Origin of anisotropic spin current generation in collinear antiferromagnetic RuO_2

Department of Materials Science[1], Center for Spintronics Research Network[2], Center for Science and Innovation in Spintronics (Core Research Cluster) Organization for Advanced Studies [3], Frontier Research in Duo (FRiD)[4], Tohoku Univ.

○Shutaro Karube[1,2], Naohiro Kadoguchi[1], Daichi Sugawara[1], Makoto Kohda[1,2,3,4] and Junsaku Nitta[1,2,3], E-mail: karube@material.tohoku.ac.jp

Electronic topology in antiferromagnetic (AFM) materials even without spin-orbit interaction (SOI) plays an important role for spin accumulation and/or spin current generation. Recently a novel effect called as magnetic spin Hall effect (MSHE) has been discovered in non-collinear AFM Weyl semimetal Mn_3Sn [M. Kimata *et al*, *Nature* **565**, 627 (2019)]. An efficiency of the spin current generation depends on the Néel vector direction especially the sign in this Mn_3Sn case. It is expected that the MSHE opens a new avenue both for fundamental physics and application on spintronics. In this study, we focus on a simple collinear AFM RuO_2 with rutile structure to understand the origin of spin current generation which is governed either by the topology such as Dirac nodal line or by the AFM order.

We fabricated epitaxial RuO_2 (101) and (100) films by means of rf magnetron sputtering using single crystalline sapphire substrates with optimized annealing temperatures. As shown in Fig. (a), We observed the single peak around 35° in X-ray diffraction and streak pattern after the 5 nm sputtering in reflection high energy electron diffraction, confirming the epitaxial RuO_2 (101) phase. Further we employed the harmonic Hall measurement to evaluate both damping-like (DL) and field-like torque. Surprisingly, for RuO_2 (101) film, we found the anisotropy of the DL torque depending on applied current direction along to the in-plane crystal direction as shown in Fig. (b). This anisotropy seems to be originated from the Néel vector direction because the vector is canted like Fig. (c) as for the RuO_2 (101). For further verification on the origin of the induced anisotropy in DL torque, we compare the angle dependence of DL torque in RuO_2(100) films which has perpendicular Néel vector (Fig. (c)).

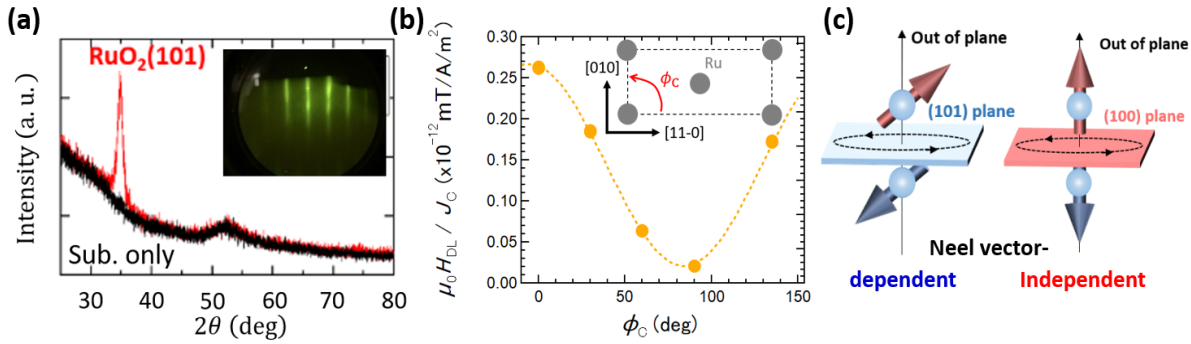

Figure (a) X-ray diffraction pattern and reflection high energy electron diffraction image in-situ for RuO_2(101).
(b) DL spin-orbit field as a function of current direction along to the crystal angle ϕ_C.
(c) Néel vector configuration on (101) and (100) crystal plane and schematic image for the ϕ_C scan.