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MAGNETIC FREEZE-OUT IN n - TYPE $Hg_{1-x}Cd_xTe$ ($0.18 < x < 0.34$) : THE METAL - NON METAL TRANSITION*

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Magnetic freeze-out has been observed in $Hg_{1-x}Cd_xTe$ ($0.18 \leqslant x \leqslant 0.34$). The Hall coefficient and the resistivity in longitudinal and transverse configuration of samples with an excess donor concentration at 77 K, lying between 3×10^{20} and 8×10^{21} m^{-3} have been investigated in the temperature range 2.5 K - 10 K. The different conduction processes occuring in presence of magnetic field in this temperature range, are discussed. For the most doped sample we have observed a transition between degenerate statistic, in weak magnetic field (Shubnikov-de Hass effect) and non degenerate statistic in high magnetic field (freeze-out effect). The magnetic field dependence of the activation energy is deduced from the analysis of freeze-out effect.

The mixed II-VI compound $Hg_{1-x}Cd_xTe$ seems to be a favourable material to observe magnetic freeze-out (low value of the electron effective mass). However at this time no evidence of this phenomenon has been shown. Dornhaus et al [1] have performed galvanomagnetic experiments on pure n-type $Hg_{0.8}Cd_{0.2}Te$ samples of high mobility. From their experiments, they deduced that neither thermal (at temperature down to 50 mK) nor magnetic (magnetic fields up to 6 T) freeze-out of carriers take place in these samples.

In this paper, experiments of magnetic freeze-out in magnetic field up to 200KG, performed on five samples of n-type $Hg_{1-x}Cd_xTe$ ($0.18 \leqslant x \leqslant 0.34$) are presented. The conduction processes occuring in presence of magnetic field in the temperature range 2.5 K - 10 K are discussed. For the samples the most doped, a transition between degenerate statistic and non degenerate statistic is observed. The temperature dependence of the carrier concentration as a function of the magnetic field is derived. The activation energy of the "purest" sample is presented.

1. Experimental procedure

The investigated samples have a parallelepipedic shape and have been well etched before soldering of ohmic contacts. All the measurements have been performed in the ohmic region. The characteristics of the samples are given in table(1)

Table 1 characteristics of the investigated samples

Samples	x(%)	E_G(4.2K;meV)	N_D-N_A(77K;m^{-3})	$K=N_A/N_D$	N_c(Mott criterion;m^{-3})
N.38.B	18.2	40	3×10^{20}	0.9	1.3×10^{18}
N.38.B'	18.2	40	3×10^{20}	0.9	1.3×10^{18}
N.3.B	23.4	130	5×10^{20}	1	5.6×10^{19}
CHT.38.7	25	150	8×10^{21}	0.5	10^{20}
16.23.B	34.4	320	4.5×10^{20}	0.96	10^{21}

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For the samples N38 the excess donor density at 77 K is equal to the intrinsic carrier density. The carrier density of the sample 16.23.B is smaller than the critical one corresponding to the metal-non metal transition deduced from the Mott criterion ($N_c^{1/3} x a_B \simeq 0.25$).

The resistivity in both configurations (longitudinal $\rho_{//}$ and transverse $\rho_{\perp}$) and the Hall coefficient R_H have been measured to obtain the components of the conductivity tensor.

To get the free carrier density n in the conduction band, we have used the general expression of the conductivity tensor σ_{xx} and σ_{xy} [2]. Neglecting the conduction of the frozen-out electrons to the σ_{xy} component we have in the high magnetic field range :

$\sigma_{xy} = \frac{ne^2}{m^* \omega_c}$ in which ω_c is the cyclotron frequency and

$$n = \frac{R_H B^2}{e(\rho_{\perp}^2 + R_H^2 B^2)}$$

2. Analysis of the experimental results

To identify the conduction processes, we have determined the σ_{xx} and σ_{xy} components of the conductivity tensor.
We have plotted the logarithm of the σ_{xx} component versus 1/T for the sample 16.23.B (Fig 1). An activation energy seems to appear even in low magnetic field range. The existence of an ε_2 process is doubtful since no common intercept at 1/T = 0 of the curves $\log\sigma_{xx}$ and $\log\rho_{//}$ (Fig 2) versus 1/T is observed 2 .

