Crystal Growth and Evaluation of BiSb Topological Insulator by Sputter Deposition

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BiSb topological insulator is a promising candidate for spin-orbit torque (SOT) magnetoresistive random-access memory (MRAM), due to its giant spin Hall effect (spin Hall angle $\theta_{SH} \cong 52$) [1, 2] and high electrical conductivity [3] at room temperature. However, high quality single crystalline BiSb thin films have been obtained only by molecular beam epitaxy (MBE), which is not used in MRAM manufacturing. In this work, we investigated the characteristics of BiSb thin films fabricated by radio frequency (RF) magnetron sputtering on sapphire substrates. We show that the sputtered BiSb thin films have relatively good crystal quality and high electrical conductivity, which are promising for MRAM applications.

We fabricated $Bi_{0.85}Sb_{0.15}$ thin films of thicknesses 10 nm, 30 nm and 50 nm on sapphire (0001) substrates. Before sputter deposition, we cleaned the sapphire substrates by chemical etching in hot phosphoric acid and sulfuric acid solution and thermal annealing at 850°C in vacuum. The growth conditions, such as the substrate temperature, growth pressure, and RF power, were optimized for BiSb of different thicknesses. Figure 1 shows the X-ray diffraction spectra of sputtered BiSb thin films, indicating that it is possible to obtain BiSb with strong (001) orientation when the thickness is over 30 nm. The electrical conductivity of the BiSb thin films exceeds $10^5\ \Omega^{-1}\mathrm{m}^{-1}$ at room temperature. Figure 2 shows the temperature dependence of the normalized resistivity, which demonstrates the existence of surface states in sputtered BiSb thin films [2, 3]. Using the parallel conduction model of bulk and surface states, we estimate that the band gaps of the 50 nm and 30 nm BiSb thin films are 132 meV and 137 meV, respectively. Furthermore, the surface conductivity remains as high as that of MBE-grown BiSb. Our results show that it is possible to obtain high quality BiSb topological thin films by sputtering for MRAM applications. **Acknowledgment:** this work is supported by JST-CREST (JPMJCR18T5). **References:** [1] N. H. D. Khang *et al.*, Nat. Mater. 17, 808 (2018). [2] T. Shirokura *et al.*, preprint at arXiv: 1810.10840. [3] Y. Ueda *et al.*, Appl. Phys. Lett. 110, 062401 (2017).

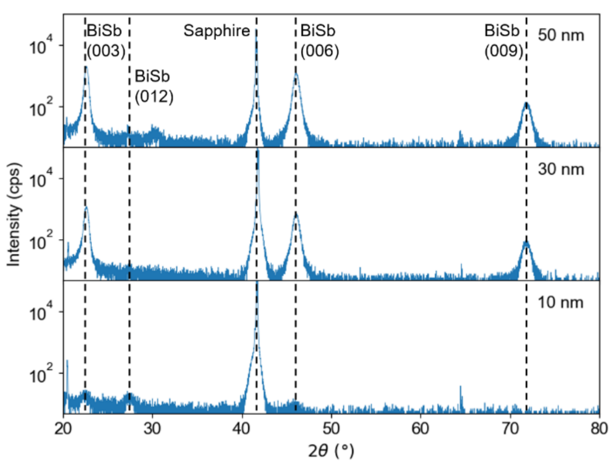

Fig. 1. X-ray diffraction spectra of the sputtered BiSb thin films of 50 nm, 30 nm, and 10 nm.

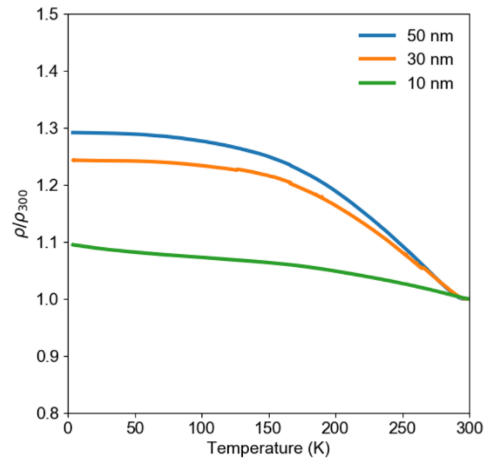

Fig. 2. Temperature dependence of the normalized resistivity of the sputtered BiSb thin films.