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Fabrication of micro/nano-crystals of organic Dirac fermion system: Nano-scale electro crystallization

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Statement of the Problem: Since the discovery of graphene, it attracted a great interest because the electrons in graphene behave like massless Dirac fermions. It shows anomalous behaviors resulting from the peculiar liner dispersion. It has been recognized that Dirac fermion system is also realized in organic conductor α-$(BEDT\text{-}TTF)_2I_3$ under high pressure. This system is composed of organic molecule BEDT-TTF and inorganic anions I_3. These molecules are stacked alternatively and forming a multi-layered structure of conducting and insulating layer, respectively. By taking advantage of its bulk nature, we have experimentally studied the physical properties of Dirac fermions in this compound. In high magnetic field, the characteristic edge state with spin current at the sample edges is theoretically predicted. By using the micro/nano crystals, which contains large amount of edges, we aimed to observe the evidence of the edge state of this system.

Methodology: Micro/nano crystal growth of α-$(BEDT\text{-}TTF)_2I_3$ is based on nano-scale electrocrystallization was carried out by using Nano-Wire Fabrication Kit, Iwata Glass Industrial Co., Ltd., The electrodes used in the crystal growth were made on a silicon substrate with 300 nm SiO_2. Platinum electrode was deposited on a masked substrate and 5 μm gap was made by photolithography. The substrate was set into a saturated THF solution of above two molecules. DC current was applied between the electrodes at 20°C in incubator during 24 h.

Findings: The typical crystal obtained by this method is shown in Figure 2. The shape of the grown micro-crystal resembles with that grown by usual electrocrystallization. The surface of the crystal is almost flat and specularly reflected suggesting that the crystal is high purity.

Conclusion: By using the nano-scale electro-crystallization, we could obtain high purity micro-crystals. We will study this micro-crystal to detect the evidence of the edge state and spin current.

Figure 1: Silicon substrate with platinum electrodes

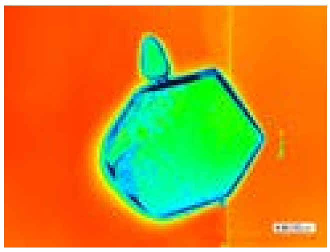

Figure 2: 3D laser microscope image of one of micro-crystal

Recent Publications:

1. Katayama S, Kobayashi A and Suzumura Y (2006) Pressure-induced zero-gap semiconducting state in organic conductor α-(BEDT-TTF) 2I3 salt. Journal of the Physical Society of Japan 75(5):054705.
2. Osada T, Uchida K and Konoike T (2011) Magneto transport of massless Dirac fermions in multilayer organic conductors. Journal of Physics 334: 012049.
3. Konoike T, Uchida K and Osada T (2012) Specific heat of the multilayered massless Dirac fermion system. Journal of the Physical Society of Japan 81:043601.
4. Konoike T, Sato M, Uchida K and Osada T (2013) Anomalous thermoelectric transport and giant Nernst effect in multilayered massless Dirac fermion system. Journal of the Physical Society of Japan 82(7):073601.

Biography

Takako Konoike has expertise in Evaluation and her passion in improving the various measurements under pressure and crystal growth of organic conductors, especially organic Dirac fermion system α-(BEDT-TTF) 2I3. We have measured the specific heat and thermo power of organic Dirac fermion System under high pressure. We have succeeded in obtaining the first experimental results of the specific heat of Dirac fermions and observing the giant Nernst effect reflecting the intrinsic nature of the zero-mode Landau level, which is characteristic of the Dirac fermion system. From these results, we can conclude that the high-purity organic crystal can provide an ideal testing ground for experimental studies of Dirac fermions.

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