Using galvanomagnetic effects, the behaviour of substitutional impurity and Hg-vacancy acceptor states is investigated at low temperature on HgTe and HgCdTe within the semimetal-to-semiconductor transition induced by hydrostatic pressure. A qualitative understanding of the experimental results is provided by a theoretical study starting with the Koster-Slater theory extended to the zero-gap configuration and using a potential highly localized on the scattering center site.

1. INTRODUCTION

The electronic structure of acceptor states in semiconductors (hereafter SC) is usually depicted by discrete levels lying in the band gap. In materials with symmetry of the diamond-zinc blende type, relativistic effects together with the degeneracy rules of the cubic symmetry may lead to an electronic structure configuration with no bandgap between the conduction and valence bands. In this situation, exemplified by α-Sn, HgTe and HgCdTe alloys, the resulting interference of impurity states with a quasi-continuum of extended band states has been studied theoretically [1,2]. Experimental evidences of resonant acceptor states were reported in HgTe and HgCdTe with alloy compositions corresponding to the semimetal configuration (hereafter SM) [3-10]. In this work, the extrinsic properties of p-type HgTe and Hg$_{1-x}$Cd$_x$Te within the SM → SC transition induced by hydrostatic pressure are investigated.

2. EXPERIMENTAL RESULTS

Galvanomagnetic data (obtained in the ranges 1.7-4.2°K, 0-10KG and 0-8Kbar) are analyzed by fitting the magnetic field (B) dependence of the Hall coefficient $R$, at each pressure, according to a two-carriers expression of $R$, as

*Acceptors are due to Cu impurities, observed in the range 0.1 - 1 at. ppm and to mercury vacancies $V_{Hg}$ produced by controlled non-stoichiometry.
FIG.1: Fit of non-oscillating part of the reciprocal relative variation of the Hall coefficient using a two-carriers expression: two sets of electrons, $n_1 = 8 \times 10^{14} \text{cm}^{-3}$, $\mu_1 = 4.3 \times 10^5 \text{cm}^2/\text{Vs}$; $n_2 = 7 \times 10^{14} \text{cm}^{-3}$, $\mu_2 = 9 \times 10^5 \text{cm}^2/\text{Vs}$

FIG.2: Galvanomagnetic data vs. pressure of Hg$_{1-x}$Cd$_x$Te; $P_c$: Transition SM$\rightarrow$SC.

illustrated by FIG.1. In addition, useful informations are obtained from an observation of quantum oscillations on the curves $R(B)$ and magnetoresistance vs. $B$: for example a good determination of the pressure coefficient of the negative $\Gamma_0 - \Gamma_8$ gap $E_g$ in HgTe at 1.7°K, $dE_g/dP = +8 \pm 0.5 \text{meV/Kbar}$.

Whereas the pressure dependence of $R$ at low $B$ gives a direct evidence of the pressure-induced SM$\rightarrow$SC transition as illustrated on an alloy HgCdTe with $x = 0.14$ (FIG.2), a subsequent analysis (through the magnetic field variation studies) is needed to show an experimental evidence of the resonant configuration of acceptor states $A_0$ and $A_1$ corresponding respectively to Cu$[5,6,10]$ and to $V_{Hg}[3,5,8,9]$. The main results concerning heights $E_A$ of virtual states (zero energy is at the band degeneracy point $\Gamma_8$) and widths of resonances $\Delta E$, are the following $[11]$:

(i). From magnetic field variation studies of $R(B)$, a two-carriers analysis shows that both electrons and holes are present for $x = 0.14$ at 4.2°K. A plot of their concentrations, through $p-n$ vs. $P$, with $p-n = N_{A1} - N_{D}$ and $N_{A1} = N_{A1} \times [1+4 \exp \left\{ \frac{(E_{A1} - E_F - E_g)}{kT} \right\}]^{-1}$, $(e = 0$ in the SM case and $e = 1$ in the SC one), indicates a strong upward shift of $A_1$ induced by pressure. This is illustrated by FIG.3 showing the relative position of $E_{A1}$ and Fermi level $E_F$.

(ii). Using a theoretical study of ionized impurity scattering appropriate to the SM$\rightarrow$SC transition $[11]$, the experimental electron mobility data (FIG.2) can be fitted with a calculated curve (labelled 2 in FIG.4), taking into account of the de-ionization of charged centers (i): in FIG.4, where $N_{cc}$ accounts for the concentration of ionized acceptors $N_{A1}$ and donors $N_{D}$, the agreement is good with $N_{cc} = 4 \times 10^{14} \text{cm}^{-3}$, except around $P = 3.7 \text{Kbar}$ where $E_F = E_{A1}$ (FIG.3). Within this pressure range, the observed feature is attributed to a pressure-induced