Unconventional spin Hall magnetoresistance in a non-collinear antiferromagnet/heavy metal heterostructure

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The spin Hall magnetoresistance (SMR) in antiferromagnet/heavy metal (AFM/HM) heterostructures helps to understand the interaction between spin current and the antiferromagnetic order [1,2]. Here we present a combined experimental and theoretical study that reveals an unconventional SMR in a non-collinear AFM/HM heterostructure.

We deposited stacks of Ru (5 nm)/Mn_3Sn (15 nm)/Pt (5 nm) on MgO(111) substrates by sputtering, followed by annealing at 500 °C. This procedure leads to the formation of (0001)-oriented epitaxial Mn_3Sn thin film in which the non-collinear spin structure aligns in the film plane [Fig. 1(a)].

Figure 1(b) shows the magnetoresistance (MR) ratio ($= [R(\theta_{xy}) - R(\theta_{xy} = 0°)]/R(\theta_{xy} = 0°)$) under an in-plane rotating magnetic field of 9 T, where R denotes the longitudinal resistance. The MR reaches its maximum (minimum) when the field is parallel (perpendicular) to the current direction, similar to the SMR in ferromagnets [3] but phase-shifted by 90° compared to that in collinear AFMs [1,2]. We find that the conventional SMR theory that focuses on the *damping-like* spin-transfer torque [1,2,4] fails to reproduce the measured angle dependence of Fig. 1(b). Instead, the obtained angle dependence can be explained by a Boltzmann transport theory considering the *field-like* torque, i.e., a conduction electron spin precession around the interface exchange fields of the local magnetic moments. These results can be attributed to the ineffective action of *damping-like* torque on non-collinear spin textures in the studied configuration, leading to the emergence of a previously ignored *field-like* torque as the dominant origin of SMR. The unraveled physics provides a new insight to engineer spintronic devices based on AFMs [5].

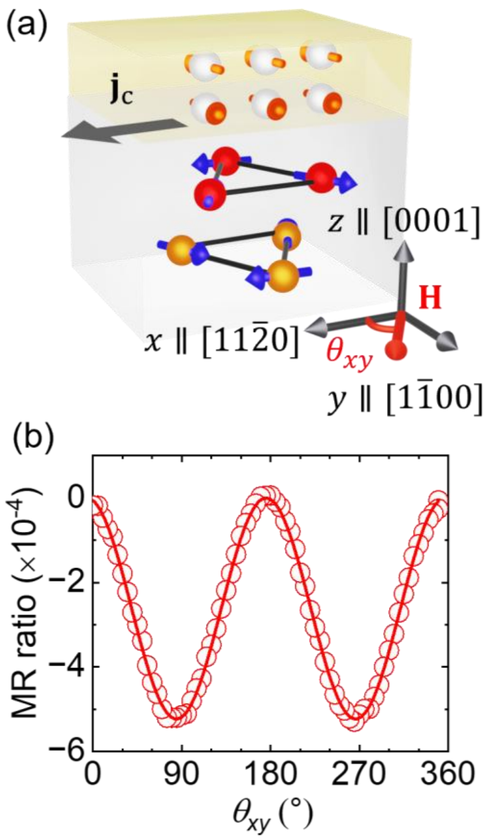

Fig. 1. (a) Schematic of angle-dependent MR measurement in (0001)-oriented Mn_3Sn/Pt. (b) Longitudinal MR as a function of the magnetic field angle θ_{xy} Magnetic field of 9 T is applied within the film plane.

References

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