In situ Heating Lorentz TEM of FeRh Thin Films

Gorji, M.S.[1], Wang, D.[2], Witte, R.[2], Mu, X.[2], Kruk, R.[2], Kübel, C.[2], Hahn, H.[2,3] and Kübel, C.[2]

[1] Karlsruhe Institute of Technology (KIT), Germany, [2] Karlsruhe Institute of Technology (KIT), Germany, [3] Technische Universität Darmstadt (TUD), Germany

Magnetic phase transitions in a magnetic material involve structural and electronic phase changes and can be triggered by temperature, applied strain or magnetic fields. Iron-rhodium (FeRh) with nearly equiatomic composition is an interesting example exhibiting two magnetic phase transitions. At room temperature it is anti-ferromagnetic but above a critical higher temperature (~77 ºC) it becomes ferromagnetic through a first-order transition [1, 2]. Above the Curies temperature of ~402 ºC it transforms to a paramagnetic state [3]. The AF-FM magnetic phase transition in FeRh is reversible and accompanied by an isotropic lattice expansion and an increase in resistivity. Although there have been some studies on the AF-FM magnetic transition properties of FeRh, the underlying fundamental dynamics of this transition under the effect of magnetic field or as a function of temperature are not yet very well understood. Here we used an aberration-corrected transmission electron microscope (TEM) at 300 kV to investigate the dynamics of the AF-FM magnetic transition using a Gatan heating holder. 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. *In situ* TEM in Lorentz mode (Fig. 1) was used to provide qualitative information on the magnetic domain wall structure, shape, and propagation. In addition, to acquire quantitative information, differential phase contrast (DPC) analysis was performed in scanning TEM (STEM) mode. The crystal structure was analyzed in high resolution (HR) TEM mode (Fig. 2) and then correlated to the observed magnetic properties of FeRh thin films. Our results give new insight in understanding the correlation of crystal structure with formation and evolution of magnetic domains and propagation of magnetic domain walls.

References:

[1] Ralf Witte *et al.*, *Physical Review B*, No. 93 (*2016*), 104416.

[2] Ralf Witte *et al.*, *Journal of Physics D*, No. 50 (2017), 025007.

[3] J. S. Kouvel, and C. C. Hartelius. *Journal of Applied Physics 33*, No. 3 (1962), 1343-1344.

M.S. Gorji gratefully acknowledges the financial supported given under the DAAD Doctoral Scholarship.

