

# Conduction anisotropy of the Bechgaard salts

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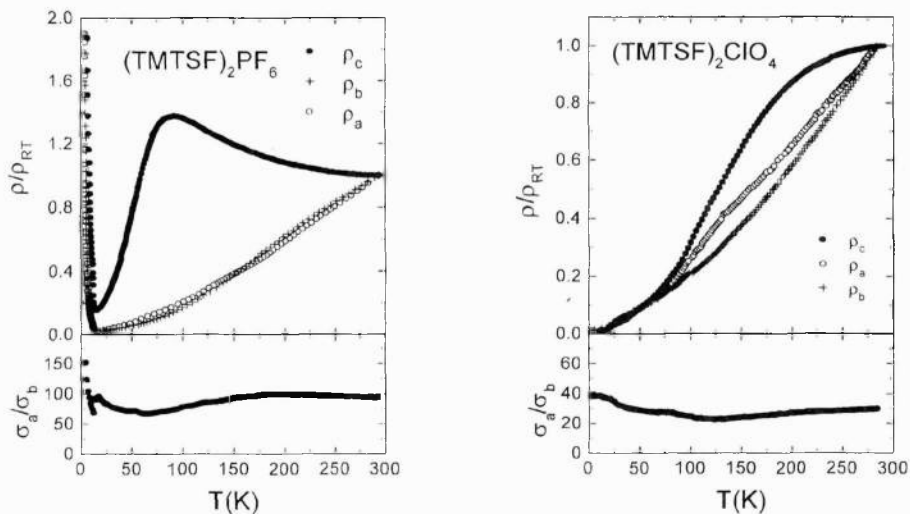
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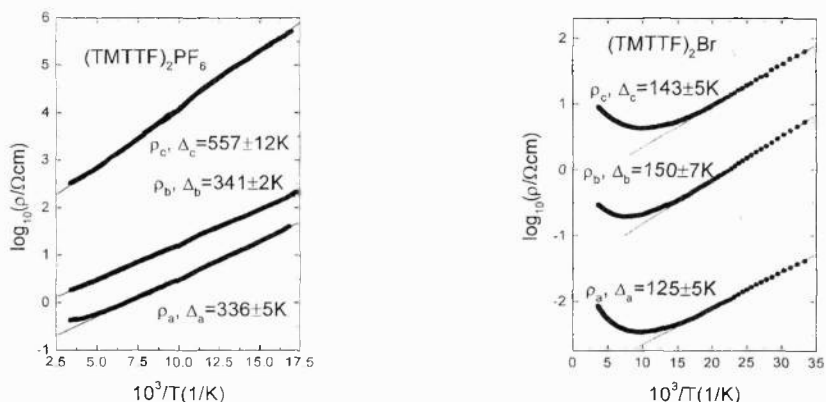
**Abstract.** We report the results of a systematic study on the temperature dependence of the normal state conductivity, measured along the a, b', and c\* axis, in a representative set of Bechgaard salts. The anisotropic electron transport of four compounds are compared:  $(\text{TMTSF})_2\text{ClO}_4$ ,  $(\text{TMTSF})_2\text{PF}_6$ ,  $(\text{TMTTF})_2\text{Br}$  and  $(\text{TMTTF})_2\text{PF}_6$ . We analyze the tendency, following this order of the compounds, of the metallic ab' plane conductivity change to a semiconductor like behavior, and we discuss the mechanism of inter- and intra-chain transport. The c\*-direction conduction is determined by the nature of the counter-ion and seems to be irrelevant in this comparison.

Some unusual properties of the correlated electrons in the Bechgaard salts raised recently the possibility of a Luttinger-liquid behavior even in the high-temperature metallic phase of these organic conductors[1-3]. In a strictly 1-d interacting electron system the Fermi-liquid picture certainly breaks down. However, in these compounds the interchain transfer is not negligible and transverse electron propagation should carefully be investigated. From this point of view the mechanism of the transport along the second most conducting direction (b') is a cardinal question. Besides the ab' plane anisotropy the third direction is also of importance, since (in absence of reliable b' results) some of the conclusions were previously drawn from measurements performed along the c\*-direction [1].

We have studied the temperature dependence of the resistivity along the a, b' and c\* axis in four compounds:  $(\text{TMTSF})_2\text{ClO}_4$ ,  $(\text{TMTSF})_2\text{PF}_6$ ,  $(\text{TMTTF})_2\text{Br}$  and  $(\text{TMTTF})_2\text{PF}_6$ . For experimental details see Ref [4]. The results obtained in the selenide compounds are presented in Fig. 1. The upper panels show the normalized resistivities on a linear scale, while the ab' anisotropy is displayed in the lower panels. The room temperature absolute values and the ratio of the conductivities are indicated in the figure captions.



**Figure 1:** The temperature dependence of the normalized resistivities measured along the various directions. The room temperature conductivity ratios are 620:7:0.04 and 700:24:0.3 for the  $\text{PF}_6$  and  $\text{ClO}_4$  salts, respectively.



**Figure 2:** The temperature dependence of the normalized resistivities measured along the various directions. The room temperature conductivity ratios are 100:2:0.009 and 110:3:0.01 for the PF<sub>6</sub> and Br salts, respectively.

For the sulfur compounds the Arrhenius plots of the temperature dependence of the resistivity is shown in Figs. 3-4. Note that in contrast to the general expectations, the *ab'* anisotropy of (TMTTF)<sub>2</sub>PF<sub>6</sub> is slightly lower than that of (TMTSF)<sub>2</sub>PF<sub>6</sub>. The room temperature *a*-axis resistivities are about 10 times higher in the sulfur compounds than in the selenide based salts, and at low temperatures their  $\rho(T)$  curves are activated.

Discussing the results, first we recall that there is a definite order of the four compounds on the generic phase diagram of the Bechgaard salts [2]. In spite of this, no systematic tendency was found in the temperature dependence of the *c*\*-direction resistivity [see for example (TMTSF)<sub>2</sub>PF<sub>6</sub> and (TMTTF)<sub>2</sub>Br]. Since the conducting channels are separated by the counter-ion along this direction, we believe that details of  $\rho_c(T)$  are to be attributed to the molecular properties of the particular anions.

The almost temperature independent *ab'* anisotropy in the selenide compounds suggests that no dimensionality crossover occurs in the temperature range investigated. Therefore the picture of a high temperature incoherently coupled non-Fermi liquid chains is not supported by our experiments. In terms of the relaxation time ( $\tau$ ) and the transverse transfer integral ( $t_b$ ) the loss of the coherence between the conducting chains occurs whenever  $\hbar/\tau \gg t_b$ . At the same time, the coherent *a*-direction propagation assumes  $t_a \gg \hbar/\tau$ . In the Bechgaard salts the conduction anisotropy suggests  $t_a/t_b \approx 6-10$ , and we believe that the resulting narrow range for  $\tau$  prohibits the coexistence of coherent in-chain and incoherent interchain transport. We conclude that the anisotropic electron transport in the selenide compounds is fully consistent with the Fermi-liquid theory in the whole temperature range investigated.

In the sulfur compounds the lower value of the transfer integrals is not accompanied with a higher *ab'* anisotropy. The temperature dependence of the conductivity suggests diffusive conduction of Mott-localized states in all directions. Note that the positions of the smooth minimum in the resistivity observed along the various directions in (TMTTF)<sub>2</sub>Br are well correlated with the activation energy observed at low temperatures, i.e. the metallic like conduction emerges when the thermal energy exceeds the barrier height.

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## References

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