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Structure and Field Evolution of Magnetic Skyrmions in Co/Pt-Based Multilayers by In-Situ Electron Holography

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Room-temperature stable skyrmions are interesting candidates for future spintronic technology. A thorough understanding of their characteristics and the ability to manipulate these topological spin structures is crucial for their application in devices. Co/Pt-based multilayer systems offer a tunable platform to study magnetic skyrmions at room temperature [1]. However, there is an experimental challenge in resolving magnetic structures in such multilayer stacks with few stack repetitions approaching the ultrathin (1 nm) limit.

In previous studies, Lorentz-TEM imaging has frequently been used, as it is a relatively fast and uncomplicated technique, requiring no special preparation apart from the standard transmission electron microscope (TEM) requirements [2]. However, in order to image weak magnetic signals, large defocus values are needed, typically of the order of mm, limiting the spatial resolution attainable. For improved resolution, the use of an advanced phase imaging technique such as off-axis electron holography (EH) in the TEM, with high sensitivity and nanometre resolution, is essential [3]. While EH is more challenging for sample preparation, as it requires the observed specimen to be within close proximity to a vacuum or a reference area, it offers a resolution that is superior to the defocused images of Lorentz-TEM.

In this study, we will use aberration-corrected in-situ EH to present a quantitative characterisation of the fine magnetic structure of skyrmions in a Ir/Fe/Co/Pt multilayered sample with few-repetitions in the presence of magnetic fields. We will follow the formation and evolution of skyrmions in-situ as the applied field is varied to study their properties at a high resolution. We additionally aim to perform operando experiments to study skyrmion motion in a multilayer device by injection of an electric current in the TEM [4].

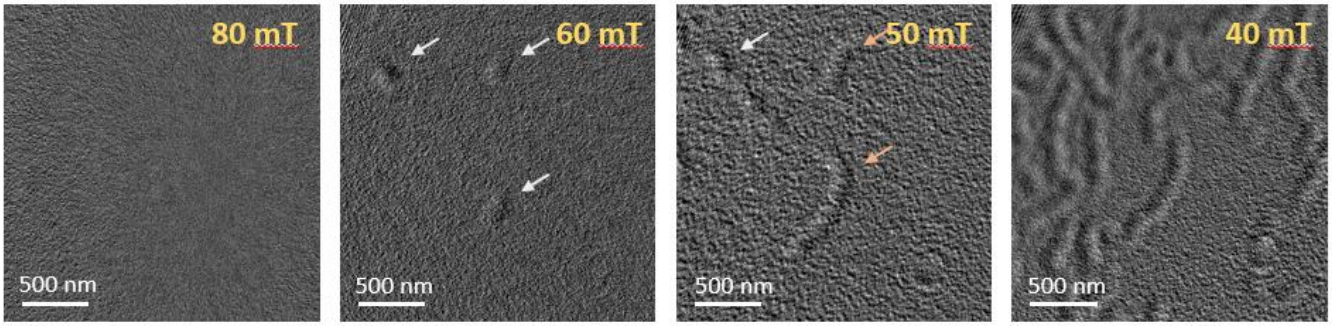

Figure 1. In-situ defocused Lorentz-TEM images of 5 repetition Ir/Fe/Co/Pt multilayered system under different magnetic field strengths. The system goes from a saturated state at 80 mT to the formation of skyrmions at 60 mT (arrowed), before turning into stripe domains (arrowed) as the field decreases further.

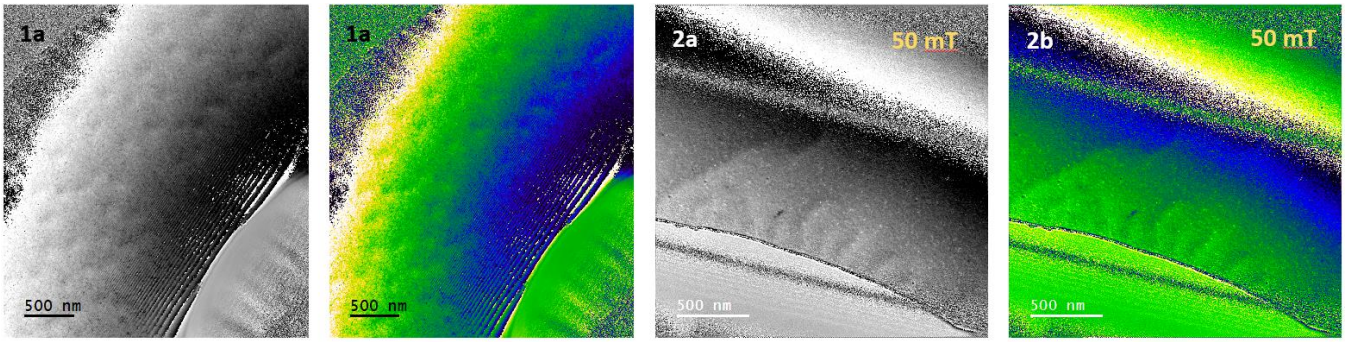

Figure 2. Reconstructed phase image (a show grayscale and b false-color) of similar samples obtained by low magnification electron holography showing multiple skyrmions in 1a-b, and stripe domains in 2a-b, next to a vacuum area in the bottom right corner and bottom left corners respectively. The false-color image clearly shows a color gradient from the sample to the vacuum area due to a change in sample thickness, showing the need for separating the electric and magnetic contribution of the phase shift from weak magnetic signals.

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