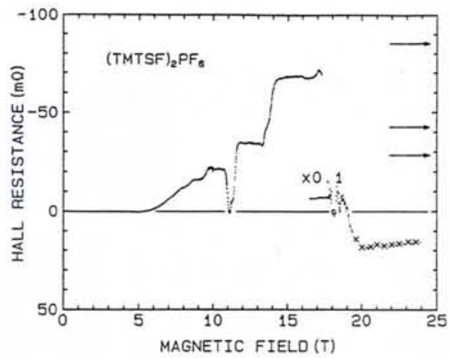
HIGH MAGNETIC FIELD RESEARCH

Field Induced Phase Transitions in Quasi One-Dimensional Metals

Bechgaard Salts are members of the tetramethyl-tetraselenafulvalenium family, denoted as [$(TMTSF)_2X$], and crystals of this material for different compounds X are made of linear conducting chains with a weak coupling between the chains. Consequently, the conduction bandstructure is highly anisotropic, *i.e.*, the bands are almost completely flat in the *c*-direction, slightly dispersive in *b*-direction and almost free-electron like in the third *a*-direction. The Fermi surface resembles therefore a set of slightly warped, almost parallel sheets.

When a magnetic field is applied parallel to the *c*-direction, carriers moving in the *a-b* plane cannot describe a closed orbit on this Fermi surface, and the only possible movement is along the sheet of the Fermi-surface in one or in the opposite direction.

It has been shown theoretically that the application of a magnetic field to such systems effectively makes the carrier motion completely one-dimensional. A well known theorem in solid state physics states that a fully one dimensional system with a certain carrier density is unstable under the formation of a spin density wave. Since, in this particular case, the instability is the result of the application of an external field it is referred to as a field induced spin density wave (FISDW) which opens a gap in the energy spectrum around the Fermi energy. Field induced symmetry breaking has the important effect of introducing two characteristic lengths, namely the period of the FISDW and the magnetic length.



The Hall resistance at 0.5 K as a function of the magnetic field along the c-axis for a $(TMTSF)_2PF_6$ single crystal using different contact points. The quantized values of $h/2ne^2$ are marked on the right [Cooper J.R. et al., Phys. Rev. Lett. ***63*** *(1989) 1984].*

Experimentally, the Hall resistance of $(TMTSF)_2PF_6$ samples at low temperatures and high fields show characteristic plateaux with values of the Hall resistance in the vicinity of $h/2\,ne^2$, with $n = 1,2,3...$(see the figure). These plateaux occur at magnetic fields B with a $1/B$ periodicity typical of magnetic quantum oscillations. The Hall plateaux bear a strong similarity to those observed in the quantum Hall effect which are explained by pinning of the Fermi energy on localized states in the gaps between Landau levels.

For the Hall plateaux observed in Bechgaard salts, the idea of the pinning of the Fermi energy is retained in much the same way, but its physical origin is believed to lie in a continuous adjustment of the wavevector of the FISDW to the magnetic length, thus minimizing the energy. At a certain field, the wavevector changes abruptly from n to n-1 times the magnetic length when this is energetically more favorable: this jump is accompanied by a spike in the Hall resistance which precedes the next plateau. The experimental results thus confirm and extend the theoretical concepts.

Although many questions concerning this peculiar behaviour of Bechgaard salts remain unanswered, it is fairly well established that a new magnetic field induced phase has been discovered. This example substantiates the belief that many fascinating discoveries in high magnetic fields are still ahead of us.

J.C. Maan, *MPI, Grenoble*