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LETTER TO THE EDITOR

Effect of controlled disorder on the transverse conductivity of TTF–TCNQ

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Abstract. Measurements are presented of the transverse conductivity of TTF–TCNQ at room temperature under x-ray irradiation conditions. The conductivity decreases with irradiation dose without any saturation effect.

In this Letter we introduce the first measurements of the effect of irradiation-induced defects on the *transverse* conductivity of TTF–TCNQ (tetrathiafulvalene–tetracyanoquinodimethane) in its *metallic* regime. The transport properties of this metallic state have been of considerable interest in recent years (see, for example, the proceedings of the Dubrovnik conference on one-dimensional conductors, 1978), because of its highly anisotropic character. Of special interest are recent experiments by Chiang *et al* (1977) which show clearly the important role of structural defects on the longitudinal resistivity. In these experiments the concentration of defects was controlled by irradiation of the samples with a deuteron beam of total flux up to 5×10^{14} cm^{-2}. As a result of the irradiation, the resistivity $\rho_{\parallel}$ increased and then saturated at a value of about twice the original pure-limit value. However, there has been no experimental information on the effect of radiation-induced defects on the transverse conductivity $\rho_{\perp}$. The need for this information has been increased since the proposal of libron-drag mechanism (Kaveh *et al* 1978) to explain the transport properties of TTF–TCNQ and the effect of defect concentration on these properties.

We report here our results for the effect of controlled disorder (through irradiation-induced defects) on the transverse conductivity in the metallic regime of TTF–TCNQ. The radiation damage was produced by a 'Rigaku' x-ray machine. This machine produces 4×10^{14} photons kW^{-1} s^{-1}, of which half are 8 keV Cu K radiation. We operated the machine at a power of 15 kW. To avoid damage from machine vibrations, the crystals were hung a few mm above the Be window, about 10 cm from the target, without touching the x-ray machine. Under these conditions the photon flux through the sample is about $1{\cdot}5\times10^{16}$ photons cm^{-2} h^{-1}. For a typical sample about 3×10^{12} photons h^{-1} impinge on the crystal, 10% of which are absorbed.

The electrical resistivity was measured by the standard four-probe method. The resistivity of each sample was measured at room temperature before irradiation and then after 10–15 h of irradiation. In order to avoid possible temperature-cycling damage the temperature dependence of $\rho_{\perp}$ was measured only twice, before the irradiation and after the last irradiation stage. The ratio of $\sigma_{\perp}^{max}$ to $\sigma_{\perp}$(RT) was found to be about 2.

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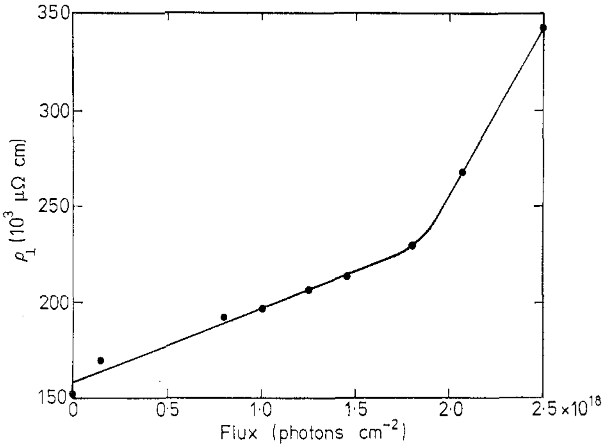

Figure 1. The transverse resistivity at room temperature as a function of photon flux.

During the intermediate stages, only room temperature values of $\rho_\perp$ were taken. The dependence of $\rho_\perp$(RT) on defect concentration is shown in figure 1. As can be seen from this figure, $\rho_\perp$(RT) increases slowly with irradiation. For a dose of 10^{18} cm^{-2} $\rho_\perp$(RT) increases by about 25%. An important point which is obviously seen in this figure is the absence of a saturation effect in $\rho_\perp$, in contrast to the situation for $\rho_\parallel$. Another interesting feature is that the monotonic increase in $\rho_\perp$(RT) consists of *two* regions. For heavily radiated samples $\rho_\perp$(RT) is increased more rapidly than for low-dose-irradiated samples.

The strong coupling between the electrons and the librons which 'drags' the librons from equilibrium (Kaveh *et al* 1978) causes an increase of the conductivity of the pure samples. By irradiation, one produces many defects which serve to return the librons to equilibrium via the libron–defect interaction, and thus the drag effect is quenched and the conductivity decreases. For strongly irradiated samples the librons equilibrate rapidly through the libron–impurity interaction, implying a saturation effect. However, it is to be noted that this drag-mechanism is valid only for the longitudinal resistivity $\rho_\parallel$. Perpendicular to the chains the conductivity is diffusive in character since the mean free path of the electrons in this direction is only a fraction of the distance between chains. Thus, the effect of structural defects, which is so dramatic for the conductivity along the chains, should be unimportant perpendicular to the chains. In particular the saturation effect is, according to the libron-drag theory, unique and typical for the longitudinal conductivity alone. This is confirmed by the lack of saturation effect in the transverse measurements.

The change of slope in $\rho_\perp$ hints that more dramatic damage occurred in heavily irradiated TTF–TCNQ samples. Since $\rho_\perp$ is expected to be influenced by the behaviour of $\rho_\parallel$ (Weger 1978, Seiden and Bloch 1979), similar dramatic changes are expected for $\rho_\parallel$.

In conclusion, our measurements indicate that $\rho_\perp$ depends on defect concentration in different ways than $\rho_\parallel$. Thus, in addition to the known dependence of the anisotropy ratio $\rho_\perp/\rho_\parallel$ on temperature, we have shown a dependence of this ratio on defect concentration.

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