

Analytical STEM Study of Dy-doped Bi₂Te₃ Thin Films

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Abstract

Breaking the time-reversal symmetry (TRS) in three-dimensional (3D) topological insulators (TIs) [1,2] is crucial for unlocking exotic physical states and exploring possible device application. Doping the prototypical 3D-TI Bi₂Te₃ with transition metal ions can lead to ferromagnetic ordering at low temperatures [3,4]. We present the study of incorporation of dysprosium (Dy) into Bi₂Te₃ 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]. 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]. A (Dy_{0.113}Bi_{0.887})₂Te₃ film was carefully detached from the substrate using a droplet of glue, and thin TEM lamellae were cut 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.

A high crystallinity (Dy_{0.113}Bi_{0.887})₂Te₃ thin film acquired at 60 kV is shown in an HAADF-STEM image in Figure 1. The characteristic crystal structure consisting of stacked quintuple layers separated by van der Waals gaps is clearly recognizable. A higher magnification 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 (in Figure 2a) are presented in Figure 2b. The intensity of the Dy-L signal is precisely 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. No evidence for cluster formation or local phase segregations could be detected [7].

Figures

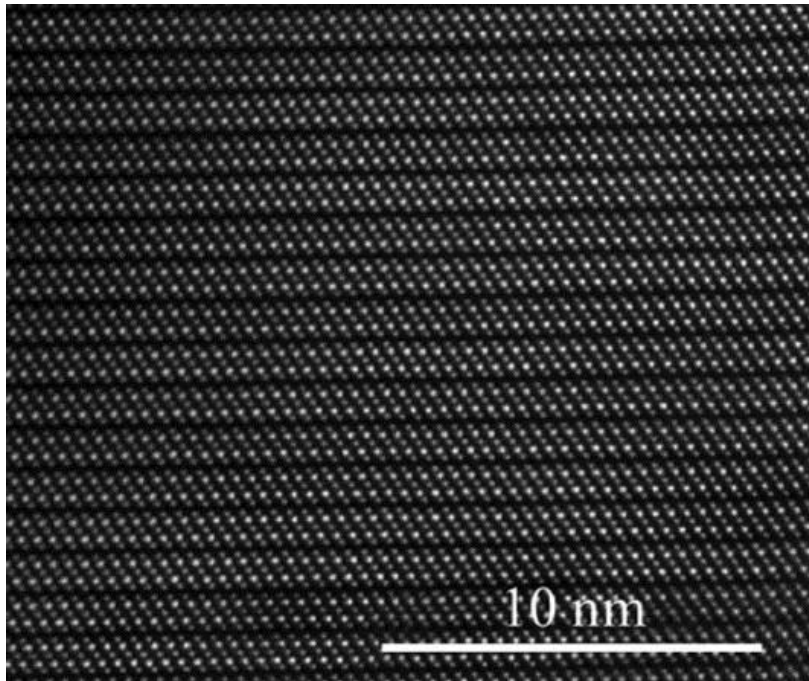


Figure 1 : HAADF-STEM image of the $(\text{Dy}_{0.113}\text{Bi}_{0.887})_2\text{Te}_3$ thin film.

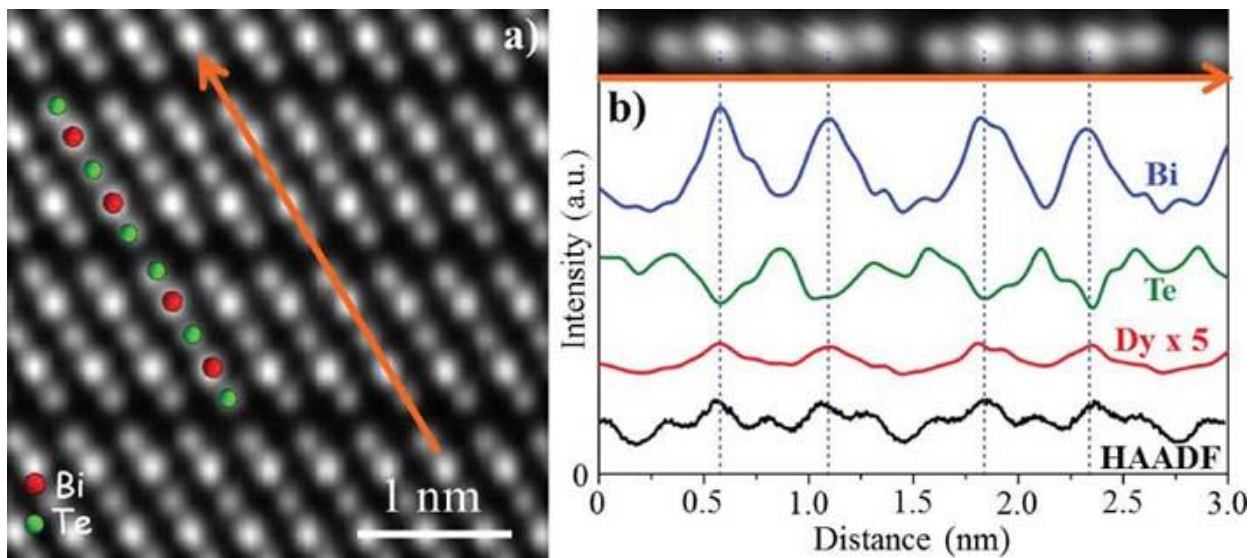


Figure 2: (a) HAADF-STEM image of high crystallinity $(\text{Dy}_{0.113}\text{Bi}_{0.887})_2\text{Te}_3$ thin film with marked position of measured EDX line-scan (orange arrow). (b) Corresponding EDX profiles of Bi-M (blue), Te-L (green) and Dy-L (red) X-ray emission intensities measured along the EDX line-scan and plotted together with HAADF-STEM intensity profile (black).

References

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