Valley-Polarized Interlayer Conduction of Anisotropic Dirac Fermions in $SrMnBi_2$

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Introduction

Controlling the valley degree of freedom can be an effective way to modulate charge conduction and to induce intriguing phases. Recent studies on a 3D Dirac material, bismuth, demonstrate that a rotating magnetic field can modulate the contribution of the conductivity from each valley and also induce the valley-polarized phase [1]. Here, the essential ingredient for magnetic valley control is the strong anisotropy in the Dirac valleys. In this respect, $SrMnBi_2$ is of particular interest because of its highly anisotropic quasi 2D Fermi surface [2]. $SrMnBi_2$ can thus provide a model system of quasi-2D Dirac valleys hosting the valley-polarized current at high magnetic field.

Experimental

Single crystals of $SrMnBi_2$ were grown using a Bi-flux method. The interlayer transport properties were measured in magnetic fields up to 30 T using a resistive magnet at NHMFL, Tallahassee.

Results and Discussion

The angular-dependent *c*-axis MR shows a characteristic resistive peak at $\theta = 90^{o}$, which is known as the coherent peak [3]. The height of the coherent peak has clear azimuthal angle (ϕ) dependence with four fold symmetry at low magnetic fields [Fig. 1(a)]. This can be attributed to the strong twofold anisotropy in the contribution of each Dirac FS, which is rotated by 90° against its neighbors [Fig. 1(b)]. Under in-plane magnetic field, electrons make complete closed orbits by the Lorentz force, significantly reducing the interlayer conduction. However, this is not the case for electrons on the flat part of the FS, which experience nearly zero Lorentz force due to almost parallel v_F to *B*. Thus the c-axis conductivity under the in-plane field is extremely sensitive to the curvature of the side wall of the FS [Fig. 1(b)]. As a consequence, the rotating field by 90° turns on or off the contribution of a single Dirac FS [Fig. 1(d)]. Hence, the in-plane field orientation controls the contribution of the valleys with odd or even indices in $SrMnB_{i2}$.

At higher magnetic field, however, one can easily notice deviation of the experimental data from the four-fold symmetric behavior. In fact, similar behavior of broken valley degeneracy was found in bismuth at high magnetic fields [1]. In $SrMnBi_2$, incipient electronic instability due to the nesting effect of the flat part of the Dirac FSs might be stabilized at high fields, lifting valley degeneracy. Our findings suggest that interlayer conduction of anisotropic quasi-2D Dirac systems can be modulated with a magnetic field, providing an effective way for valley control.

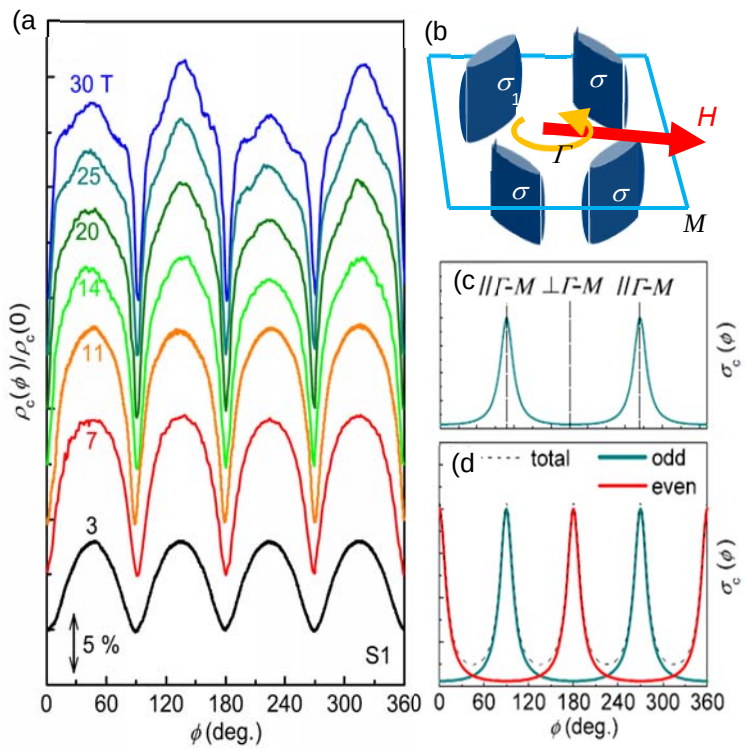

Fig.1 (a) The □ dependence of the normalized $\rho_c(\square)=\rho_c(\square)/\rho_c(\square=0)$ of $SrMnBi_2$ up to H = 30 T at T = 2 K. (b) Schematic illustration of quasi-2D FSs and magnetic field orientation. (c) The expected twofold □-dependent conductivity $\sigma_c(\square)$ from a single Dirac FS. (d) Each contribution from the valleys with odd and even index (solid lines) together with the total conductivity (dashed line).

Conclusions

In conclusion, we have shown that the coherent interlayer conduction of a quasi-2D Dirac system $SrMnBi_2$ is significantly modulated by a rotating magnetic field, which is attributed to the valley-selective conduction.

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