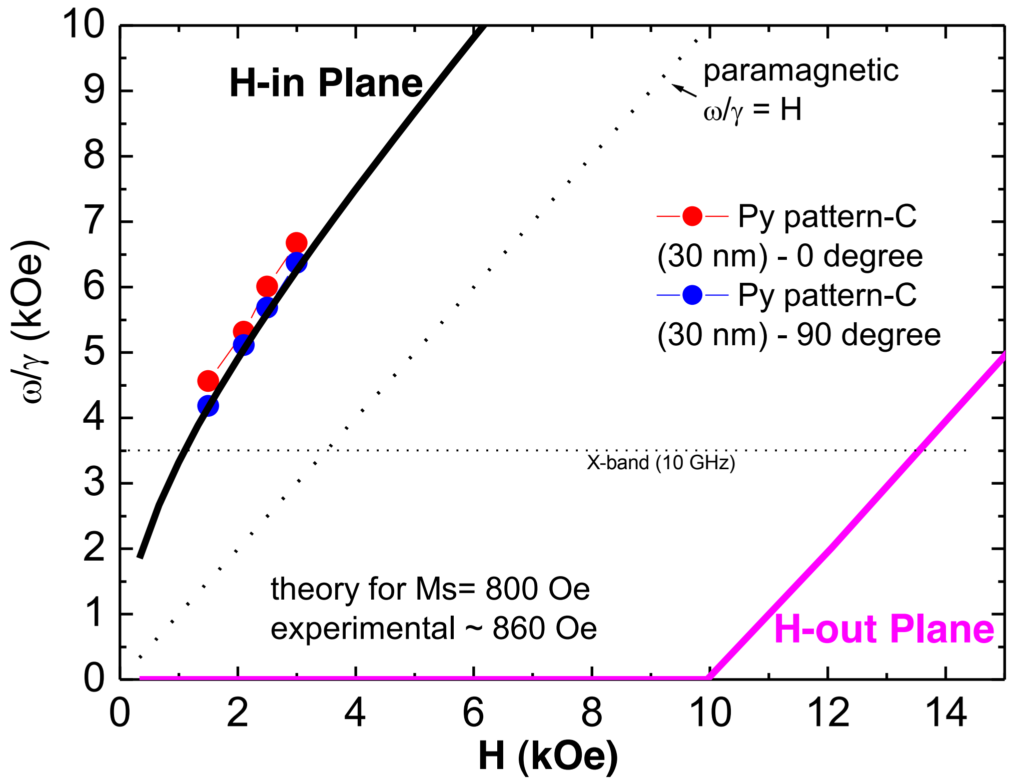


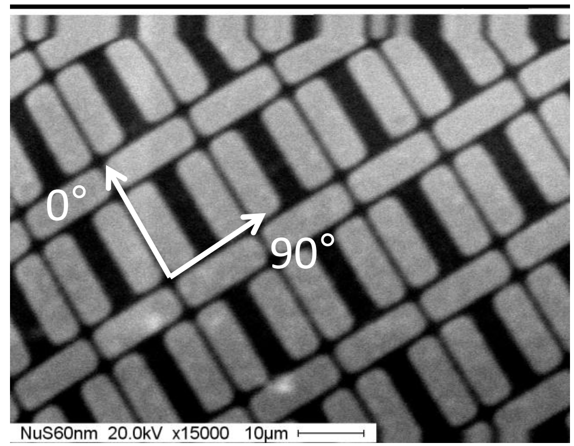






Resonance frequency as a function of the magnetic field for C pattern and control sample

