ESRF	Experiment title: **SXRMS imaging of magnetic properties in patterned structures**	**Experiment number**: HE-2827
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Aims of the experiment and scientific background

Recently, Eisebitt *et al.* [1] demonstrated the application of soft x-ray resonance magnetic scattering (SXRMS) in lenseless imaging of magnetic domains in CoPt films. In this experiment the sample was grown on a thin Si_3N_4 membrane and a special absorption mask was used to split the coherent beam into two parts: the imaged area and the reference pinhole [1,2]. The *reference* pinhole played an essential role in the experiment by assisting to retrieve the phase from the Fourier "image". Due to the transmission geometry, the main contrast of magnetic components lies in the axis parallel to the beam direction. XMCD from the in-plane components of the magnetization is zero. This restricts the application of the technique to only films with perpendicularly magnetized domains. However in many magnetic thin film materials (e.g. permalloy) the magnetization is in plane of the thin film due to shape anisotropy.

Experimental results

We proposed an alternative technique, which we believe can be used to apply the same principles of holographic imaging, but instead using in-plane geometry. We suggested performing a holographic experiment in reflection geometry. Figure 1 shows the experimental set-up and the design of the samples. There are two main aspects of the sample geometry. Firstly, the role of the reference pinhole is now played by a reference pin. The pin diameter (~100 nm) was chosen small enough to provide the required resolution of the image, and at the same time it had to provide good reflectivity. Secondly, both pin and imaged area need to provide sufficient intensity for the image. The rest of the sample had to be isolated from reflection. This was implemented by putting the imaged area and the pin on 50nm and 100nm thick "pedestals" of gold (or another highly reflective surface) and allow the rest of the beam to pass through the sample with minimum reflection. The latter was pursued by using a 200nm Si_3N_4 membrane as a substrate. The experiment was carried out in a standard diffraction chamber with an attached CCD camera. To obtain a coherent x-ray beam and restrict the footprint of

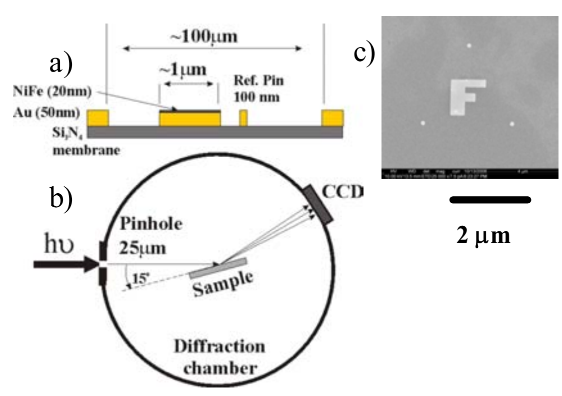

Fig.1. Sample diagram a) and an experimental arrangement b) for holographic imaging in reflection geometry (IDO8, ESRF). c) Sample. 100nm thick gold feature 'F' and three circular pins (100 nm) on 200nm SiN membrane.

the beam a several pinholes (20,10 and 5micron) were used on a separate translation stage within the chamber.

In order to locate the features we considered to use a set of markers (reflective lines) which would indicate the area of the feature. In the fabrication procedures we found however that the use of larger features was incompatible within the process we setup for smaller elements (such as pins and features). In the lift-off procedure the markers would be normally removed or only partially left due to insufficient undercut, and a relatively thick layer of gold. At the end it was decided to leave only features on the samples, and use the frame of the membrane as the coordinate reference. The drain current from the sample was used to track the topological modification in the surface (e.g. change of thickness on the boundary of the membrane). After a series of difficulties with the alignment of the beam and the positioning it (because of the faults with the translation stage) a number of diffraction images were obtained from the area of the sample where we expected the features to be located. In many cases the diffraction pattern includes an Airy pattern, which results from the pinhole before the sample. The Fast Fourier Transform of the images however have not showed the expected geometrical forms of the feature. The measurements were repeated for a larger (4 micron) feature with 300nm reflective pins with a similar effect. It was however observed that the diffraction pattern and its intensity varied as the sample was scanned around the position of the feature, having the indication that the alignment is correct. Some form of the pattern, although modified, could still be observed some distance away (larger than the size of the pinhole) from the feature, indicating a contribution of the background.

Conclusions

The background signal of the reflection coming from the areas surrounding the feature represents the main difficulty in the considered reflection geometry. In the transmission geometry this signal is cut off by the diaphragm mask grown directly on the sample. In reflection geometry such a mask (the pinhole) has to be positioned away from the sample, thus giving a larger footprint (extended by the inclined geometry) of the beam covering a large amount of the surrounding area of the feature. By our estimates (even with the smallest 5 micron pinhole) this area is several times exceeding the area of the feature. It was expected that the reflected background light would mostly be reflected in to the lower angles (specular reflection peak), however, it was found that there is also a significant rise in the background signal in the higher angles of scattering.

It is clear that in order to resolve the diffraction pattern from the features the background signal has to be isolated. There is a number of possibilities to achieve this. We consider the following ways that can be effective in our case. i) the thickness of the Si_3N_4 membrane can be reduced from to 50nm (the tests of EBL fabrication on such thin membranes have been already successfully carried out). ii**)** smaller pinholes (~5 micron) should be arranged as close as possible to the sample to reduce the footprint of the beam. Ideally the pinhole (diaphragm) should be placed directly on the sample, however in this case a care must be taken to avoid the reflection from the diaphragm (for instance, by inclining it); iii**)** some part of the membrane surrounding the feature can be cut-out (using FIB) to make the 'free-membrane' scattering area minimal. In this case the magnetic feature will be 'suspended' on the Si_3N_4 bridge, the beam size in transverse direction will be close to the size of the feature, the rest of the 'footprint' of the beam in longitudinal direction will be passing through the empty holes without reflection. In the following experiments we hope to implement the proposed modifications.

References

[1] S. Eisebitt, Nature, **432,** 885 (2004)
[2] O. Hellwig et al. J. Appl. Phys. **99** 08H307 (2006)