Transport property of molecular massless Dirac fermion systems

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A zero-gap state with a Dirac cone type energy dispersion was discovered in the organic conductor α-(BEDT-TTF)$_2$I$_3$ under high hydrostatic pressures [1-6]. This is the first two-dimensional (2D) zero-gap state discovered in bulk crystals with a layered structure. In contrast to the case of graphene, the Dirac cone in this system is highly anisotropic [1, 2]. The present system, therefore, provides a new type of massless Dirac fermion systems with anisotropic Fermi velocity. This system exhibits remarkable transport phenomena characteristic to electrons on the Dirac cone type energy structure. Temperature (T) dependence of the carrier density (n), written as $n=AT^2$, is a characteristic feature of the 2D zero-gap structure [6]. Slope A depends on the Fermi velocity which is estimated to be about 10^7 cm/s. On the other hand, the resistivity per layer (sheet resistance R_S) is given as $R_S = h/e^2$ and is independent of temperature [6]. The effect of a magnetic field on samples in the zero-gap system was examined. In the zero-gap system, n=0 Landau level (zero-mode) always appears at the contact points of Dirac cones under the magnetic field normal to the 2D plane. Zero-mode Landau carriers give rise to strong negative inter-layer magnetoresistance [7, 8]. This is a characteristic feature of transport in multilayer massless Dirac Fermions systems. At high magnetic field, spin splitting of the zero-mode level plays an important role in determining the carrier density. It works to reduce the density. Inter-layer resistance depends on the magnetic field (B) and the temperature as $\exp(\mu_B B/k_B T)$ [8].

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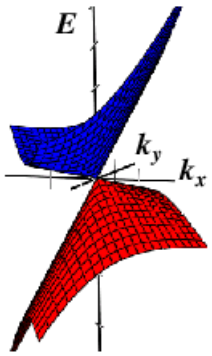

Figure: Zero-gap structure. Note that the origins of the axes are taken at the position of the