Quantum Hall Effect in the 2-Dimensional Organic Conductor, t-(EDO-*S*,*S*-DMEDT-TTF)$_2$(AuBr$_2$)$_{1+y}$ Based on a New Mechanism

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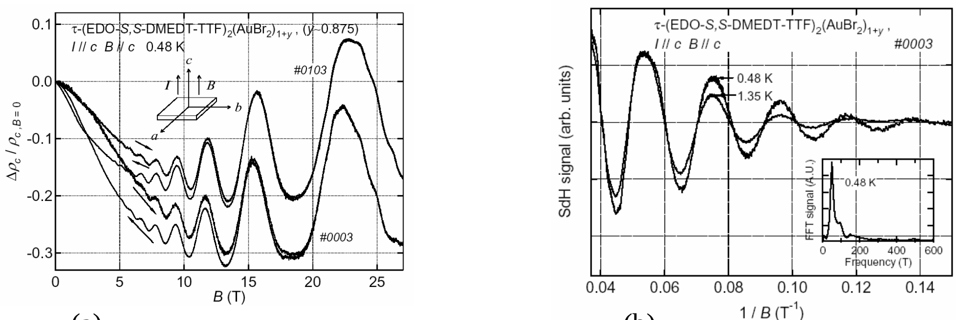
1. Introduction

Quantum Hall Effect (QHE) has been observed in the inversion layers of Si-MOS, hetero-junction of GaAs-Ga$_{1-x}$Al$_x$As and in the organic conductors, (TMTSF)$_2$PF$_6$ and (TMTSF)$_2$ClO$_4$ which are in the field induce spin density wave (FISDW) state. These systems provide two-dimensional (2D) electron gas, which is quantized into small number (<<10) of Landau levels, i.e. close to the quantum limit, in magnetic field perpendicular to the 2D plane at low temperature. Therefore, when we meet a two-dimensional electron system, which is close to the quantum limit in Shubnikov de Hass effect, we are very much tempted to be encountered with a *new QHE*.

In the present two-dimensional organic conductor, τ-(EDO-*S*,*S*-DMEDT-TTF)$_2$(AuBr$_2$)$_{1+y}$, we have observed Shubnikov de Hass oscillations with Landau level down to n = 2 in field up to 27 Tesla in Sendai[1, 2]. We then studied Hall effect in pulsed field up to 60 Tesla in Los Alamos, and found Hall resistance plateau above 40 Tesla. We propose here this plateau originates from QHE but is quite different from previously presented QHE in Si-MOS or TMTSF salts. The purpose of the present paper is to show our recent work on τ-(EDO-*S*,*S*-DMEDT-TTF)$_2$(AuBr$_2$)$_{1+y}$ and discuss the new mechanism of QHE.

2. Experiment

Figure 1 shows the Shubnikov de Haas oscillation in the 2D organic conductor, τ-(EDO-*S*,*S*-DMEDT-TTF)$_2$(AuBr$_2$)$_{1+y}$. Although ρ_{zz} was measured, it is understood that ρ_{zz} behaves similarly with ρ_{xx}, where xy is the 2D conducting plane. It is noted that there are two series of oscillation and one of which reaches n = 2 state, i.e. close to quantum limit. Then we proceeded to the study of the Hall effect in pulsed magnetic field, where Hall plateau is observed as shown in Fig. 2.



(a) (b)

Fig. 1. Shubnikov de Hall oscillations in τ-(EDO-*S*,*S*-DMEDT-TTF)$_2$(AuBr$_2$)$_{1+y}$ (a), and the oscillatory part is plotted against inverse field with Fourier analysis in the inset(b). Two series of oscillation are obvious in (a) in two samples. The system is already n = 2 state, i.e. close to quantum limit [Ref. 1 and 2].

