Magnetic field influence on the spin-density wave of the organic conductor (TMTSF)₂NO₃

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Abstract. - We present the influence of a transverse magnetic field on the spin-density wave (SDW) ground state of the organic conductor (TMTSF)₂NO₃. Magnetic field increases the single-particle activation energy. A finite magnetic field (H_C) induces discontinuities in the magnetoresistance behaviour and its value is temperature dependent. The threshold electric field (E_T) for the SDW sliding increases in a magnetic field. All observed effects are strongly angle-dependent indicating that they are determined by the magnetic field component along the least-conduction (c^*) direction. We discuss these results in the framework of a theoretical model for the SDW with large imperfect nesting.

1. Introduction.

The Bechgaard salts are materials characterized by rather high anisotropy and important Coulomb interaction at low temperatures. These two properties present necessary ingredients for the stabilization of spin-density wave (SDW) ground state [1]. The model examples are the PF₆ and AsF₆ compounds in which the perfect nesting of the Fermi surface could be achieved with the wave vector $\mathbf{q} = (2k_F, \pi/b)$. The SDW phase ($T_C \approx 11\text{K}$) behaves as an antiferromagnet and is semiconducting with the well defined BCS activation energy ($\Delta = 21\text{K}$). The translatory displacement of a collective SDW phason mode gives rise to the additional electrical conduction channel similarly as in the charge-density waves (CDW) [2]. An interesting behaviour arises when a magnetic field is applied in the plane perpendicular to the best-conduction (a) direction [3, 4, 5]. If the ground state is superconducting and once the normal phase is restored, the deviation from the perfect nesting becomes a relevant parameter. Then, further increase of the magnetic field leads, through the orbital coupling, to a unique series of transitions into different field-induced SDW (FISDW) phases. The same mechanism also causes the decrease of the SDW coherence length which should induce an increase of the threshold electric field for the SDW sliding. Effects

on the SDW activation energy and the transition temperature are expected, as well [6].

The purpose of this paper is to review and discuss experiments performed in order to reveal the theoretically expected orbital influence of the transverse magnetic field on the SDW phase with large imperfect nesting [7, 8]. The material is the NO_3 compound which, at low temperatures, contains ordered anions with the longitudinal wave vector $(2k_F, 0, 0)$.

2. Static properties of the SDW phase.

The SDW transition temperature is 9K, the activation energy is rather low ($\Delta \approx 5\text{K}$) and non-uniform over the Fermi surface indicating the ground state might be semimetallic, rather than semiconducting (see Fig.1.). We estimate the deviation from the perfect nesting to be in between 0.8 and 0.97. The applied magnetic field increases the activation energy and this effect is angle dependent. Par exemple, the 6 tesla magnetic field along c^* axis (the low conduction direction) increases the slope

Fig 1. Logarithm of the resistance ($\log R$) versus inverse temperature ($1000/T$). Full and dashed line for zero and 6 tesla magnetic field, respectively.

Fig 2a. Magnetoresistance ($\Delta\rho/\rho(0)$) at 1.8K for several field (H) orientations.

Fig 2b. Derivation of the resistance (dR/dH) for several field (H) orientations.

of the Arrhenius plot by about 55% ($\pm 10\%$), while there is virtually no effect for H along b' axis (the intermediate direction). As far as the increase of T_C with H is concerned, we could not detect a change larger than the experimental error.

Magnetoresistance sweeps taken at $T=1.8\text{K}$ have discontinuities at the positions which depend on the field orientation (Fig.2.a.). They become clearly visible in the plots of the resistance derivative (dR/dH) versus field (Fig.2.b.). From these plots we can define a critical field (H_C). The angular dependence of H_C is given in Fig.3. The critical field display the $\cos\theta$ dependence, revealing the orbital origin of the phenomenon. We note that observed H_C values differ between samples with different rr ($rr = \rho_{RT}/\rho_{min}$, where ρ_{RT} and ρ_{min} are the resistivities measured at room temperature and 11.5K , respectively). In particular, the best resistivity ratio sample had the lowest critical field. This finding indicates the importance of the scattering of electrons by defects and impurities. Hereabove data strongly suggest a phase transition induced by magnetic field inside the SDW phase with large imperfect nesting. We are tempted to propose that the nature of a field-induced phase is similar as of the FISDW phases established in the PF_6 and AsF_6 systems at high pressure. Further experiments are under a way to test this possibility.

Fig 3. Angular dependence of the critical magnetic field (H_C).

Fig 4. Normalized threshold field $[E_T(H)/E_T(0)]$ versus magnetic field (H) at 1.8K

Fig 5. Function $[f_1(x)/f_1(0)]^{-1}$ (full line) and the normalized longitudinal coherence length $[\xi_a^*(x)/\xi_a^*(0)]$ (dashed line) versus magnetic field ($H\cos\theta$) for several values of the imperfect nesting parameter (ϵ_0/Δ_0).

3. Dynamics of the SDW.

It is now well established that the translation mode of the SDW couples to an applied electric field and gives rise to an additional contribution to the electrical conductivity. Overall data have shown similar behaviour as in CDW. Searching for particular features of the SDW, we have looked for the influence of the transverse magnetic field on the SDW motion. The threshold electric field (E_T) was found to increase and the magnitude of the rise was angle dependent (Fig.4.). Again, the c^* component of the magnetic field revealed to be a crucial one.

The orbital coupling of the SDW with the external magnetic field is theoretically expected to decrease the SDW coherence length and therefore increase E_T . However, measurements in the SDW phase with perfect nesting have not detected any effect. It turns out that a necessary ingredient which also causes a decrease of the longitudinal coherence length (as well as the transverse length) is the imperfect nesting. This gives rise to rather important and thus measurable effects (Fig.5.). In particular, the magnitude of the effect directly probes the degree of the imperfect nesting.

4. Conclusion.

We have presented some interesting features of the spin-density wave phase with large imperfect nesting in the transverse magnetic field. Changes of the order parameter, phase coherence length and low electric field properties reveal the orbital coupling of the SDW and the magnetic field to be in the origin of the observed effects.

References

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