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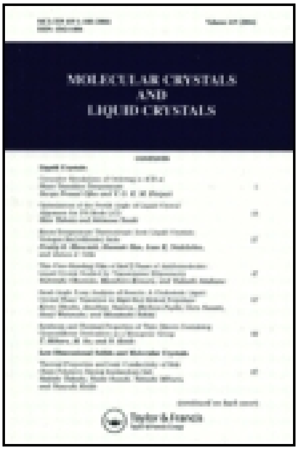

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Publication details, including instructions for authors and subscription information:
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Transverse Resistivity of $(TMTSF)_2PF_6$ and $(TKTSF)_2ClO_4$ in a Magnetic Field, Evidence for Kohler's Rule

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Version of record first published: 17 Oct 2011.

To cite this article: B. Korin-hamzić , L. Forró & J. R. Cooper (1985): Transverse Resistivity of $(TMTSF)_2PF_6$ and $(TKTSF)_2ClO_4$ in a Magnetic Field, Evidence for Kohler's Rule, Molecular Crystals and Liquid Crystals, 119:1, 135-139

To link to this article: http://dx.doi.org/10.1080/00268948508075147

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Mol. Cryst. Liq. Cryst. 1985, Vol. 119, pp. 135-139
0026-8941/85/1194-0135/$10.00/0
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TRANSVERSE RESISTIVITY OF $(TMTSF)_2PF_6$ AND $(TMTSF)_2ClO_4$ IN A MAGNETIC FIELD, EVIDENCE FOR KOHLER'S RULE

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Abstract - We report data for the c* axis resistivity of $(TMTSF)_2PF_6$ and $(TMTSF)_2ClO_4$ in magnetic fields of up to 70 kilogauss. The results are analysed in the form of Kohler's plots. Deviations from Kohler's rule can be used to detect the onset of magnetic ordering at low temperatures. In the PF_6 salt there are also deviations at higher temperatures which may be due to the breakdown of the band description of electron states.

Recently[1] it was shown that the resistivity of $(TMTSF)_2ClO_4$ crystals in the least conducting direction (ρ_{c*}) obeyed Kohler's rule (KR) from 2-22K in fields up to 70 kilogauss. This surprising result indicated that ρ_{c*} could be understood in terms of the usual Boltzmann equation picture developed for ordinary metals and also that transport along c* is coherent in the sense first discussed by Soda et al[2]. That is the condition:

$$t_\perp^c \gtrsim \hbar/\tau_\parallel \qquad 1)$$

is satisfied, where $t_\perp^c$ is the tight binding transfer integral and $\tau_\parallel$ the electron scattering time on a single chain. In this paper we report a study of KR for ρ_{c*} of $(TMTSF)_2PF_6$ and present evidence for deviations from KR which may be due to the coherent-diffusive transition as the temperature approaches 40K. We also compare ρ_{c*} of the PF_6 and ClO_4 salts and show how deviations from KR are associated with the magnetic phase transition in rapidly cooled, quenched (Q) ClO_4 crystals.

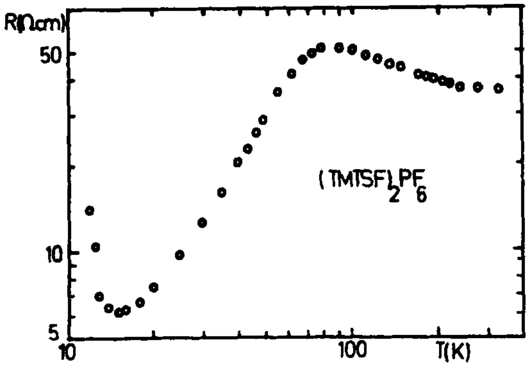

Fig. 1. Transverse resistivity (ρ_{c*}) versus temperature for a single crystal of $(TMTSF)_2PF_6$

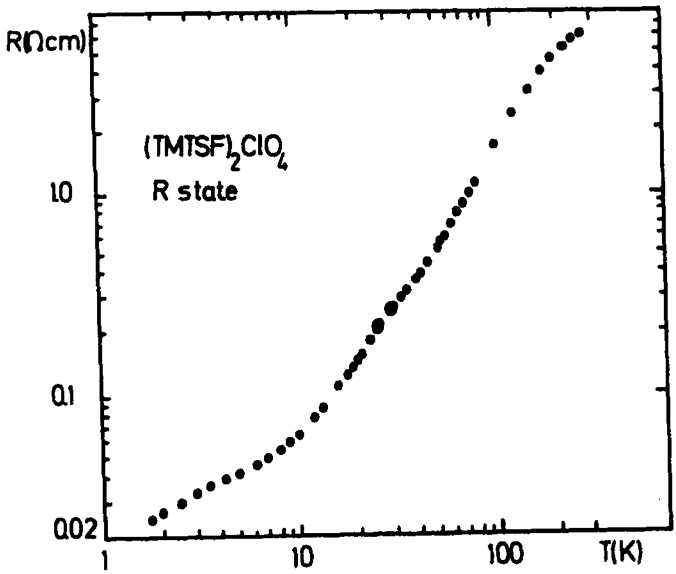

Fig. 2. Transverse resistivity (ρ_{c*}) versus temperature for a single crystal of $(TMTSF)_2ClO_4$, in the relaxed state

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Data for $\rho_{c*}(T)$ of PF_6 and ClO_4 salts are shown in Fig.1 and 2 respectively. They agree very well with independent studies (3,4). There are marked differences both in the magnitude and temperature dependences of ρ_{c*} for the two isostructural salts. As far as we know most other properties, e.g. lattice parameters, spin susceptibility and needle axis transport do not show such large differences.