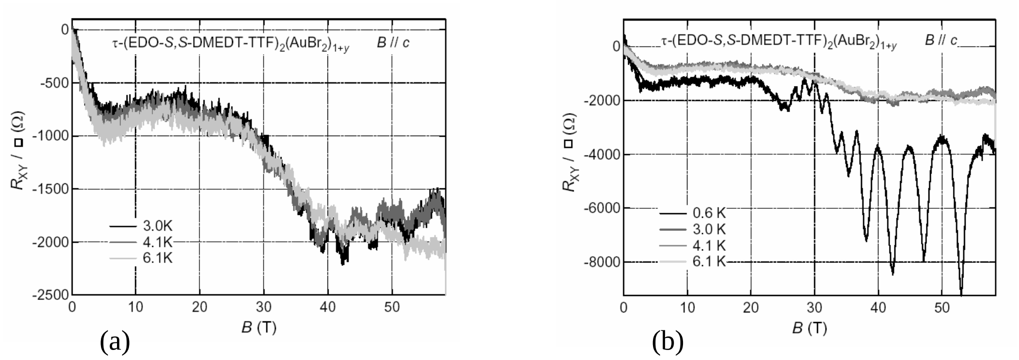


Fig. 2. Hall resistance per one conducting layer of τ-(EDO-*S*,*S*-DMEDT-TTF)$_2$ (AuBr$_2$)$_{1+y}$ at T = 3.0 -6.1 K (a), and with data at T = 0.6 K(b).

3. Results and Discussion:

The results are summarized as: i) Hall resistance per conducting layer R_{xy} shows plateau-like structure beyond 40 Tesla. ii) The plateau structure is clear between 3.0 -6.1 K, but becomes less clear with lowering temperature. iii) R_{xy} is about 1/10 of the universal value, h/e^2 ~ 25 kΩ. iv) R_{xx} = 0 is *not* seen (not shown by figure) where R_{xy} shows plateau.

The features from ii) to iv) seem to be very contradictory to what are common to Si-MOS, or FISDW state of TMTSF salts. However, if we examine how QHE appears, the observed phenomenon is really QHE, but requires new scenario as interpreted in the following. From Shubnikov de Haas effect, it is known that there are two series of oscillations corresponding to 2D Fermi surface (FS) pockets of 0.66 and 6.1 % of the first Brillouin zone [1, 2]. The analyzed SdH parameters ((area of Fermi surface)/(Brill. zone), m_e, T_D) are (0.66 %, 1.6 m_0, 1.3 K) and (6.1 %, 3.5~5.2 m_0, unclear). With two 2D FS's present, FS with light mass undergoes clear Landau-quantization at higher temperature. In our case, FS with 0.66 % shows large oscillation at 3.5 - 6 K below 30 Tesla. In this temperature region, quantization of the FS with 6.1 % is not well established, and therefore FS with 6.1 % behaves as a reservoir for the FS with 0.66 % to exhibit QHE. Generally, when QHE is observed, the Hall resistance is ruled *only* by completely filled Landau levels even when the field value is deviated from the strict value, which should separate the Landau levels into completely filled and completely empty ones. This self-tuning scenario is introduced to Si-MOS in terms of weak localization, and to TMTSF salts in FISDW state in terms of the self-adjustment of Q-vector, where Q is the nesting vector in FISDW. The third scenario, which we present here, requires a reservoir with FS with larger effective mass and larger electron density. This scenario does not require R_{xx} to be zero. Since the reservoir FS has 10 times larger in area, R_{xy} can be 1/10 of h/e^2. At lower temperature (~0.6 K) and in high field (>30 Tesla), larger FS with heavier mass is also clearly quantized, the role of being just a reservoir for the smaller FS is reduced, and consequently, large oscillation appears as shown in Fig. 2 (b).

In conclusion, the Hall plateau which we observed in τ-(EDO-*S*,*S*-DMEDT-TTF)$_2$ (AuBr$_2$)$_{1+y}$ is a QHE, in the sense that Hall effect is flat and is ruled just with a completely filled Landau levels in a certain range of magnetic field. Further, this *new QHE* is based on different mechanisms introduced neither for Si-MOS nor for TMTSF salt in FISDW state. We appreciate Prof. Y. Hasegawa of Himeji Institute of Technology for useful discussions.

References

1. T. Konoike, K. Murata, K. Iwashita, H. Yoshino, T. Sasaki, K. Hiraki, T. Takahashi, Y. Nishio, K. Kajita, G. Papavassiliou, J. Phys. and Chem. of Solids, **63** (2002) 1245.

2. T. Konoike, K. Iwashita, H. Yoshino, K. Murata, T. Sasaki, G.C. Papavassiliou, Phys. Rev **B66** (2002) 245308.