High field Fermi surfaces studied by AMRO in η–Mo_4O_{11}

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Abstract

The high field Fermi surface in η–Mo_4O_{11} at low temperatures has been studied by the Angle-dependent Magenetoresistance Oscillation (AMRO) method [1]. The Shubnikov-de Haas (SdH) oscillation so far obtained shows existence of the several closed surfaces, but the results only give the area of the pockets. The AMRO result at high fields in the plane perpendicular to the crystal b axis shows the angle-dependent resistance oscillation together with the SdH oscillations. We see no clear AMRO for the fields in the plane perpendicular to the c axis. The results indicate the existence of very anisotropic Fermi surfaces, which are expected from the Fermi surface model [3] taking into account the lower temperature CDW nesting vector q_2.

Key words: AMRO effect; η–Mo_4O_{11}; Fermi surface: CDW

1. Introduction

The η–Mo_4O_{11} system is a quasi-two-dimensional metal and the low temperature electronic properties have been studied extensively. The recent transport study reports the possible model considering the quantum limit of the semi-metallic Fermi surface [2]. The resistivity of η–Mo_4O_{11} system shows two step anomalies due to the CDW transitions with T_{c1} of 109 K and T_{c2} of 30 K. The corresponding nesting vectors are q_1(which corresponds to q_c in ref. [3])=(0, 0.232b^*, 0) and q_2=(0.552a^*, 0.47b^*, 0.30c^*) from our measurements [4]. The room temperature Fermi surface has been calculated using tight-binding method, and the possible Fermi surfaces below T_{c1} has been proposed [3]. But no electronic band calculation below T_{c2} has been performed because the complete nesting vector had not been obtained before our low temperature results [4]. The low temperature Fermi surface is considered to have closed pockets of electrons and holes. We propose a new view for the field dependence of the magnetoresistance which is consistent with the obtained Fermi surface anisotropy and the nesting vectors.

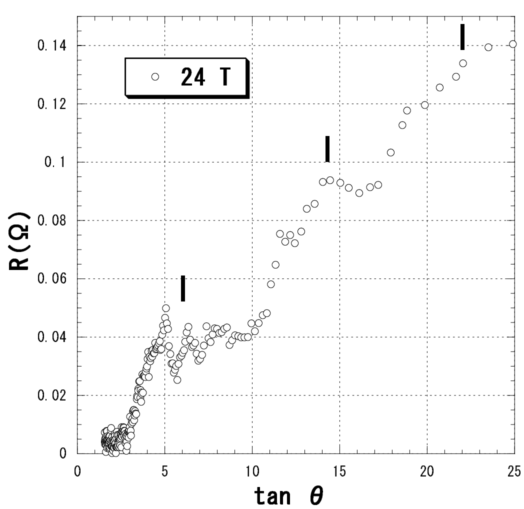

Fig. 1. Angular dependence of the resistance along a^* at 24 T plotted as R vs. tan θ. Vertical lines indicate peak positions corresponding to the AMRO. (See Eq. (1).)

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2. Experimental

Single crystals have been obtained using a vapor transport method. To perform the AMRO measurements, we tried to obtain a pair of flat parallel surfaces grinding the as grown samples because they have irregular shapes. As we should measure the conductivity component along the magnetic field, we attached electrical leads on both sides of the plate-like samples. Samples are rotated in the constant magnetic field using stepping motors and gears. The fundamental aspects of the SdH oscillation and the Hall effect have been confirmed to reproduce the reported studies using shaped samples, and the results will be reported elsewhere. The hybrid magnet of Tohoku University has been used for the measurements above 15 T.

3. Results and Discussion

The AMRO method measures the resistivity component that oscillates depending on the direction of the applied magnetic field. If a Fermi surface is quasi-two-dimensional, the peaks of the resistivity oscillation obey the following formula,

$$tan\ \theta = \frac{\pi}{ck_F}(n - 1/4) \quad (1)$$

where θ is the polar angle measured from the normal direction to the two-dimensional plane, c is the spacing between the two-dimensional conducting sheets, and n is an integer. k_F is the conducting-plane component of the Fermi wave vector in the plane defining field direction. Therefore, if we change the azimuthal angle of the magnetic field, we can get a profile of the Fermi surface in the two-dimensional plane.

Fig. 1 shows the angular dependence of the resistance along a^* at 24 T. It should be noted the magnetic field component normal to the two-dimensional plane is smaller than 9 T where anomalous behavior of the longitudinal magnetoresistance has been reported [2]. The measurement was performed at 0.5 K. The lines above the plot show the resistance peak positions depending on the formula (1). It should be noted that we have very small Fermi surfaces in this case, therefore the observed peaks are few. We have rotated the sample around the crystal b axis, therefore we obtain the Fermi wave vector along the c^* direction. We anticipate that the Fermi surface has a larger diameter along the c^* than the b^*. In principle, it is possible to get a similar result along any direction other than b^*, but it will be difficult to get reliable result because the Fermi surface diameter is much smaller. From the AMRO result, the Fermi surface diameter is about $0.07c^*$, which is comparable to the diameter of pockets shown in the Fig. 2(b). In this estimation, we used $a/2$ as the value of c in Eq. (1), because a unit cell contains two conducting layers. The crystal parameters used are $a = 24.54$ A, $b = 5.439$ A and $c = 6.701$ A. The small oscillations observed near tan $\theta \simeq 5$ are SdH-type ones. Their intensities and shapes change rapidly when we change measuring temperatures or fields.

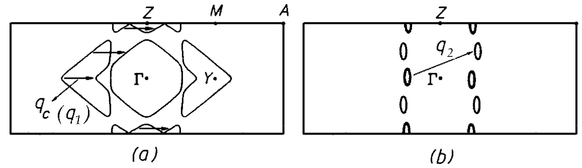

Fig. 2. (a) Room temperature Fermi surface. Arrows indicate the nesting vectors $q_c(q_1)$. $A = (b^*, c^*/2)$ b) Low temperature Fermi surface below T_{c1}. The arrow q_2 is the nesting vector related to T_{c2} . [3], [4]

Though we have two types of carriers, we can expect that both carriers have similar sizes and anisotropy as the system is nearly compensated. Therefore, we consider that both carriers are related to the AMRO result. To explain the high field magnetoresistance behavior, Hill *et al.*. proposed a model depending on the quantum limit of the Landau levels [2]. But, they considered only the level movement of the semi-metallic bands due to magnetic fields. We propose another possibility of the nesting vector variation due to the magnetic field. We found that the nesting below T_{c2} along a^* is incommensurate. Therefore, there is a possibility that the component changes due to the magnetic field. As the wave function along the field changes due to the magnetic field, the nesting condition can possibly change at the same time. The fact that the nesting is related to the hidden quasi-one-dimensionality along the b^* direction reminds us the field induced state in organic metals [1].

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