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INFLUENCE OF THE ANION ORDER ON THE GROUND STATE OF THE ORGANIC CONDUCTOR $(TMTSF)_2ReO_4$

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Abstract - We argue that the low temperature behaviour and the ground state in $(TMTSF)_2ReO_4$ are sensitive to the anion ordering which can be controlled by pressure and cooling rate.

$(TMTSF)_2ReO_4$ undergoes a metal-insulator transition at 180 K[1] as a consequence of the anion ordering (AO) with a wave vector $(1/2,1/2,1/2)$ [2]. This transition can be suppressed by pressure and SC is established at pressures higher than 9 kbar [3]. A detailed investigation of the influence of the cooling rate on the ground state of $(TMTSF)_2ReO_4$ through carefully controlled thermal treatments at pressures around 10 kbar has been already published [4]. Here we briefly show these results (Fig. 1 and Fig. 2) and present new ones obtained at 11 kbar (Fig. 3 and Fig. 4). They can be summarized as follows. (i) Rapid cooling down to the temperature where the resistivity displays a maximum and slow cooling below drives a system to an SC ground state at the highest attainable critical temperature (T_{sc}= 1.52 K and 1.46 K at 10.5 and 10 kbar, respectively). In contrast, the opposite procedure drives the system into the semiconducting state with very high resistivity and SC transition is decreased to and below 1.3 K, at 10.5 kbar and 10 kbar, respectively. (ii) There is an opposite hysteresis effect in the T-region above and below the resistivity peak, when the warming rate was much slower than the cooling one. In particular, in the T region below the peak, the resistivity is lower on warming, while it is much higher above. (iii) At 10 kbar there is

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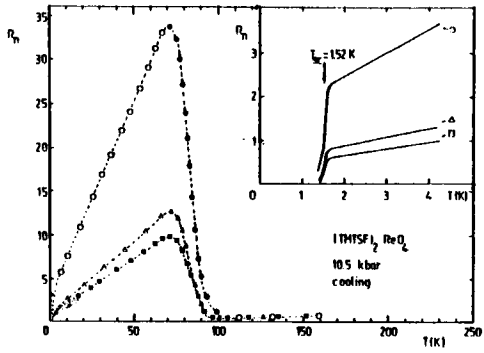

FIGURE 1

Normalized resistivity vs T on cooling at 10.5 kbar Open and solid symbols for slow and rapid cooling, respectively. Note the thermal hysteresis effect in run (c) as indicated by dotted line.

an upturn in the resistivity, above the SC transition, whose amplitude and the onset temperature depend on the cooling rate. (iiii) Above 11 kbar when the metallic behaviour is restored [3], an anomaly in the resistivity is observed around 30 K and the SC critical temperature reaches 1.66 K.

$(TMTSF)_2ReO_4$ is a quasi-1D metal at ambient pressure and high temperatures (HT) as its parent compound $(TMTSF)_2ClO_4$. Anions are distributed statistically in two symmetrically equivalent positions and so create a pseudouniform Coulomb potential along organic chains which does not disturb the electron conduction. On cooling this structure changes either in (i) non-ordered structure obtained by fast quenching which freezes in HT phase (ex: the Q-state in $(TMTSF)_2ClO_4$ [2]) (ii) new ordered structure established below a phase transition driven by the anion-electron coupling. If a wave vector is such that the unit cell is doubled only along the b (or c) direction, the system enters

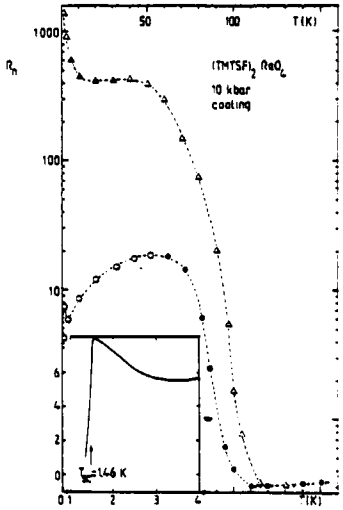

FIGURE 2 - Normalized resistivity vs T at 10 kbar on cooling. Open and solid symbols for low and rapid cooling T-regions, respectively.

