# Anomalous spin transport properties and orbital magnetic susceptibility in gapped Dirac electrons with tilting 

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The anomalous spin transport coefficients of gapped Dirac electrons are studied considering a quasi-two dimensional organic conductor $\alpha$-(BETS) $)_{2} \mathrm{I}_{3}$ [1]. In the presence of a gap induced by spin-orbit interaction, we show that the effective Hamiltonian is similar to the model considered by Kane and Mele [2] with additional tilting. With this effective Hamiltonian, conductivity tensors up to the linear order of the applied magnetic field are obtained analytically using the microscopic linear response theory or Kubo formula. It is shown that spin Hall conductivity $\sigma_{\text {SHE }}$ and anomalous diagonal spin conductivity proportional to the magnetic field $\sigma_{\mathrm{Syy}}{ }^{(1)}$ become nonzero in this system, which are written in terms of the Berry curvature and orbital magnetic moment (see Fig. 1 below). The estimated values of spin conductivities using typical parameters turn out to be comparable to the spin Hall conductivity in Pt. Other physical quantities such as conductivity, Hall conductivity, and magnetic susceptibility are also discussed and compared with the experimental results.


Fig. 1. Temperature dependences of chemical potential $\mu$, spin Hall conductivity $\sigma_{\text {SHE }}$, and diagonal spin conductivity proportional to the applied magnetic field $\sigma_{\text {Syy }}{ }^{(1)}$ per valley for a tilted Dirac electrons with a gap $\Delta$ and a fixed value of the electron density. For comparison, the case of a fixed chemical potential is also shown by dashed lines.

## References

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[2] C. L. Kane and E. J. Mele, Phys. Rev. Lett., 95, 226801 (2005).

