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COOLING RATE AND ELECTRIC FIELD EFFECTS in $(TMTSF)_2FSO_3$

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Abstract

We have performed an experimental investigation of the influence of the anion kinetics and anion-dipole order on the ground state of $(TMTSF)_2FSO_3$ in the pressure range 1 bar to 11 kbar.

The sensitivity to the anion ordering (AO) of the low temperature (LT) behaviour and the ground state of $(TMTSF)_2X$ (X non centrosymmetric anion) compounds and alloys is now quite well established experimentally [1-2]. $(TMTSF)_2FSO_3$ and recently synthetized $(TMTSF)_2F_2PO_2$ are the only ones whose anions carry a permanent dipole moment [3-4]. In the former salt the superconducting (SC) transition is apparently not complete [5] and only a weak Meissner effect suggests that SC is well developped in only 2 % of the total sample volume [6]. In the latter one where a dipole moment is much stronger, SC is not observed at all.

We have performed resistivity measurements at pressures 1 bar to 11 kbar. The experiments done at low pressures where a dc current pulse was applied along the sample are described elsewhere [7]. In short, at LT, a dc current pulse can switch the material from a semiconducting to a low resistance metastable state. The so obtained drop of the resistivity at 4.2 K can reach 10^5 (in most cases the ratio was $\sim 10^3$). This state is stable in time and is destroyed

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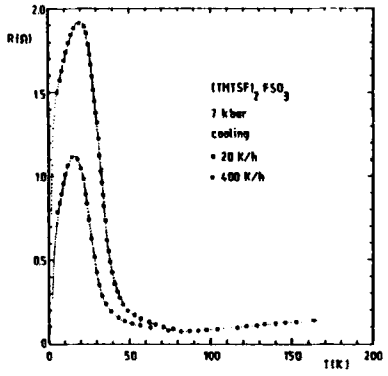

FIGURE 1 - R vs T curve at 7 kbar on cooling. Open and solid cicles for slow and rapid cooling,respectively.

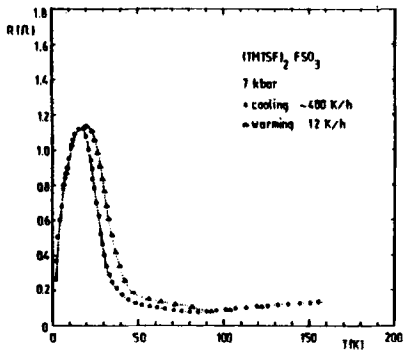

FIGURE 2 - R vs T curve at 7 kbar. Solid circles for rapid cooling and open triangles for slow warming.

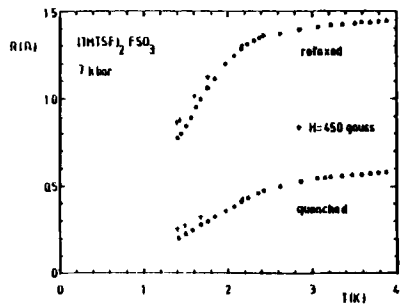

FIGURE 3 - The onset of the "SC" transition for slow (open circles) and rapid (solid circles) cooled sample, at 7 kbar.

above 30 K where the material displays a transition to a high resistance stable state. Experiments to separate electric field effects from fast quenching of the sample are in progress, with the aim to understand better the origin of this striking result.

Here we present in greater details thermal treatment measurements at 7 kbar and 11 kbar performed on two samples of approximate dimensions 1.5 x 0.13 x 0.05 mm^3. In each run samples were cooled from above 100 K down to 1.3 K and rewarmed up slowly before subsequent cooling. The main results of these experiments are as follows : (i) At

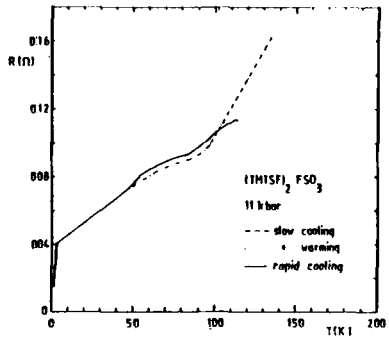

FIGURE 4 - R vs T curve at 11kbar.

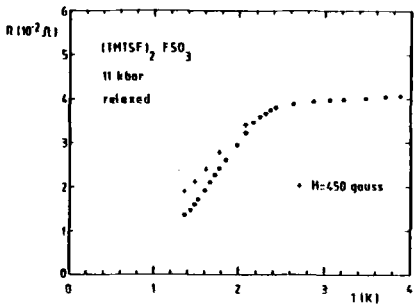

FIGURE 5 - The onset of the "SC" transition for slowly cooled sample at 11 kbar.

7 kbar rapid cooling down to 4.2 K drives a system to a LT state with lower resistivity than in the slow cooling treatment. Below 4.2 K the resistivity decreases more rapidly and T_{SC} is higher (T_{SC} = 1.6 K and 1.3 K for Q and R samples, respectively). T_{SC} is defined as the temperature where the resistivity drops to half of its value just above the transition. Furthermore, the increase of the resistivity under the magnetic field ($H \perp a$) is larger for Q samples than for R samples : 27 % and 13 % at 1.3 K under a field H = 450 gauss, respectively. Note that ≈ 450 gauss is the field sufficient to restore the normal state resistivity in $(TMTSF)_2ReO_4$ [2]. (ii) At 11 kbar a metallic behaviour is recovered and the value of the resistivity at 4.2 K is the same for R and Q samples. However, there are hysteresis effects in the T-region 35 K - 86 K where the resistivity is lower on slow cooling.

Moreover, the SC transition temperature is higher for R-samples (1.65 K) than for Q-ones (1.5 K). The increase of the resistivity under H = 450 gauss is about 40 % at 1.3 K for R-samples in contrast to only 25 % for Q-samples. (iii) The temperature below which the resistivity starts to increase does not

depend on the pressure and is equal to the transition temperature at p = 1 bar, i.e. 86 K. Even at 11 kbar, there is a break in the slope of R(T) vs T at ∿ 86 K. This is in contrast with $(TMTSF)_2ReO_4$ behaviour under pressure [8].

R. Lacoe et al. [3] have already investigated the phase diagram of $(TMTSF)_2FSO_3$ and have shown that it was very similar to that of the ReO_4 salt. Furthermore, they have found the SC transition temperature above 2 K and assumed that this increase in T_{SC} is due to the increased electron-phonon interaction renormalized by the dipole moments. In our measurements the SC transition was never complete [5] and T_{SC} attains similar values as in $(TMTSF)_2ReO_4$ [2] (only onset ∿ 2 K which is higher than in other $(TMTSF)_2X$ compounds). Moreover, T_{SC} is cooling rate dependent in the similar manner as in $(TMTSF)_2ReO_4$. However, the striking point is that the SC transition is cooling rate dependent once the metallic behaviour is restored. Hysteresis effects hint that the order parameter of the LT phase is still not fully developed at long range. All these features indicate that the necessary symmetry due to the anion-dipole order and compatible with SC is not established on the long range scale. This is, maybe, not se surprising because each of the two equivalent anion positions has now four soubgroups depending on the position of the fluorine atom. In other words, the uniform potential along the conducting chains is created only if both anions and dipoles order together creating a superstructure such as (0,1/2,0). Therefore, it is tempting to assume that this order is not fully developed even at 11 kbar and consequently that residual dipole moment disorder prevents the establishment of bulk SC within the entire sample volume. More work is now in progress to understand better the unusual behaviour of $(TMTSF)_2FSO_3$ as far as superconductivity is concerned.

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