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An anomaly in anomalous Hall effect of the noncollinear antiferromagnet Mn_3Sn thin films

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The anomalous Hall effect (AHE) has been investigated in a variety of ferromagnetic metals that possess spontaneous magnetization. The intrinsic origin of AHE is explained in terms of the Berry curvature while extrinsic origins are thought to be classified into skew-scattering or side jump mechanisms due to the spin-orbit interaction [1]. As long as the systems hold a finite Berry curvature, AHE can be observed even if they do not have macroscopic magnetization.

Noncollinear kagome-lattice antiferromagnet Mn_3Sn is one of the model materials, exhibiting AHE comparable to conventional ferromagnets at room temperature within the kagome plane by hosting the large Berry curvature acting as a fictitious field in the momentum space [2, 3]. This phenomenon is related to the macroscopic time reversal symmetry breaking due to the noncollinear spin structure.

On the other hand, when Mn_3Sn becomes cluster spin glass at low temperature, where spin moments grow normal to the kagome plane, AHE coming from the real space Berry curvature should appear for the out-of-plane direction [4, 5]. In this phase, there exist noncoplanar spin configurations with scalar spin chirality $S_i \cdot (S_j \times S_k)$ (SSC) corresponding to the solid angle subtended by the neighboring three spins on the unit sphere. The AHE derived from SSC termed as topological Hall effect (THE) has been employed sometimes to claim the existence of noncoplanar microscopic spin structures such as the skyrmion [6] and pyrochlore systems[7, 8]. The validity, however, of analysis based solely on transport properties and fitting magnetization to those properties has been questioned recently [9, 10].

We have controlled the crystalline orientation of polycrystalline Mn_3Sn films and observed humplike features in AHE where both the momentum and real space Berry curvature origins contribute. These features are often concluded to be THE by comparing magnetization results without careful consideration, but our results imply that the further analysis utilizing the anomalous Hall coefficients is significant.

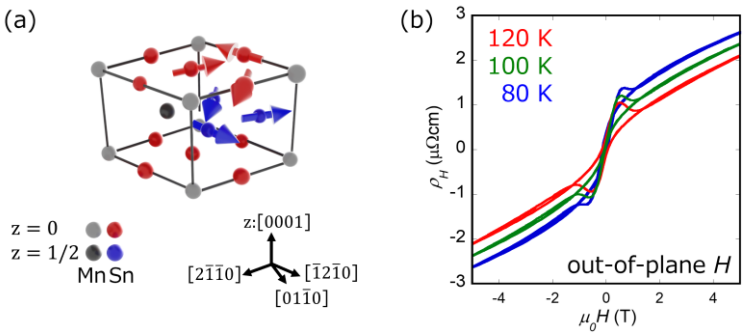

Fig.1 (a) Crystal structure of Mn_3Sn. (b) Field dependence of Hall effect of Mn_3Sn films.

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