Quantum limit transport and Two-dimensional Weyl fermions in epitaxial ferromagnetic oxide $SrRuO_3$ thin films

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High-mobility two-dimensional carriers originating from pairs of Weyl nodes in magnetic Weyl semimetals are highly desired for accessing exotic quantum transport phenomena and their topological and spin electronics applications. Recent observation of two-dimensional carriers in Dirac semimetal Cd_3As_2 [1] also promotes the quest in Weyl semimetals and magnetic Weyl semimetals. The two-dimensional carriers in topological semimetals are realized due to surface Fermi arcs. Hence, high-quality epitaxial films of Weyl semimetal, where the surface transport is prominent, are mandatory. Ultrahigh-quality thin films of $SrRuO_3$, in which we have recently provided quantum transport evidence of magnetic Weyl semimetals [2,3], are a promising material platform for exploring such novel transport phenomena.

In this invited talk, we review our recent work on the two-dimensional quantum transport properties via thickness- and angle-dependent magnetotransport experiments, including quantum oscillations, of magnetic Weyl semimetal $SrRuO_3$. The $SrRuO_3$ films were grown by machine-learning-assisted molecular beam epitaxy [4] with a thickness between 10 nm and 63 nm. The quantum oscillations for the 10-nm film show a high quantum mobility of 3.5×10^3 cm^2/Vs, a light cyclotron mass of $0.25m_0$ (m_0: the free electron mass in a vacuum), and two-dimensional angular dependence (Fig. 1). When the film thickness is 63 nm, which is too large to observe the quantum confinement effect, we still observe the two-dimensional angular dependence of the quantum oscillations, suggesting that the high-mobility two-dimensional carriers originate from surface Fermi arcs. By measuring the magnetoresistance (MR) up to 52 T with small $\theta = 5.3°$ [θ is defined in Fig. 1(a) inset], we also observed the saturation of the negative MR in the quantum limit, confirming that the negative MR is induced by the chiral anomaly of Weyl nodes. These findings further highlight $SrRuO_3$ as an intriguing platform for topological oxide electronics and for exploring exotic quantum transport phenomena in magnetic Weyl semimetals [5].

References: [1] C. Zhang *et al.*, Nat. Commun. **8**, 1272 (2017). [2] K. Takiguchi, Y. K. Wakabayashi *et al.*, Nat. Commun. **11**, 4969 (2020). [3] S. Kaneta-Takada, Y. K. Wakabayashi *et al.*, Appl. Phys. Lett. **118**, 092408 (2021). [4] Y. K. Wakabayashi, *et al.*, APL Mater. **7**, 101114 (2019). [5] S. Kaneta-Takada, Y. K. Wakabayashi *et al.*, arXiv:2106.03292.

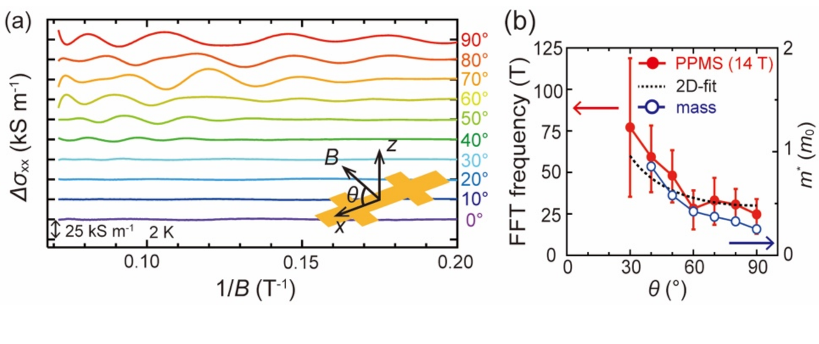

Fig. 1 (a) Angular dependence of the quantum oscillations in conductivity at 2 K with B (5 T < B < 14 T) for the $SrRuO_3$ film with t = 10 nm. (b) Angular dependence of the oscillation frequency (red filled circles) and the cyclotron mass (blue open circles). The dashed line is the fitting of a two-dimensional angular dependence ($\sim1/\cos(90°-\theta)$).