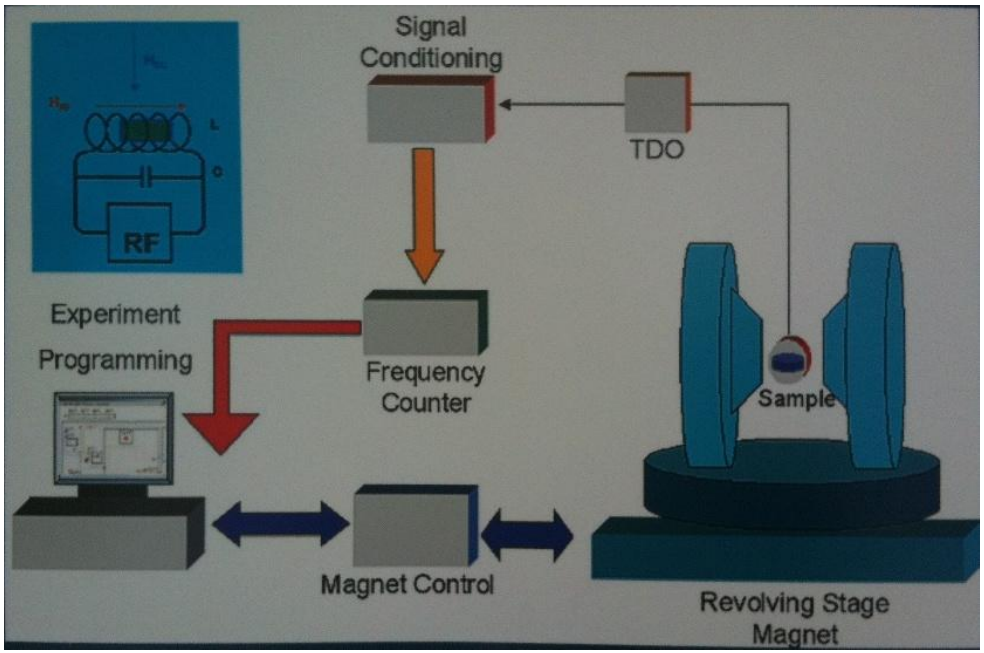


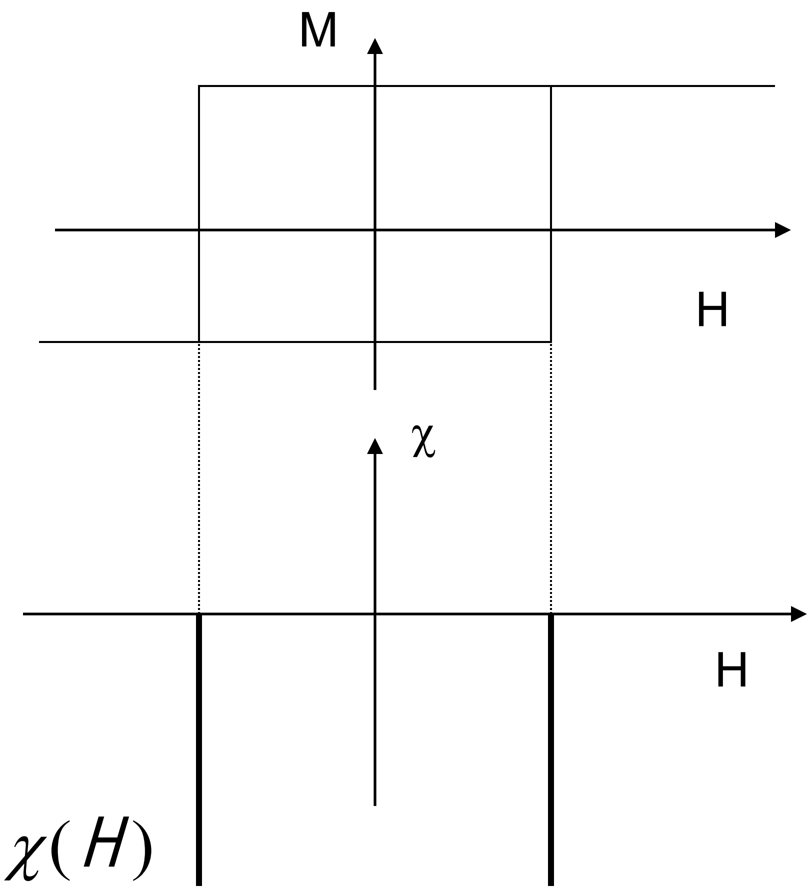


The continuous line correspond to the ideal ferromagnetic resonance field variation for a ideal Py film at 0° (field in plane) and 90° (field out of plane) degree orientation.

Critical Curve Experiment

The critical curves were measured by the method of reversible susceptibility, where the angular variation was conducted with magnetic field in plane.