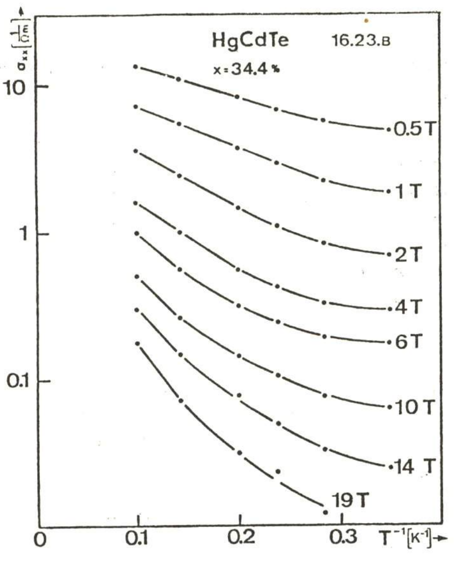

Fig 1 σ_{xx} component versus 1/T for sample 16.23.B

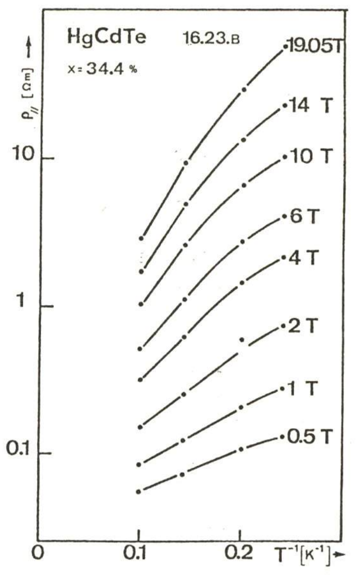

Fig 2 longitudinal magnetoresistance versus 1/T for sample 16.23.B

Considering that the conduction takes place in the conduction band, we have plotted (Fig 3) the log $nT^{-1/2}$ versus 1/T in order to calculate the activation energy E. The well known formula is used

$$\frac{n(N_A + n)}{N_D - N_A - n} = \frac{N_B}{2} \exp\left(-\frac{E}{kT}\right) \quad \text{with } N_B = (2\pi m^* kT)^{1/2} \frac{eB}{h^2}$$

The magnetic field dependence of the energy E of this sample is presented on Fig(4).

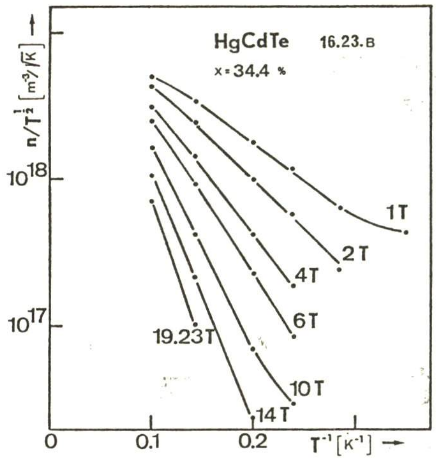

Fig 3 log $n/T^{1/2}$ versus 1/T for sample 16.23.B

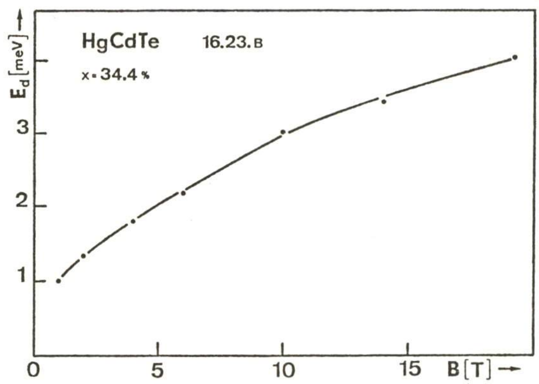

Fig 4 Magnetic field dependence of the activation energy for sample 16.23.B

We can notice that the character of this variation is similar to the Y.K.A. theory [3] but the values are much smaller.
The same plots log $nT^{-1/2}$ versus 1/T have been reported for the others samples (N.38.B - N.38.B'-N.3.B) (Fig 5-6-7).