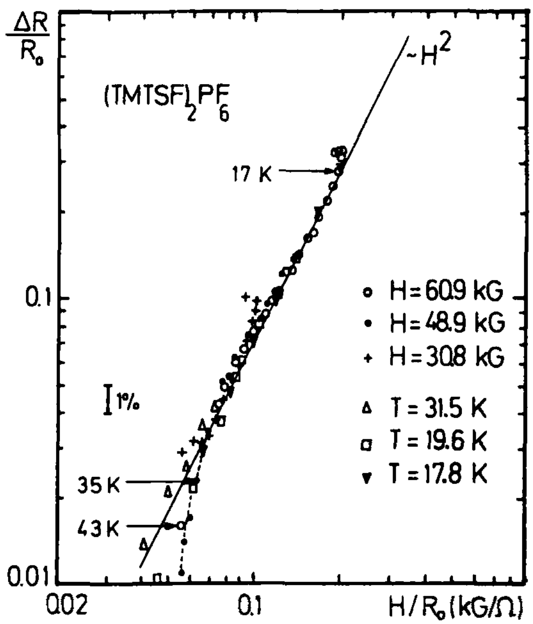

Fig. 3. Kohler's plot for the transverse resistivity (ρ_{c*}) of the same $(TMTSF)_2PF_6$ crystal as in Fig.1., with H ∥ b′

As shown in Figure 3 for H∥b′, ρ_{c*} obeys KR from 17 to 34K. Deviations at lower temperatures are due to the onset of the spin density wave transition and we believe those at higher temperatures are due to the breakdown in the 3D band picture as the scattering rate increases. Similar deviations have been observed in all three crystals studied.

Using the same analysis as before[1] we obtain a mean free path along $\underline{a}$ of 69a at 17K and hence (taking $t_{\parallel} = 0.3eV^{5}$) a relaxation time τ of 10^{-13} secs. Such a value of τ is consistent with the measured value of $\rho_{c*}(17)$ only if $t_{\perp}^{c}$ is as low as 0.2 meV. Although this value is smaller than the theoretical estimate[6] the value obtained in the same way for the ClO_4 salt is 7x larger and does agree with the calculation in ref.6. Note that the results in Figures 1 and 2 imply substantial differences in $t_{\perp}^{c}$ for the PF_6 and ClO_4 analogues.

At 34K where deviations from KR start, we find $\tau = 3.3\ 10^{-14}$ secs. This corresponds to $\hbar/\tau = 19$ meV, a value much nearer to $t_{\perp}^{b}$ (5) than $t_{\perp}^{c}$.

In Figure 4 are shown magnetoresistance data for $(TMTSF)_2ClO_4$ in the quenched state (50 seconds from 40 to 4.2K). Although the resistivity versus temperature shows only a smooth increase (inset), when the data are analysed as Kohler plots there are clear deviations from KR at 6K corresponding to the onset of SDW ordering. Using the same analysis as before we find $\tau = 2.5\ 10^{-13}$ sec and $t_{\perp}^{c} = 1.4$ meV at 6K. Within our accuracy ($\pm 5\%$) the latter value is the same in the relaxed and quenched states.

In summary we have shown that a Kohler's rule analysis may give useful information about the electronic properties of the Bechgaard salts. There appears to be evidence for deviations from KR due to the diffusive-coherent transition in the PF_6 salt near 40 K. But our analysis indicates that it occurs at much higher values of ρ_{c*} than those expected from equation (1).

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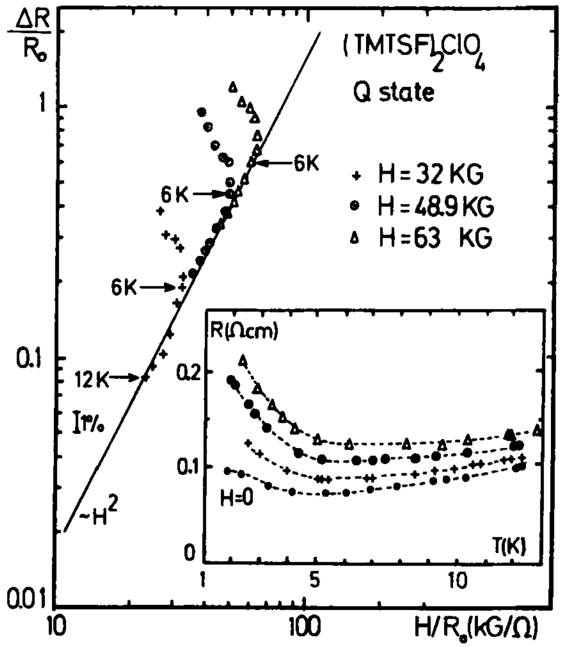

Fig.4. Kohler's plot for the transverse resistivity (ρ_{c^*}) of a quenched $(TMTSF)_2ClO_4$ crystal with H ∥ b'. The inset shows resistivity versus temperature in various magnetic fields.

We are grateful to Klaus Bechgaard (Copenhagen) and Alex Moradpour (Orsay) for the single crystals used in this work.

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