doi:10.1017/S1431927616008424
Microsc. Microanal. 22 (Suppl 3), 2016

High Resolution STEM Study of Dy-doped Bi_2Te_3 Thin Films

Vesna Srot[1], Piet Schönherr[2], Birgit Bussmann[1], Sara E. Harrison[2,3], Peter A. van Aken[1] and Thorsten Hesjedal[2]

[1.] Stuttgart Center for Electron Microscopy, Max Planck Institute for Solid State Research, Stuttgart, Germany.
[2.] Department of Physics, Clarendon Laboratory, University of Oxford, Oxford, United Kingdom.
[3.] Department of Electrical Engineering, Stanford University, Stanford, USA.

Breaking the time-reversal symmetry (TRS) in three-dimensional (3D) topological insulators (TIs) is essential for unlocking exotic physical states and exploring potential device application. Doping of the prototypical 3D-TI [1,2] Bi_2Te_3 with transition metal ions can lead to ferromagnetic ordering at low temperatures [3,4]. Here we report the study of incorporation of dysprosium (Dy) into Bi_2Te_3 with the intent to achieve higher ferromagnetic ordering temperatures and higher magnetic moments [5].

Dy-doped thin films were grown on c-plane sapphire substrates by molecular beam epitaxy (MBE) [6]. High-quality samples with a Dy concentration of $x \leq 0.113$ were selected for high-angle annular dark field (HAADF) scanning transmission electron microscopy (STEM) and energy-dispersive X-ray spectroscopy (EDX-) STEM investigations [5]. The $(Dy_{0.113}Bi_{0.887})_2Te_3$ film was carefully delaminated from the substrate using a droplet of glue. Next, thin TEM lamellae were cut out of the delaminated films in cross-sectional geometry using an ultramicrotome. Thin sections were obtained using an oscillating water-filled diamond knife to cut approximately 40 nm thick slices that were captured on Cu grids covered with a lacey carbon film.

Low-magnification HAADF-STEM images of the high crystallinity $(Dy_{0.113}Bi_{0.887})_2Te_3$ thin films acquired at 60 kV are shown in Figure 1. The characteristic crystal structure formed by the stacked quintuple layers separated by the van der Waals gaps is clearly visible. A higher magnified HAADF-STEM image with the overlaid structural model is presented in Figure 2a. EDX line-scans were acquired traversing the van der Waals gap between the adjacent quintuple layers (see arrow in Fig. 2a). The corresponding intensity profiles of Bi-M, Te-L and Dy-L X-ray emission lines along the arrow shown in Figure 2a are presented in Figure 2b. The intensity of the Dy-L signal is exactly following the Bi-M signal, indicating the substitutional incorporation of Dy atoms on Bi sites and the absence of Dy in the van der Waals gaps. Our measurements show no evidence for cluster formation or local phase segregations [7].

References:
[1] CL Kane and EJ Mele, *Phys Rev Lett* **95** (2005), 146802.
[2] BA Barnevig et al., *Science* **314** (2006), 1757.
[3] J Choi et al., *Phys Stat Sol (b)* **241** (2004), 1541.
[4] Y Chen et al., *Science* **329** (2010), 659.
[5] SE Harrison et al., *Sci Rep* **5** (2015), 15767.
[6] SE Harrison et al., *J Phys: Condens Matter* **27** (2015), 245602.
[7] The research leading to these results has received funding from the European Union Seventh Framework Program [FP/2007-2013] under grant agreement No. 312483 (ESTEEM2).

