BIO Web of Conferences **129**, 29016 (2024) https://doi.org/10.1051/bioconf/202412929016
EMC 2024

L-TEM characterization of controlled skyrmion nucleation in synthetic antiferromagnetic multilayers

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Background incl. aims

Skyrmions are circular magnetic textures whose topologically protected nature makes them great candidates for the development of novel information storage devices which are both power efficient and non-volatile [1]. Effective control of the skyrmion nucleation process is required for the development of such devices. Previous research has demonstrated how a focused ion beam (FIB) microscope can be used to engineer skyrmion nucleation sites in ferromagnetic multilayers by creating artificial point-life defects [2]. Such defects induce intermixing at the interfaces between the layers, which results in local modifications of the magnetic properties in this kind of samples where the strength of exchange interactions is highly correlated with the sharpness of the interfaces.

The present work builds on this research by applying this technique to a synthetic antiferromagnetic (SAF) multilayer sample. SAF multilayers are characterized by the presence of the RKKY interaction, which creates antiferromagnetic coupling between individual ferromagnetic layers. SAF skyrmions, which have been found to arise in such systems under specific field regimes, are characterised by minimal dipolar fields and are not susceptible to the skyrmion Hall effect. These properties make them more stable and better suited for spintronic applications than ferromagnetic skyrmions [3].

Methods

In this project, an array of point-like defects was irradiated on a SAF multilayer using the 10 nm probe (FWHM) of a Ga+ FIB. Defects were induced by a range of Ga+ ion doses, spanning from 10^{13} ions/cm^2 to 10^{18} ions/cm^2. The magnetic behaviour of the sample within the irradiated region was observed under Lorentz transmission electron microscopy (L-TEM) in the Fresnel mode, which allows for the direct visualization of magnetic textures. This led to the in-situ observation of the skyrmion nucleation and pinning behaviour in the presence of an external magnetic field. The magnetic behaviour of the sample outside of the skyrmion phase was also recorded.

Results

Nucleation and pinning of skyrmions were observed at the location of the defects. This behaviour was observed in the ferromagnetic regime of both sides of the hysteresis loop (Fig.1). We note that, in the non-irradiated state, skyrmion nucleation is only observed when starting from a saturated state, and only after the field had passed through zero.

Conclusion

The behaviour recorded in the irradiated areas of this SAF system differs from the behaviour recorded prior to irradiation. The field regime at which we observe skyrmion nucleation and pinning at the location of the artificial defects indicates that these skyrmions are likely to be ferromagnetic in nature in this initial study. The effects of FIB irradiation on the SAF phase of the sample are currently under investigation.

Graphic:

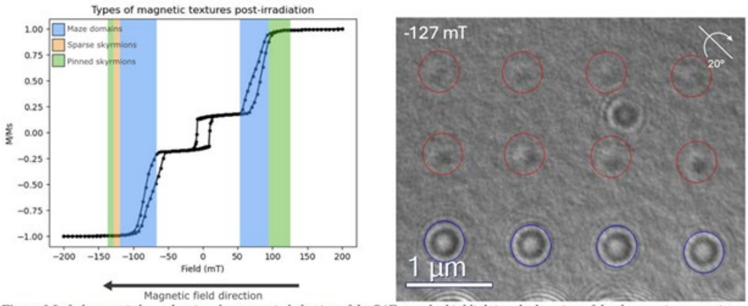

***Figure 1** Left: hysteresis loop showing the magnetic behavior of the SAF sample, highlighting the location of the three main magnetic textures observed in this study. Right: L-TEM image showing skyrmions pinned at the location of the artificial defects (circled in red). Some electrostatic contrast (circled in blue) can also be seen coming from a row of defects whose irradiation dose was high enough to cause surface damage.*

Keywords:

Magnetism, Skyrmions, L-TEM, Synthetic Antiferromagnets

Reference:

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