Field-induced SDW phase diagram of $(TMTSF)_2PF_6$ at high magnetic fields

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Abstract

Magnetoresistance measurements have been carried out along the highly conducting a axis in the field-induced SDW (FISDW) phase of $(TMTSF)_2PF_6$ under 1.0GPa, with the field up to 27 T parallel to the lowest-conductivity direction c^*. We have determined the phase boundary between the last semimetallic FISDW phase with n=1 and the FISDW insulating phase with n=0 and found that the semimetallic FISDW phase existed above the transition temperature of the FISDW insulating phase at least up to 24 T. These results suggest the necessity of the theoretical calculation for more realistic quasi-one-dimensional Fermi surface to explain the FISDW phase of $(TMTSF)_2PF_6$.

Key words: field-induced SDW ; $(TMTSF)_2PF_6$; metal-insulator transition; magnetoresistance

The Bechgaard salt $(TMTSF)_2PF_6$ shows quasi-one-dimensional (Q1D) electric properties and has rich ground states, spin-density-wave (SDW), metallic, superconducting and field-induced SDW (FISDW) phases depending on pressure. [1] At ambient pressure, the PF_6 salt undergoes a metal-SDW transition at 12 K. With increasing pressure, the SDW phase is suppressed and the superconducting phase is induced at 1.1 K above the critical pressure of 0.9 GPa. When the magnetic field is applied to the SDW state suppressed by the imperfect nesting of Fermi surface, it has been predicted that T_{SDW} increases nearly quadratically with the field in low magnetic fields and shows a saturation behavior to the transition temperature for the perfect nesting case T_{SDW_0} in high magnetic fields. [2] In fact, the quadratic magnetic field dependence and the saturation behavior have been confirmed by the experiments for $(TMTSF)_2PF_6$ [3,4]. In the magnetic field parallel to the lowest conductivity direction c^* and above the critical pressure, a cascade of FISDW states is observed, with quantized Hall resistance $\rho_{xy} \sim h/(n2e^2)$ in the sequence n=.....4,3,2,1,0 as the magnetic field is increased. The states labeled with integer n have been identified as semimetallic FISDW states while that with n=0 is a FISDW insulating state. It has been believed that the FISDW phase diagram for the PF_6 salt is successfully explained by the mean field (MF)theory based on the nesting of the slightly warped, quasi-one-dimensional Fermi surface.

In this paper, we present the results of resistivity measurements for the FISDW phase of $(TMTSF)_2PF_6$ under pressure and strong magnetic fields. We discuss an applicability of the MF predictions for the FISDW phase of $(TMTSF)_2PF_6$.

Single crystals of $(TMTSF)_2PF_6$ were synthesized by the standard electrochemical method. Magnetoresistance measurements have been carried out using a standard four probe dc method with the field up to 27 T.

Figure 1 shows magnetoresistance along the highly conducting a-axis in $(TMTSF)_2PF_6$ at 1.0 GPa with the magnetic field parallel to the lowest conductiv-

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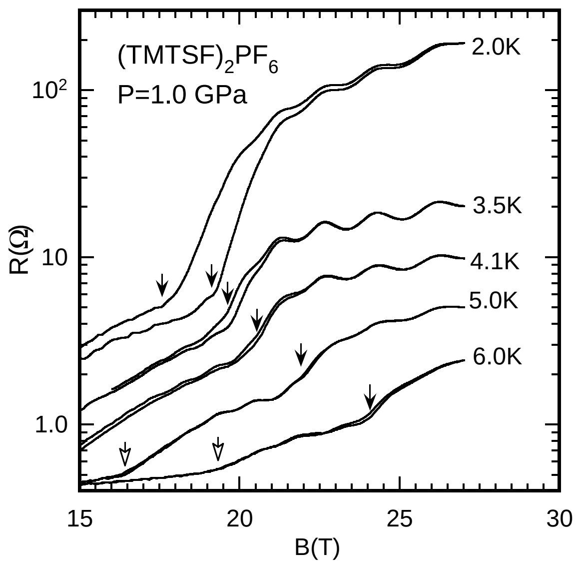

Fig. 1. Magnetoresistance along the highly conducting a-axis in $(TMTSF)_2PF_6$ at 1.0 GPa with the magnetic field parallel to the lowest conductivity direction c^*. The open and closed downward arrows indicate the metallic-semimetallic FISDW transition and the semimetallic-insulating FISDW transition, respectively.

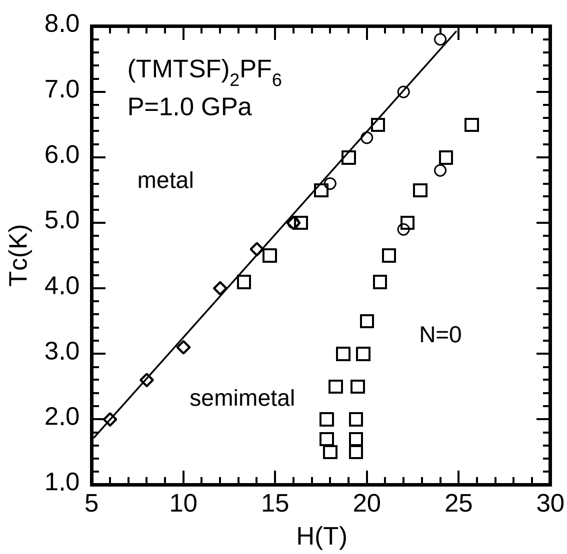

Fig. 2. The FISDW phase diagram in $(TMTSF)_2PF_6$ at 1.0 GPa constructed from many temperature (open circles) and field (open squares)sweeps. The bold line is guides to the eye.

ity direction c^*. The open and closed downward arrows indicate the metallic-semimetallic FISDW transition and the semimetallic-insulating FISDW transition, respectively. It is found from the sudden increase of resistance at 2 K that, the transition from the last (n=1) semimetallic SDW phase to the (n=0) insulating one take place at about 18 T with the large hysteresis of magnetoresistance. The rapid oscillation (RO) is clearly seen in the (n=0) insulating FISDW phase. The sudden increase and the large hysteresis of the magnetoresistance are consistent with previous results at low temperature. [5] With increasing temperature, the increase and the hysteresis of the magnetoresistance at the transition become small, and the RO of the magnetoresistance becomes dim. Moreover, the transition field determined from the increase and the hysteresis of the magnetoresistance is shifted towards a higher field when temperature is increased. The transition temperature from the last semimetallic SDW phase to the insulating one is plotted as a function of the magnetic field in Fig. 2. We have also determined the value of the transition fields between the metallic phase and the FISDW one from the intersection of the extrapolations of the magnetoresistance and have plotted them in Fig. 2. The phase boundary between the metallic phase and the FISDW one is consistent with previous results. [5] From this figure, it is clear that the semimetallic FISDW phase existed above the transition temperature of the FISDW insulating phase at least up to 24 T. When the magnetic field is applied to the symmetrically warped quasi-one-dimensional Fermi surface with above the critical two-dimensionality of the system, it has been predicted in the MF theory that a cascade of FISDW states appears where the field between the different quantized Hall state is independent of temperature and, with decreasing temperature from the metallic phase, only once phase transition to the FISDW phase occurs. [6] The experimental results in Fig. 2 suggest the necessity of the theoretical calculation for more realistic quasi-one-dimensional Fermi surface to explain the FISDW phase of $(TMTSF)_2PF_6$.

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