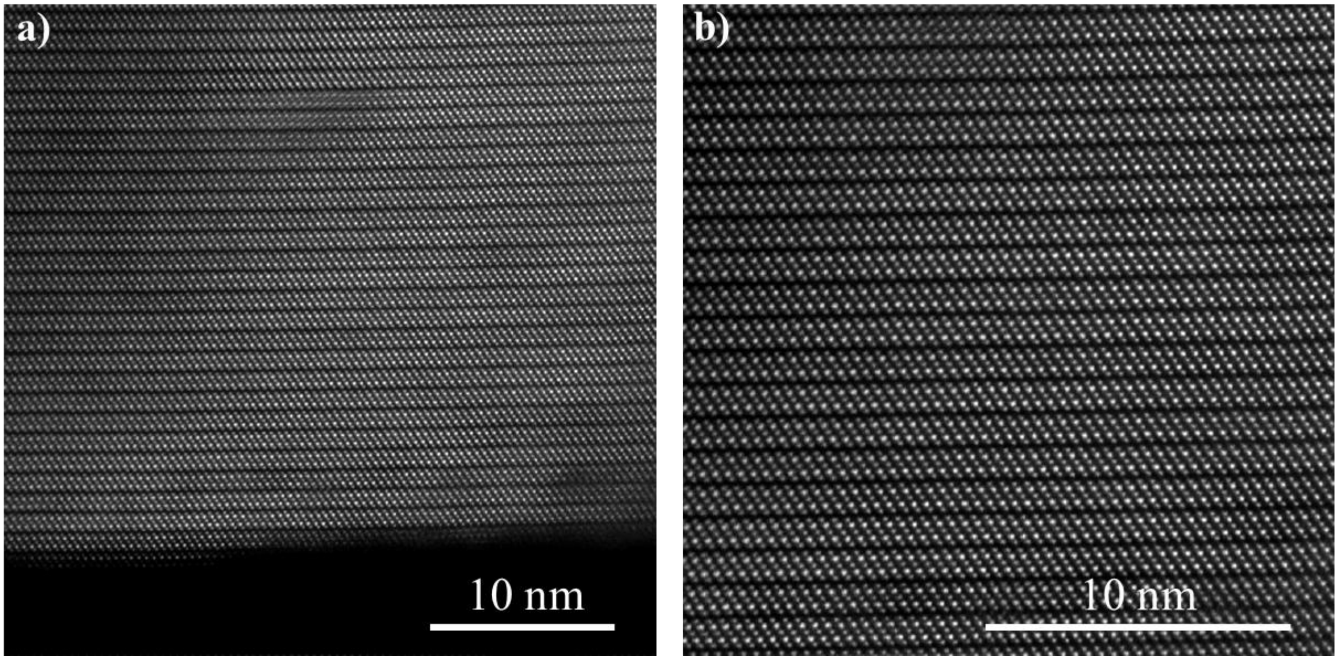

Figure 1. (a,b) Low-magnification HAADF-STEM images of the $(Dy_{0.113}Bi_{0.887})_2Te_3$ thin film.

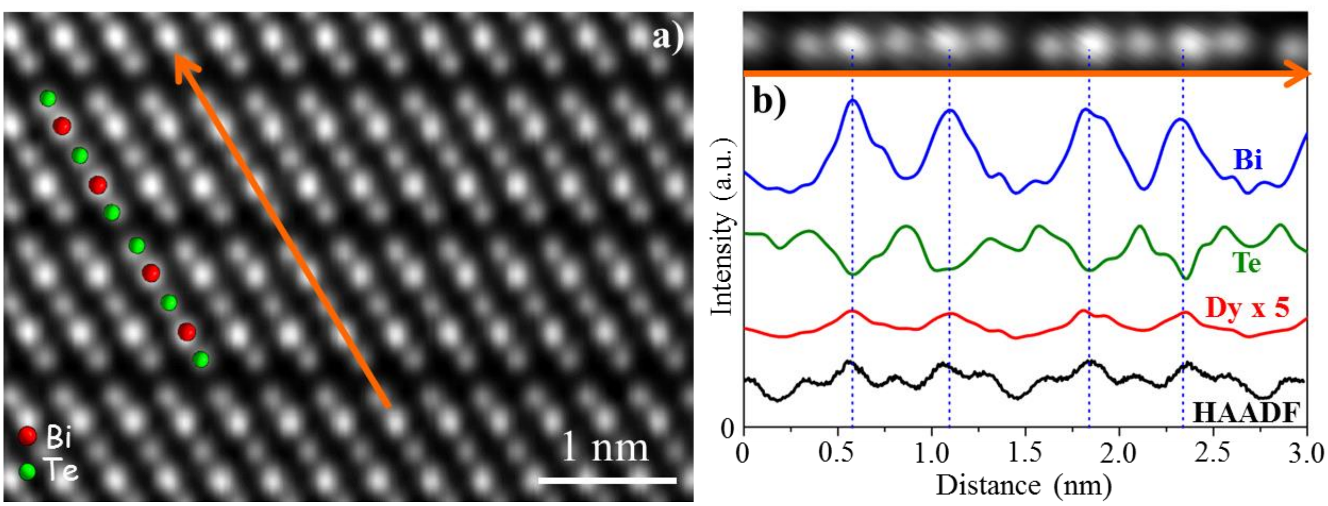

Figure 2. (a) HAADF-STEM image of $(Dy_{0.113}Bi_{0.887})_2Te_3$ thin film with marked position of measured EDX line-scan (orange arrow). (b) Corresponding EDX profiles of Bi-M (blue), Te-L (green) and Dy-L (red) X-ray emission intensities along the EDX line-scan plotted together with HAADF-STEM intensity profile (black).

https://doi.org/10.1017/S1431927616008424 Published online by Cambridge University Press