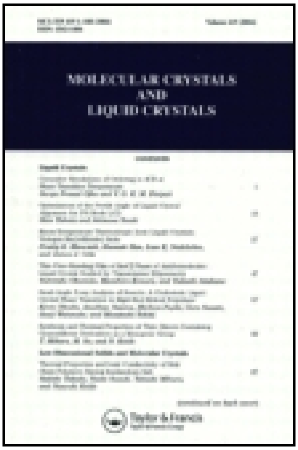
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Resistivity and Upper Critical Field of $(TMTSF)_2clo_4$ in Various Intermediate States

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RESISTIVITY AND UPPER CRITICAL FIELD OF $(TMTSF)_2ClO_4$ IN VARIOUS INTERMEDIATE STATES

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ABSTRACT

The intermediate state of $(TMTSF)_2ClO_4$, obtained by quenching the sample from several temperatures T_Q around the anion ordering temperature T_{AO}=24 K with a rapid cooling rate (>60 K/min), was investigated by electrical resistance, magnetoresistance and ac-susceptibility measurements. The effect of frozen anion disorder is discussed within a model of an inhomogeneous mixture of superconducting and spin density-wave regions in the sample.

It is well established now that a very rapid cooling rate below 40 K prevents the anions from ordering in $(TMTSF)_2ClO_4$(TCl) thus leading to a spin-density-wave (SDW) groundstate below T_{SDW}=6.05 K whereas a relaxed sample exhibits superconductivity with T_c=1.2 K /1-4/. In this paper we discuss results of measurements on TCl in various intermediate states of partially frozen anion disorder that have been prepared by quenching the sample with maximum cooling speed from different temperatures T_Q in the critical region around the anion ordering temperature T_{AO}=24 K.

The measurements of the ac-susceptibility were performed in a tunnel diode oscillator circuit operated at 125 kHz, where the a-axis of the single crystal sample was always oriented parallel to the ac-field so that the induced supercurrents had to flow in the b^*-c^* plane. The sample together with the tank coil was cooled by a ^{3}He evaporation cryostat and could be rotated in a magnetic field while it remained at low temperatures with an angular alignment better than 1^o. The resistivity measurements have been carried out in a dilution refrigerator with a standard low-frequency (30 Hz) ac-method.

The superconducting transition of a relaxed sample in zero field as determined from the ac-susceptibility (which is proportional to the frequency shift of the oscillator circuit) is shown in fig. 1. T_c is defined here as extrapolation of the linear part of the transition to zero. The temperature dependences of H_{c2a}, H_{c2b^*}

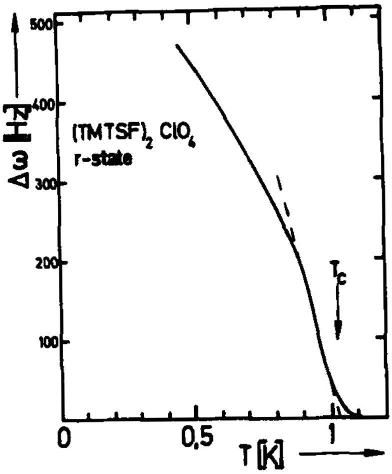

Fig. 1 Transition curve of a relaxed sample of $(TMTSF)_2ClO_4$ as determined from the ac-susceptibility in zero dc-field. The arrow indicates the definition of T_c as linearly extrapolated onset.

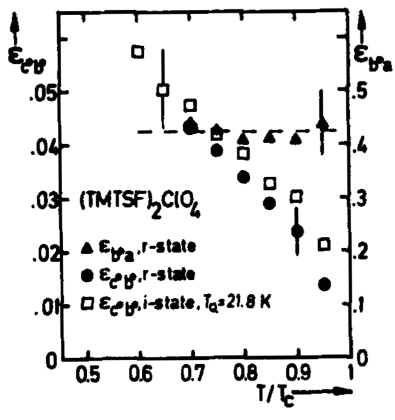

Fig. 3 Temperature dependence of the anisotropy parameters $\varepsilon_{c^*b^*} = H_{c2c^*}/H_{c2b^*}$ and $\varepsilon_{b^*a} = H_{c2b^*}/H_{c2a}$, as determined from the ac-susceptibility.

