Out-of-plane Magnetoresistance in Quasi 2D Massless Dirac Fermions System, α-(BEDT-TTF)$_2$I$_3$

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A zero-gap conductor α-(BEDT-TTF)$_2$I$_3$ has Dirac-cone type energy dispersion under high pressures. Low energy excitations around Fermi energy are quasi 2D massless Dirac fermions. A peculiar Landau level structure appears in this system under a magnetic field, $B$, perpendicular to the plane. It is characterized by the $n = 0$ level at the Fermi energy and a large energy gap, $\Delta_0$, proportional to $B^{1/2}$, opens between the $n = 0$ and $n = 1$ levels. The level structure well explains the non-monotonic temperature-dependence of the out-of-plane longitudinal MR as shown in Fig. 1. The MR exhibits anomalous peak at $T_{\text{max}} = 16$ K, and negative MR is observed below 8 K. Qualitatively speaking, the quantum limit ($k_B T << \Delta_0$) is achieved below $T_{\text{max}}$. At high temperatures, the thermally excited carriers beyond the gap $\Delta_0$ contribute to the positive MR. On the other hand, in the quantum limit below $T_{\text{max}}$, the negative MR appears due to the very high degeneracy of the $n = 0$ level.

Fig. 1 Out-of-plane MR vs. temperature