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In situ Lorentz Transmission Electron Microscopy of FeRh Thin Films

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Magnetic materials are crucial for various applications in modern technological devices. Magnetic phase transitions are one of the unique behaviors in a magnetic material, which is related to the structural and electronic phase changes and can be triggered by temperature, applied strain or magnetic fields. FeRh with roughly equiatomic composition is an interesting example exhibiting two magnetic phase transitions [1, 2]. It is anti-ferromagnetic at room temperature but above a critical higher temperature (~77 ºC) becomes ferromagnetic before its Curies temperature transition to a paramagnetic (~402 ºC) state [3]. The near room temperature AF-FM magnetic phase transition in FeRh is reversible and accompanied by an isotropic lattice expansion and an increase in resistivity. For modern device applications epitaxially grown FeRh thin films on different substrates have been fabricated to study their magnetic transition properties. However, the underlying fundamental dynamics of the magnetic transition under the effect of magnetic field or as a function of temperature are not yet very well understood. There are a few techniques appropriate for *in situ* dynamic studies of the magnetization behavior namely, X-ray microscopy, photoemission electron microscopy, Kerr microscopy, magnetic force microscopy, and scanning and transmission electron microscopy (TEM) [4]. Among these techniques TEM provides the highest spatial resolution (below 10 nm). *In situ* TEM in Lorentz mode would provide qualitative information on the magnetic domain wall structure and shape. In addition, it is possible to acquire quantitative information by performing differential phase contrast (DPC) analysis in scanning TEM (STEM) mode. The main advantage of this method is the possibility of local analysis of crystal structure in high resolution (HR) TEM mode and then correlating it to the observed magnetic properties. In this work, we have investigated the dynamics of the AF-FM magnetic transition using *in situ* Lorentz TEM using a Gatan heating holder in an aberration-corrected TEM (FEI Titan 80-300 kV). Measurements were carried out as a function of temperature and by performing *in situ* magnetization inside the microscope using the magnetic field induced by the objective lens of the TEM. Furthermore, the FeRh crystal structure was analyzed by HR-TEM (Figure 1) and the effect of crystal defects on the magnetization behavior of the FeRh thin films were studied. Our results give new perspectives in understanding the correlation of crystal structure with formation and evolution of magnetic domains [5].

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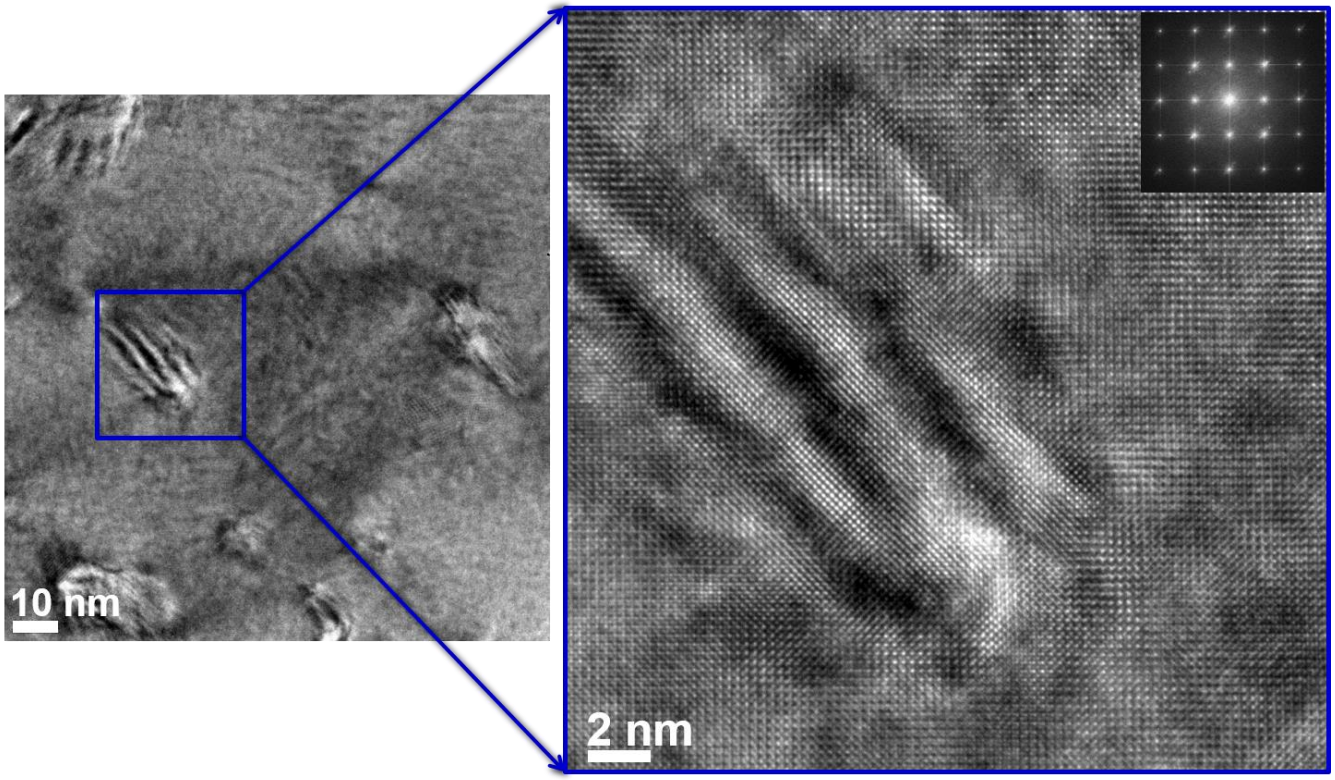

Figure 1. HR-TEM images of FeRh thin film. Inset in the magnified image is the Fast Fourier Transform (FFT) of the image.

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