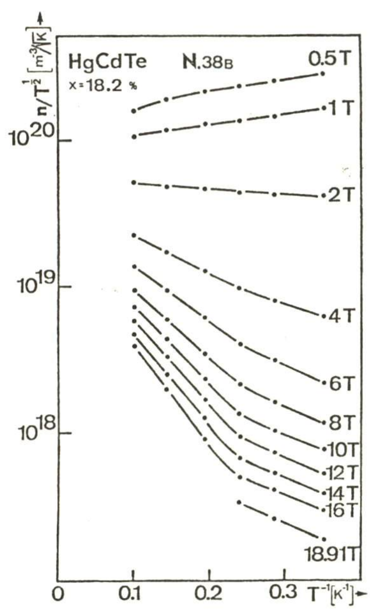

Fig 5 log $n/T^{1/2}$ versus 1/T for sample N.38.B

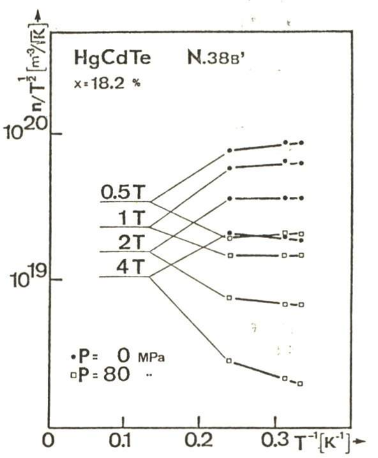

Fig 6 log $n/T^{1/2}$ versus 1/T for sample N.38.B'

It is worthwhile noticing that in the low magnetic field range the behaviour of these last samples is metallic. A transition between the metallic to the non-metallic state is observed when the magnetic field is increased.

As expected, the activation energy increases with the magnetic field.

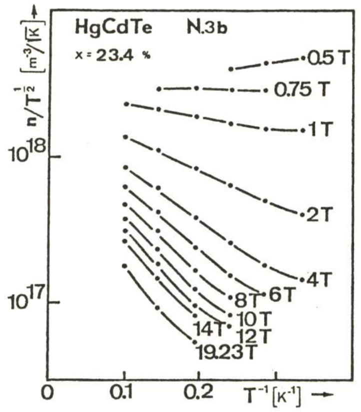

Fig 7 log $n/T^{1/2}$ versus 1/T for sample N.3.B

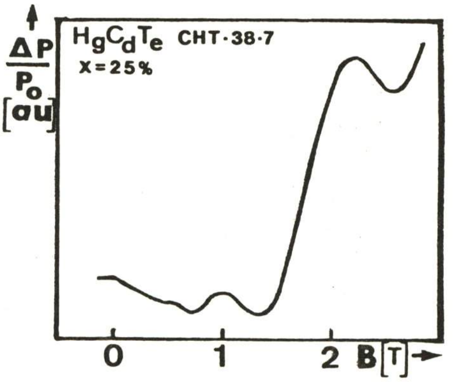

Fig 8 Transverse magnetoresistance in degenerate statistic(SdH.osc.)for sample CHT.38.7

For sample N.38.B', experiments have been performed also under hydrostatic pressure (Fig 6).The magnetic field induced metal-non metal transition without pressure appears when the magnetic induction is larger than 2 T. This transition occurs for lower magnetic induction when a pressure is applied. (B = 1T for P = 80 MPa). Similar experiments have been performed on the most doped sample (CHT.38.7). In the low magnetic field range magnetoresistance oscillations have been observed (Fig 8), which show the genuine metallic character of the conduction. As it has been mentioned on n-type InSb, magnetic freeze-out is observed in the high magnetic field range.

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