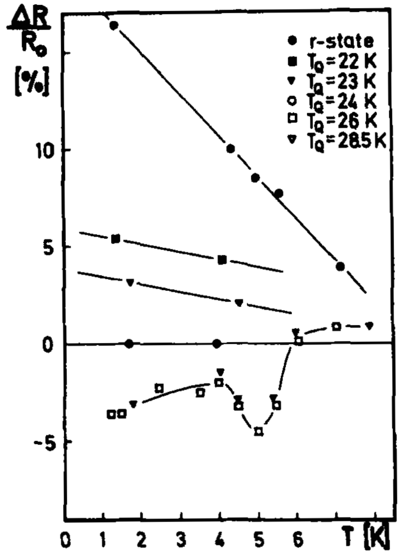

Fig. 5 Temperature dependence of the magnetoresistance $\Delta R/R_o = (R(8.6\ \mathrm{kG}) - R(o))/R(o)$ of $(TMTSF)_2ClO_4$ in various intermediate states and in a magnetic field that is roughly oriented along the a-axis. The lines are just a guide to the eye.

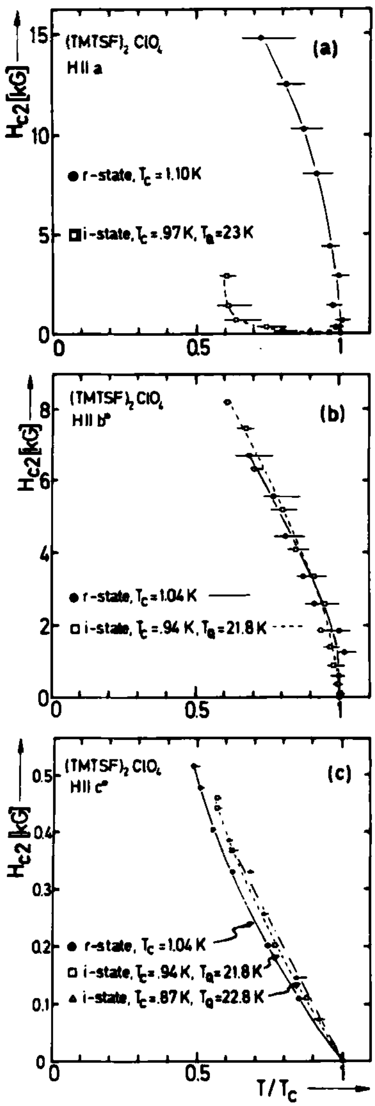

Fig. 2 Temperature dependence of the upper critical field H_{c2}- as determined from the ac-susceptibility- of $(TMTSF)_2ClO_4$ in the relaxed and various intermediate (i) states along the a, b^* and c^* directions.

