Current-induced switching in epitaxial Mn_3Sn thin films: A temperature dependent study

K. Nihei[1,2], T. Uchimura[1,2], J. Han[1,3], S. Kanai[1–7], H. Ohno[1–4,8], and S. Fukami[1–4,8,9]
RIEC, Tohoku Univ.[1], Graduate School of Engineering, Tohoku Univ.[2], AIMR, Tohoku Univ.[3], CSIS, Tohoku Univ.[4], PRESTO, JST[5], DEFS, Tohoku Univ.[6], QST[7], CIES, Tohoku Univ.[8], InaRIS[9]
Presenter e-mail: nihei.kota.s3@dc.tohoku.ac.jp

Current-induced spin-orbit torques (SOTs) offer an efficient mechanism to switch the non-collinear antiferromagnetic order in Mn_3Sn [1]. While the switching experiments in epitaxial Mn_3Sn films can be consistently understood by the SOT-driven spin dynamics [2–4], some studies with polycrystalline Mn_3Sn films reveal a significant role of Joule heating [5–7], suggesting that the switching process involves a step that heats the sample close to or above the Néel temperature (T_N) of Mn_3Sn [5].

Here we evaluate the role of SOT and Joule heating from the temperature (T) dependence of current-induced switching in the $(10\bar{1}0)$-oriented epitaxial Mn_3Sn adjacent to heavy metal W/Ta (Fig. 1a). From the switching loops (Fig. 1b), we extract the switching current I_{sw} at different T (red dots in Fig. 1c). By comparing the sample resistance as functions of T and current, we calibrate the current-induced temperature rise and, accordingly, determine I ($T \rightarrow T_N$), the threshold current that heats the sample to the Néel temperature (black dots in Fig. 1c). We find that I_{sw} is well below I ($T \rightarrow T_N$) at 140~300 K, indicating that the sample maintains the non-collinear antiferromagnetic order during the switching. Our results suggest the persistent role of SOT and less dominant role of Joule heating in epitaxial Mn_3Sn films than polycrystalline samples.

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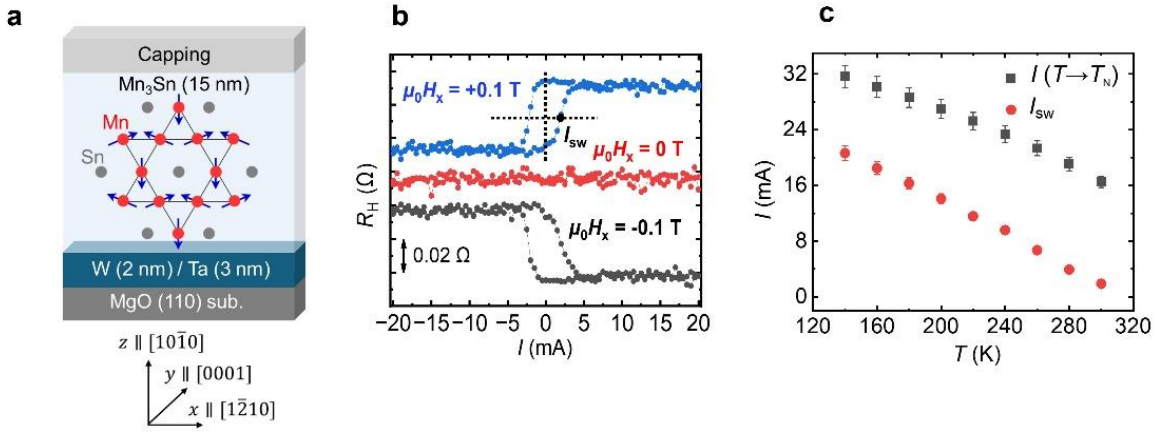

Fig. 1. (a) Sample structure. (b) Hall resistance R_H as a function of the applied pulse current under different magnetic fields at 300 K. The current and the magnetic field are along the x axis. (c) Temperature dependence of the switching current I_{sw} and the current that heats the sample to the Néel temperature, I ($T \rightarrow T_N$).

References

[1] Tsai, et al. *Nature* **580,** 608 (2020). [2] Y. Takeuchi, et al. *Nat. Mater.* 20, 1364 (2021). [3] T. Higo, et al. *Nature* **607,** 474 (2022). [4] J.-Y. Yoon, et al. *Nat. Mater.* **22,** 1106 (2023). [5] B. Pal, et al. *Sci. Adv.* **8**, eabo5930 (2022). [6] G. Krishnaswamy, et al. *Phys. Rev. Appl.* **18,** 024064 (2022). [7] M.-W. Yoo, et al. *APL Mater.* **12,** 081107 (2024).