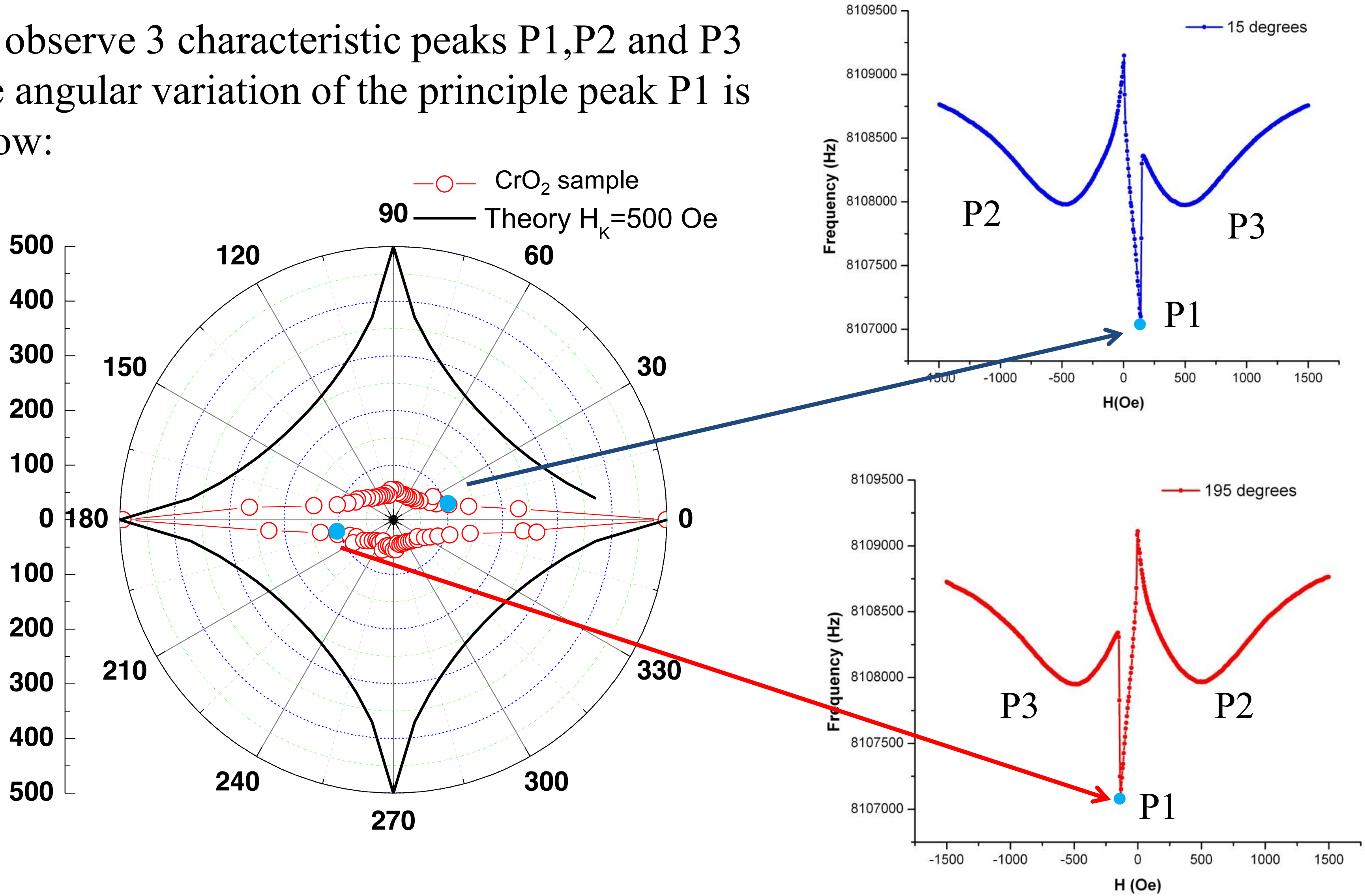




Frequency shift → $\dfrac{f - f_0}{f_0} \propto \chi(H)$

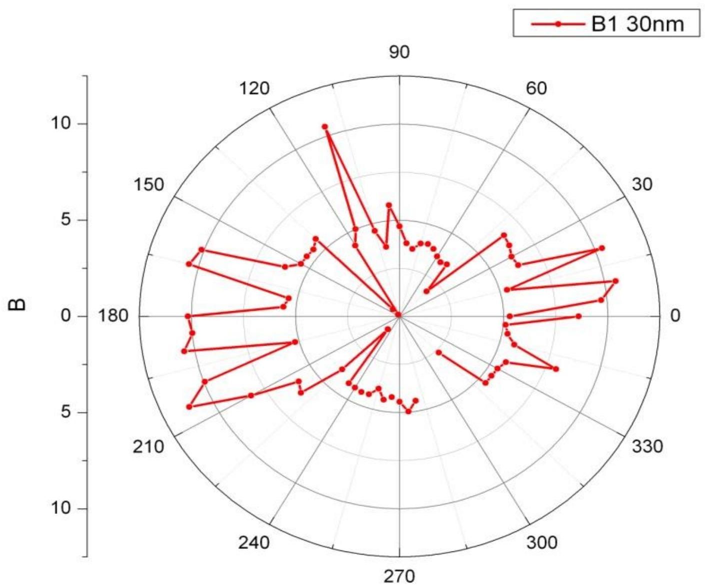
Critical Curves measurements of CrO_2 film sample

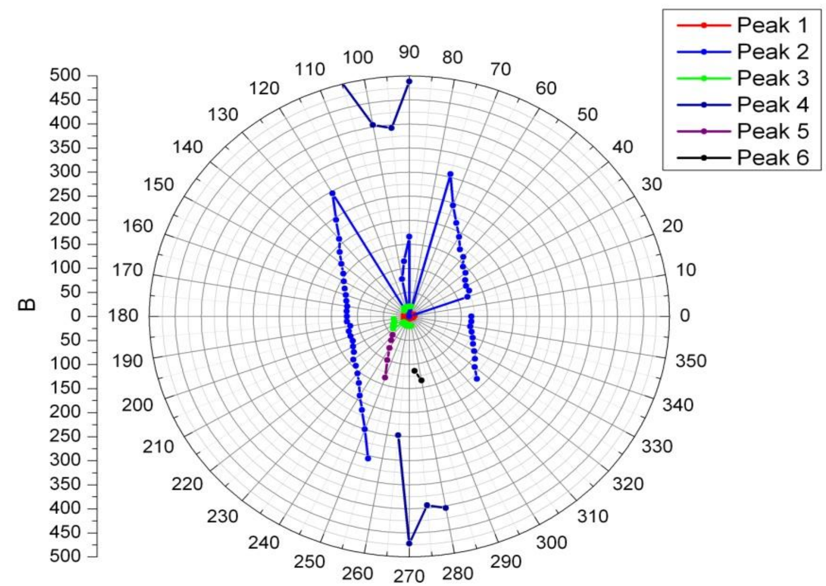
We observe 3 characteristic peaks P1,P2 and P3
The angular variation of the principle peak P1 is below:



Preliminary Results of Critical Curve of sample B1

Multiple peaks: We measured and followed the angular variation for the principal frequency shift peak and secondary peaks.





CONCLUSION

- From magnetization loop, we observe drastic change on shape, coercivity and irreversibility fields that can be correlated with the geometrical arrangements of Py cells.
- From the broadband FMR experiments, we observe two resonance absorption peaks where the angular variation shows strong correlation with the geometrical arrangements of the Py cells.
- From TDO experiments, we studied two different samples , the CrO_2 film control sample and B1 Py cell pattern. The first sample show the angular variation of the critical field is close to the theoretical curve. However, the second sample show different trend with multiple peaks which can be associated with the complex geometry.

REFERENCES

- [1] S. Jain, A. O. Adeyeye, and N. Singh, "Spin re-orientation in magnetostatically coupled Ni(80)Fe(20) ellipsoidal nanomagnets," *Nanotechnology,* vol. 21, Jul 2010.
- [2] L. Spinu, H. Pham, C. Radu, J. C. Denardin, I. Dumitru, M. Knobel, L. S. Dorneles, L. F. Schelp, and A. Stancu, "Probing two-dimensional magnetic switching in Co/SiO2 multilayers using reversible susceptibility experiments," *Applied Physics Letters,* vol. 86, p. 012506, Jan 3 2005.

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