Magneto-thermopower in Ferromagnetic Semiconductor $In_{1-x}Fe_xSb$

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Spin caloritronics, which studies the interaction of spin current with heat current, has recently attracted much attention due to its novel physical effects and possible applications to thermoelectric as well as spintronic devices. Among promising candidates for spin caloritronics, ferromagnetic semiconductors (FMS) are technologically interesting as they possess both ferromagnetic and semiconducting properties which could be exploited for development of more efficient energy harvesting devices. In this research, we systematically studied the transverse magneto-thermoelectric effects in an n-type $In_{1-x}Fe_xSb$ (x = 16%) thin film [1], epitaxially grown on GaAs (001) substrates by molecular beam epitaxy (inset of Fig. 1a). The sample exhibits semiconducting and ferromagnetic behavior based on resistivity (Fig. 1a), magnetization, anomalous Hall effect, and magnetic circular dichroism measurements, which show the Curie temperature of 127 K. The top view experimental setup for transverse magneto-thermopower measurements is shown in Fig. 1b. The transverse thermal voltage V_{xy} increases linearly with the temperature gradient (Fig. 1c), indicating the thermoelectric origin of the effect. We find that the transverse Seebeck coefficient S_{xy} increases monotonically at high magnetic fields (Fig. 1d), and also increases with increasing temperature up to T_C. This might be related to the negative magnetoresistance ρ_{xx} at high magnetic fields following the Mott relation $S_{xy} \sim 1/\rho_{xx}$ [2]. Meanwhile, in a low magnetic field range, the polarity of S_{xy} depends on the angle α between the external magnetic field and the temperature gradient (Fig. 1e). Furthermore, α-dependence of S_{xy} at 5 K and 100 K under a magnetic field of 8 kG follows the sin(2α) function (Fig. 1f), indicating the Planar Nernst effect (PNE) origin of S_{xy} at low fields. However, PNE is nearly temperature independent (~ 0.3 μV/K), despite the large change in the conductivity at 5 K and 100 K. Our findings are the first step toward better understanding of the magneto-thermoelectric phenomena in similar Fe-doped ferromagnetic semiconductors.

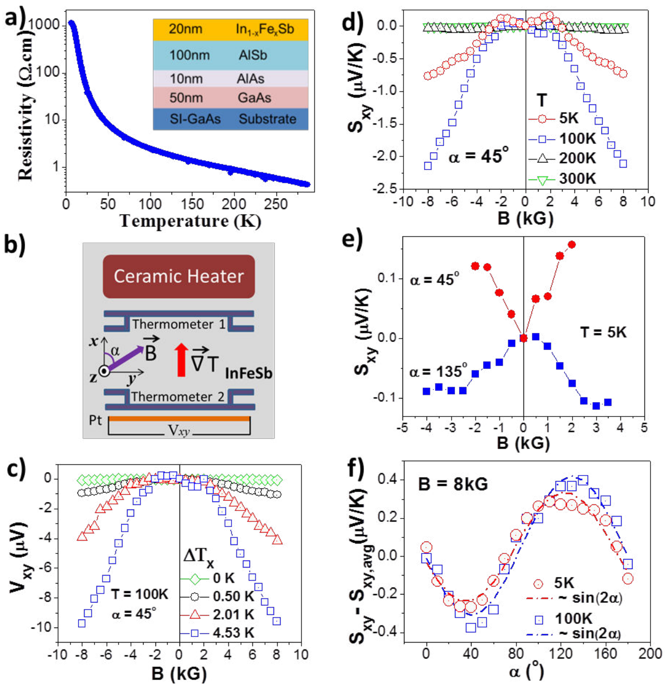

Fig. 1. (a) Temperature dependence of the resistivity of an n-type $In_{1-x}Fe_xSb$ layer grown on GaAs substrate. (b) Top view experimental setup for magneto-thermoelectric measurement. (c) Magnetic field dependence of the transverse thermal voltage V_{xy} at different temperature gradient. (d) Magnetic field dependence of the transverse Seebeck coefficient S_{xy} at different temperatures. (e) Planar Nernst effect in a low magnetic field range. (f) Angular dependence of S_{xy} at 5 K and 100 K.

Refs. [1] N. T. Tu *et al.*, arXiv:1706.00735. [2] Y. Pu *et al.*, Phys. Rev. Lett. 101, 117208 (2008).