Anomalous quantum Hall effect in η-Mo_4O_{11}

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Abstract

Anomalous quantum Hall effect (AQHE) in the quasi-two-dimensional conductor η-Mo_4O_{11} was observed under pulsed high magnetic field. The Hall resistivity with plateaus shows negative field dependence in the field range $10<B<19$ T in contrast to the conventional QHE. This behavior is explained by the field-dependent Fermi surface model. We investigate the sample dependence of anomalous QHE.

Key words: Anomalous quantum Hall effect; Charge-density-wave material; High magnetic field

η-Mo_4O_{11} has layered structure. The crystal structure consists of layers of MoO_6 octahedra, parallel to (100), separated by MoO_4 tetrahedra. Two layers of quasi-two-dimensional conduction plane are formed per unit cell.

This material undergoes twice Charge-density-wave (CDW) transitions at $T_{C1} = 105$ K and $T_{C2} = 35$ K. Below T_{C2} there are only quasi-two-dimensional (Q2D) small electron and hole pockets because each transition nests large sections of Fermi surface. These pockets have a cylindrical shape with opened edges along the a*-axis. The material consists of normal electrons, holes and two types of CDW condensates (CDW_1 and CDW_2) at low temperature[1]. Above $B_C \sim 10$ T field-induced transition from CDW to normal phase occurs at a small portion of the CDW systems[2]. This transition causes the enhancements of electron and hole pocket sizes since the removed Fermi surface due to the nestings are much larger than their pocket sizes.

The bulk quantum Hall effect (QHE) in Q2D system of η-Mo_4O_{11} has been observed[3,4]. The mechanism of the QHE in η-Mo_4O_{11} is considered to originate from a charge transfer between the quantized Q2D small pockets and CDW_2 states.[5].

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Anomalous QHE (AQHE) in this material is observed in the previous work[6]. The Hall resistivity ρ_H with plateaus decreases with increasing magnetic field in the field range $10<B<23$ T. Such a negative field dependence of ρ_H with plateaus was not found in other material. The filling factor increases as $\nu = 2 \rightarrow 3 \rightarrow 4$ against usual manner $\nu = 2 \rightarrow 1$. AQHE is a unique phenomenon that has two characteristic features *i.e.*, QHE and anomalous Hall effect. It is considered that such AQHE is caused by an increase of Fermi energy with increasing magnetic field above $B_C \sim 10$ T.

Thus AQHE in η-Mo_4O_{11} is closely related to Fermi energy and Q2D small pockets at low temperature. In this work we investigate the relation between Q2D small pockets and AQHE by using two samples, which are regarded to have different size of the Q2D small pocket.

Single crystals of η-Mo_4O_{11} were grown by a vapor-transport technique. First we measured the temperature dependence of resistivity for two samples (#1 and #2) with current parallel to b-axis. Then the Hall resistivity measurement have been done up to 26 T with current parallel to b-axis by using a pulsed magnet. Magnetic field was applied parallel to a*-axis.

Figure 1 shows the temperature dependence of resistivity ρ for two samples (#1 and #2) with current parallel to b-axis. Twice CDW transitions occurs at T_{C2}

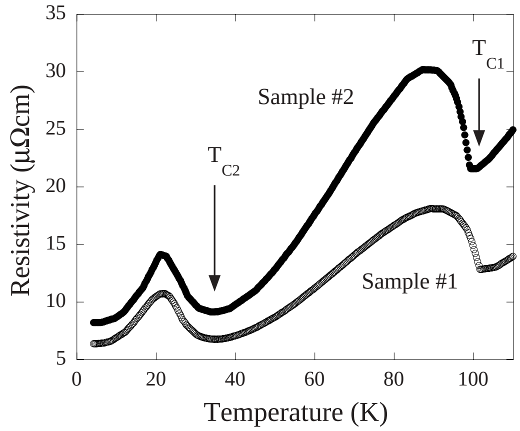

Fig. 1. Temperature dependences of the resistivity ρ for sample #1 (white circles) and #2 (black circles) with decreasing temperature. The current direction is parallel to b-axis.

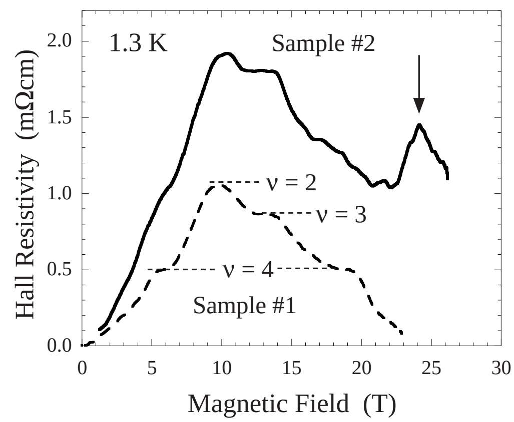

Fig. 2. Magnetic field dependences of Hall resistivity ρ_H for sample #1 (solid line) and sample #2 (dashed line) at 1.3 K up to 55T.

and T_{C1} on cooling. The absolute value of ρ for sample #2 is larger than the value of sample #1.

Figure 2 shows the magnetic field dependence of Hall resistivity ρ_H for sample #1 (dashed line) and #2 (solid line) up to 26 T at 1.3 K. We depicted the data on increasing magnetic field. The ρ_H of sample #1 was measured in the previous work[6]. We plotted the previous data for comparison. In this work sample #2 shows AQHE as shown in sample #1. For these two samples general behavior of ρ_H is the same. Negative field dependence of ρ_H is observed in the field range $10<B<19$ T and Hall plateaus are seen at the same magnetic fields of 6, 10 and 12-14 T. However, the behavior of ρ_H is different in detail. The plateau of sample #2 at 6 T can not be seen clearly. Above 22 T ρ_H of sample #2 increases with increasing magnetic field and has a peak at 24 T. On the other hand, ρ_H of sample #1 shows the plateau ($\nu = 4$) at 19 T and just decreases with increasing magnetic field above 20 T. Moreover, according to the previous work [6] ρ_H of sample #1 increases with increasing magnetic field above 22 T and has a peak at 28 T.

The absolute value of ρ shows the sizes of Q2D electron and hole pockets. Figure 1 indicates that sample #2 has small Q2D pockets compared with sample #1. And the contribution of the impurity scattering seems to be large in sample #2 more than in sample #1. From the temperature dependence of ρ, the different behavior of AQHE may be observed in these two samples. However, similar AQHE was observed in these two samples. And also the similar peak was seen above 24 T in these two samples. Sample #1 shows the peak at 28 T and #2 shows the peak at 24 T. Although the magnetic fields at the peak are different, these two samples show the similar peak. We consider that such a difference of ρ is too small to affect the general behavior of AQHE. The unclear plateau at 6 T in sample #2 was caused by an impurity scattering.

We observed similar anomalous QHE in different samples. The essential behavior of AQHE doesn't change though the sizes of Q2D small pockets are different.

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