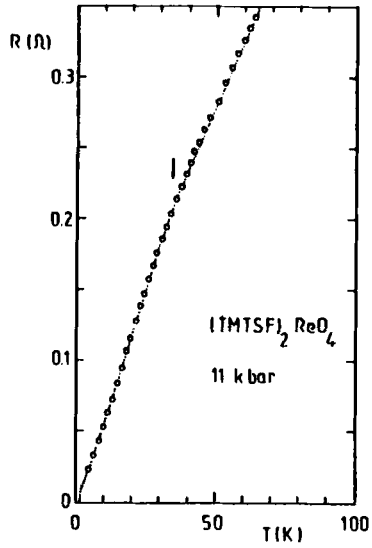

FIGURE 3 - R vs T curve at 11 kbar. The dotted line is a guide for the eye.

a SC ground state (ex: a structure $q_2 = (0,1/2,0)$ at 1 bar in $(TMTSF)_2ClO_4$, T_{AO}= 24 K) [2]. The other case can be that a wave vector is such that a gap opens in the electronic spectrum at the FS and the system enters in an insulating ground state (ex: a structure $q_1 = (1/2,1/2,1/2)$ at p = 1 bar in $(TMTSF)_2ReO_4$, T_{AO}= 180 K). Such a transition can be suppressed either by pressure, or by fast quenching, or again combining the both effects. Once the metallic behaviour is restored and the SC ground state established, the question arises about the structure of a LT phase. This question already can be asked at lower p when the system at higher T displays semiconducting behaviour and a metallic one at LT, before entering in the SC ground state. First possibility is that the pressure restores HT phase and the other is that it transforms a structure q_1 into a new one compatible not only with a single-particle conduction but also with SC. As pointed out by

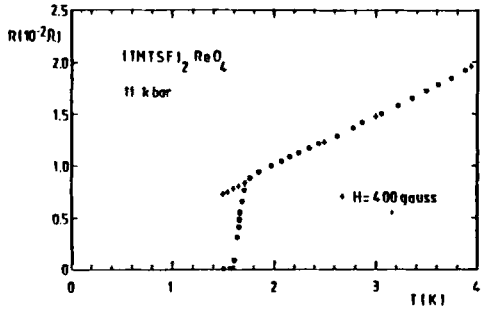

FIGURE 4

R vs T curve at 11 kbar below 4 K. The SC transition width is about 0.11 K, T_{SC}= 1.66 K and it is suppressed by the field of 400 gauss.

Emery [1], there are only two "good" anion structures for SC due to the existence of a short Se-O contact between each TMTSF molecule and one nearly non-centrosymmetric anion. These are (0,1/2,0) and (0,0,1/2) which create an uniform potential along conduction chains. Regarding HT phase we expect that the thermic motion of the anions ceases at LT leading so to a certain non-ordered structure. Therefore, it is tempting to interpret a behaviour of $(TMTSF)_2ReO_4$ under pressure as a consequence of a transformation from a (1/2,1/2,1/2) AO to a (0,1/2,0) or (0,0,1/2) AO, as described in a theoretical model by Bruinsma and Emery [1]. Our experiments favour the latter interpretation for the following reasons (i) for pressures 9 kbar<p<11 kbar slow cooling below a peak in the resistivity gives lower resistance than a rapid one ; (ii) even fast cooling throughout all T-region down to 4.2 K drives the system into the SC ground state and we know from $(TMTSF)_2ClO_4$ in the Q-state that a frozen disorder suppresses SC ; (iii) for $p \gtrsim 11$ kbar there is a kink in R vs T curve below which the resistivity decreases more rapidly, similarly to the ClO_4 case in the R-state at p = 1 bar.

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