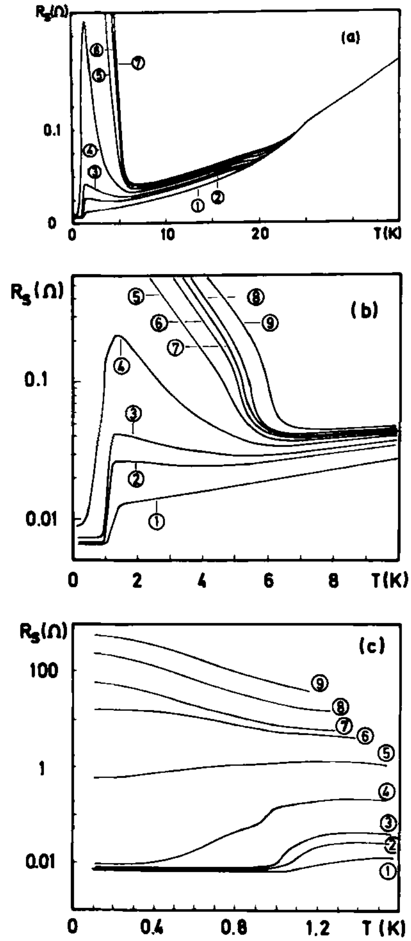

Fig. 4 Resistance vs temperature (taken upon slow warming) of $(TMTSF)_2ClO_4$ in states with various degrees of anion disorder, characterized by T_Q. ① to ⑨: T_Q=0 (relaxed state); T_Q=22 K; T_Q=23 K; T_Q=24 K; T_Q=24.5 K; T_Q=25 K; T_Q=26 K; T_Q=28.5 K; T_Q=35 K.

and $H_{c2c}{}^{*}$ for the relaxed and some intermediate states as determined from $T_c(H)$ (temperature sweeps in constant fields) via the ac-susceptibility are shown in fig. 2a, 2b and 2c. The fields in the ab plane are very reminiscent of thin film behavior ($H_{c2} \sim (T_c - T)^{1/2}$). The anisotropy in the b^*-c^* plane, $\varepsilon_{b^*c^*}$ is very temperature dependent whereas ε_{ab^*} is almost constant (fig. 3). These results are in contrast to H_{c2} data obtained from the resistivity /5/ that indicate temperature independent anisotropy for all three crystallographic directions. Details will be discussed in a forthcoming paper /6/.

The temperature dependence of the resistivity for several intermediate states is presented in fig. 4. The data are consistent with a model of an inhomogeneous mixture of superconducting and SDW regions /7/. Growing frozen disorder increases the size of the SDW regions at the expense of the superconducting regions. Superconducting regions in the sample in states with a high degree of anion disorder (T_Q>25 K) have been identified by the typical magnetic field dependence of the resistance at constant temperature. For the T_Q=35 K state we still detected a 5 % contribution of superconducting regions to the sample resistance, an indication of the fact that for a completely quenched state still much higher cooling rates would be necessary. At the percolation threshold (24 K<T_Q<24.5 K), no complete superconducting path through the sample exists any more.

The magnetoresistance in a field of 8.6 kG oriented roughly along a is shown in fig. 5. The negative magnetoresistance in states with a higher degree of frozen disorder is explained within the beforementioned model by the decreased probability of the carriers not to hit the interfaces between superconducting and SDW regions and thus reducing the scattering rate, when the cyclotron radius decreases in an increasing magnetic field. A calculation of the cyclotronradius within an isotropic free electron model of TCl in a field of 10 kG yields $r_c = 4.4 \cdot 10^{-6}$ m, which is an order-of-magnitude-wise estimate of the diameter of the superconducting and SDW regions and corresponds to several thousand lattice constants. A negative magnetoresistance in a state with a small degree of frozen anion disorder has previously been reported /8/, but with a different explanation, viz. the suppression of the SDW gap by the magnetic field.

REFERENCES

/1/ T. Takahashi, D. Jèrome and K. Bechgaard, J. Phys. (Paris) Lett. 43, L565 (1982).
/2/ S. Tomić, D. Jèrome, P. Monod and K. Bechgaard, J. Phys. (Paris) Lett. 43, L839 (1982).
/3/ J.P. Pouget, G. Shirane, K. Bechgaard and J.M. Fabre, Phys. Rev. B27, 5203 (1983).
/4/ H. Schwenk, K. Andres and F. Wudl, Phys. Rev. B29, 500 (1984).

/5/ R.L. Greene, P. Haen, S.Z. Huang, E.M. Engler, M.Y. Choi and P.M. Chaikin, Mol. Cryst. Liq. Cryst. 79, 183 (1982).

/6/ C.-P. Heidmann, H. Schwenk, K. Andres and F. Wudl, to be published.

/7/ H. Schwenk, K. Andres and F. Wudl, Phys. Rev. B27, 5846 (1983).

/8/ K. Murata, T. Ukachi, H. Anzai, K. Kajimura, T. Ishiguro and S. Saito, J. Magn. Magn. Mat. 31-34, 1145 (1983).