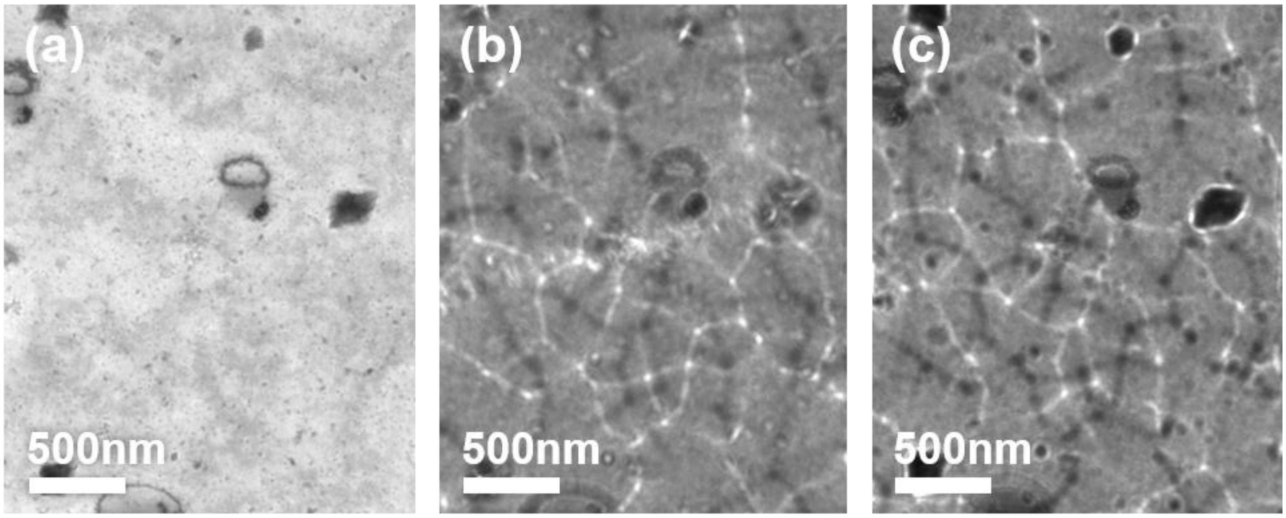

Figure 1. *In situ* Lorentz TEM images of FeRh thin film with the sample in-focus (a), over-focus (b), and under-focus (c). The bright and dark lines in (b) and (c) represent magnetic domain walls.

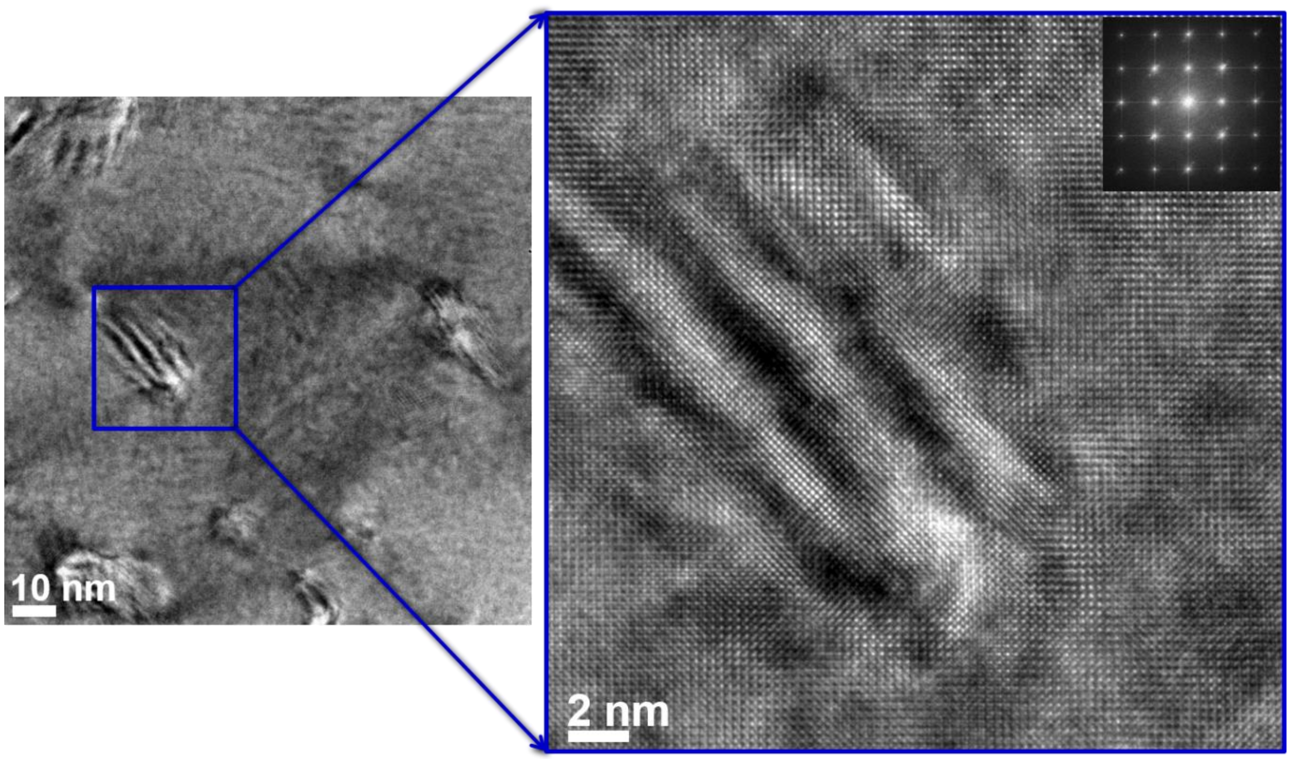

Figure 2. HR-TEM images of FeRh thin film. Inset in the magnified image is the Fast Fourier Transform (FFT) of the image.