Ferromagnetic Fe-Sn nanocrystalline films for flexible Hall sensors

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Detection of magnetic fields is one of the core technologies for ubiquitous sensing. In conventional Hall sensors, a magnetic field is measured as transverse Hall voltage generated by the ordinary Hall effect in semiconductors like Si and GaAs. However, since the sensitivity is proportional to mobility, growth of highly crystalline films at high temperature is inevitable for the device fabrication. Magnetic materials exhibiting large anomalous Hall effect (AHE) can potentially allow for further use of Hall sensors by overcoming the limitations inherent to semiconductors. In this work, we focused on the kagome metal Fe_3Sn_2 [1–3] as a candidate material.

The crystal structure of Fe_3Sn_2 consists of alternate stacking of stanene and bilayer of Fe_3Sn with a kagome network of Fe, as shown in Fig. 1(a). A recent study proposed that the interplay of the kagome lattice, which in analogy to graphene forms linearly dispersed bands, and spin-orbit coupling produces a gap at the band crossing point [3], inducing large intrinsic AHE at room temperature thanks to large Berry curvature. By fabricating Fe_xSn_{1-x} alloy thin films using the co-sputtering technique, we discovered that large AHE emerges even in room-temperature sputtered nanocrystalline Fe_xSn_{1-x} films on Al_2O_3 (0001) (Fig. 1(b)), glass, and also organic polyethylene naphthalate (PEN) substrates [4]. The tangent of Hall angle, the ratio of Hall resistivity ρ_{yx} to electrical resistivity ρ_{xx}, is maximized in the alloy composition corresponding to Fe_3Sn_2 ($x \sim 0.6$), suggesting the kagome origin. Our nanocrystalline Fe_xSn_{1-x} films not only show better thermal stability than semiconductor-based Hall sensors but also hold promise for use in flexible electronics (Fig. 1(c)). These results should accelerate thin-film research on the ferromagnetic kagome compounds as well as the spintronic applications.

References [1] T. Kida *et al.*, *J. Phys.: Condens. Matter* **23,** 112205 (2011), [2] Q. Wang *et al.*, *Phys. Rev. B* **94,** 075135 (2016), [3] L. Ye *et al.*, *Nature* **555,** 638 (2018), [4] Y. Satake *et al.*, *Sci. Rep.* **9**, 3282 (2019).

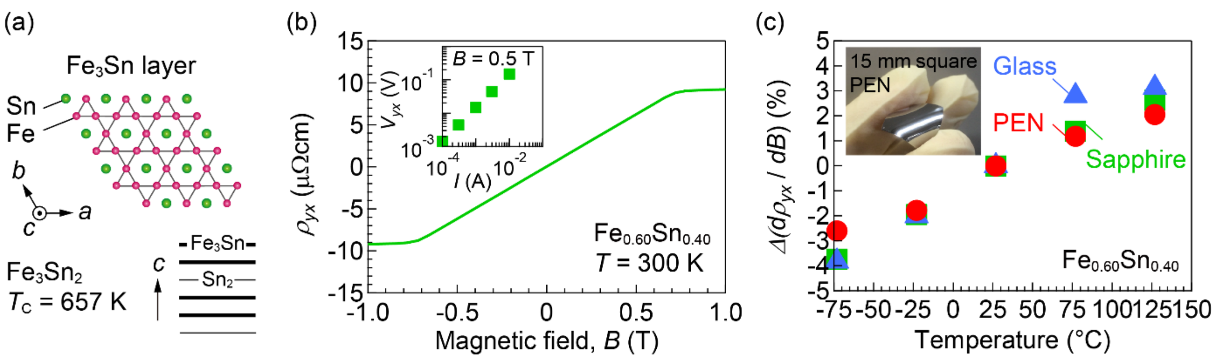

Fig. 1(a) Crystal structure of Fe_3Sn_2. (b) AHE at T = 300 K measured for a 4-nm-thick nanocrystalline $Fe_{0.60}Sn_{0.40}$ film on an Al_2O_3(0001) substrate ($B \perp$ plane). The inset displays the output Hall voltage V_{yx} against the input current I. (c) Thermal stability of the devices on various substrates. The inset shows a photograph of a $Fe_{0.60}Sn_{0.40}$ film grown on a flexible PEN sheet (15 mm × 15 mm).