HALL EFFECT IN $p-CuInTe_2$ CRYSTALS

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Abstract

The temperature dependences of hole concentration and hole mobility in $CuInTe_2$ *crystals have been determined in the temperature range* $T = 80 \div 400\ K$ *studying the Hall effect by using the Van der Paul method. It is found that these dependences are controled by the acceptors with energy ionization* $E_A = 15\ meV$ *and concentration* $N_A = 7.72\ 10^{17}\ cm^{-3}$.

1. INTRODUCTION

$CuInTe_2$ belongs to the $I-III-VI_2$ family of chalcopiryte semiconductors, it has received an increasing amount of attention recently due to its potential for opto – electronic application [1-3]. $CuInTe_2$ has a direct band gap of about 1 eV at 300 K [4], and there are few reports of the $CuInTe_2$ properties.

The results of a study of Hall effect of the $p-CuInTe_2$ crystals grown from the melt by the horizontal Bridgman method are presented and discussed in this work. The melt contained stechiometric quantities of Cu, In and Te with small excess of Te. The $p-CuInTe_2$ monocrystalline platers of size 5x5x0,3 mm^9 were cute off from crystal ingot of $CuInTe_2$, and then they were mechanically polished and etched in $H_2SO_4 : K_2Cr_2O_7$ water solution. Because the thermoelectric power measurements showed that the crystals obtained in this way were p-type so the ohmoc contacts were prepared by vaccum evaporation of gold.

Measurements of resistivity and Hall voltage were taken in the temperature range 100-400 K using Van der Paul method. Fram these measurements the temperature dependence of the hole mobility $\mu_p(T)$ and the hole concetration p(T), the compensation degree N_A / N_D (where N_A and N_D are acceptor and donor

concentrations respectively) the activation energy E_A for the crystals, and the concentracion N_I of ionized impurities were determined.

2. RESULTS

Hall mobility μ_p versus temperature is shown in Fig. 1.

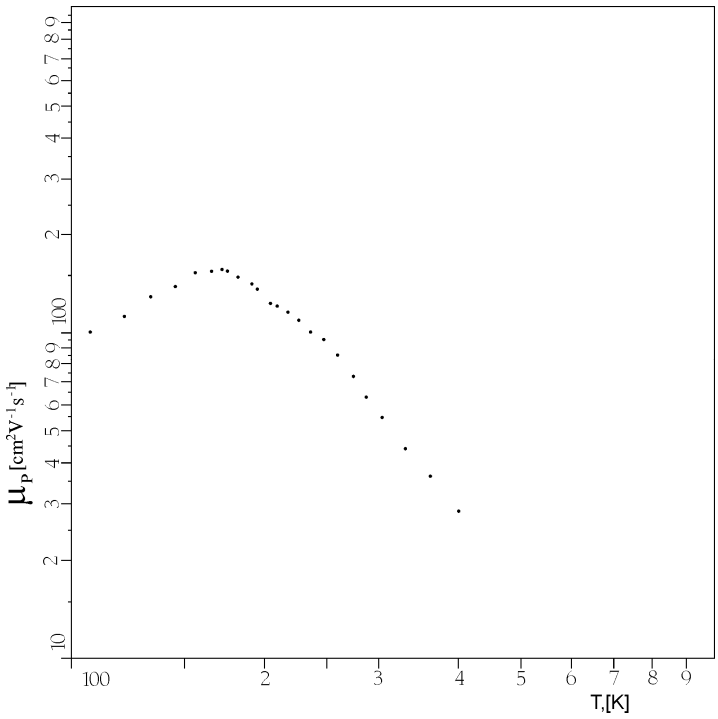

Figure 1. Hole mobility μ_p as a function of temperature for $p-CuInTe_2$ crystal.

The mobility characteristic was analyzed according to the contributions of the different scattering mechanisms. At low temperatures μ_p is proportional to $T^{3/2}$ which indicates the ionized impurity scattering mechanism [5]. In the high temperature range μ_p is proportional to $T^{-3/2}$ as expected for the scattering mechanism of phonons [6].

The temperature dependence of the measured hole concentration p(T) [Fig.2] was analyzed by using of theoretical formula:

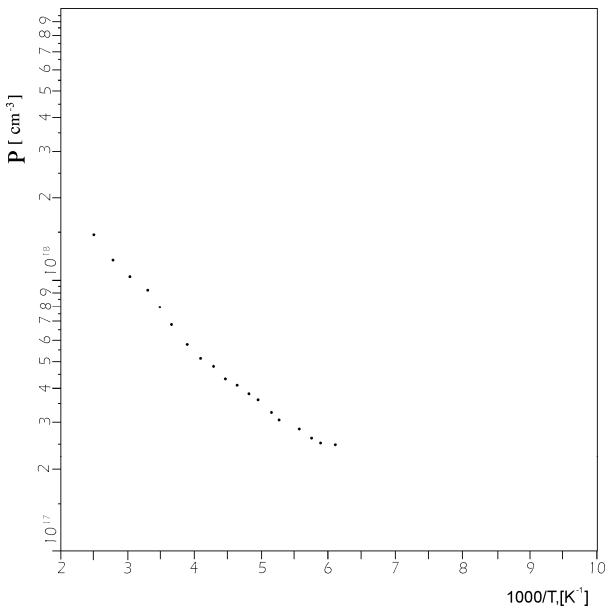

Figure 2. Hole concentration **p** as a function of reprocal temperature for $p-CuInTe_2$ crystal.

$$p = \frac{N_A - N_D}{N_D} 2\left(\frac{2\pi m_p^* K_0 T}{h^2}\right)^{3/2} \exp\left(-\frac{E_A}{K_0 T}\right) \quad (1)$$

where N_A and N_D are acceptor donor concentrations, respectively; m_p^* is the effective mass ratio of holes, K_0 is the Boltzmann constant, h is the Plank constant and E_A is the ionization energy. It reveals that electrical conductivity is governed by acceptor states with ionization energy $E_A = 15\,\text{meV}$ which was obtained from the slope of $pT^{-3/2} = f\left(\frac{1}{T}\right)$ plot (see formula (1)) [Fig.3].

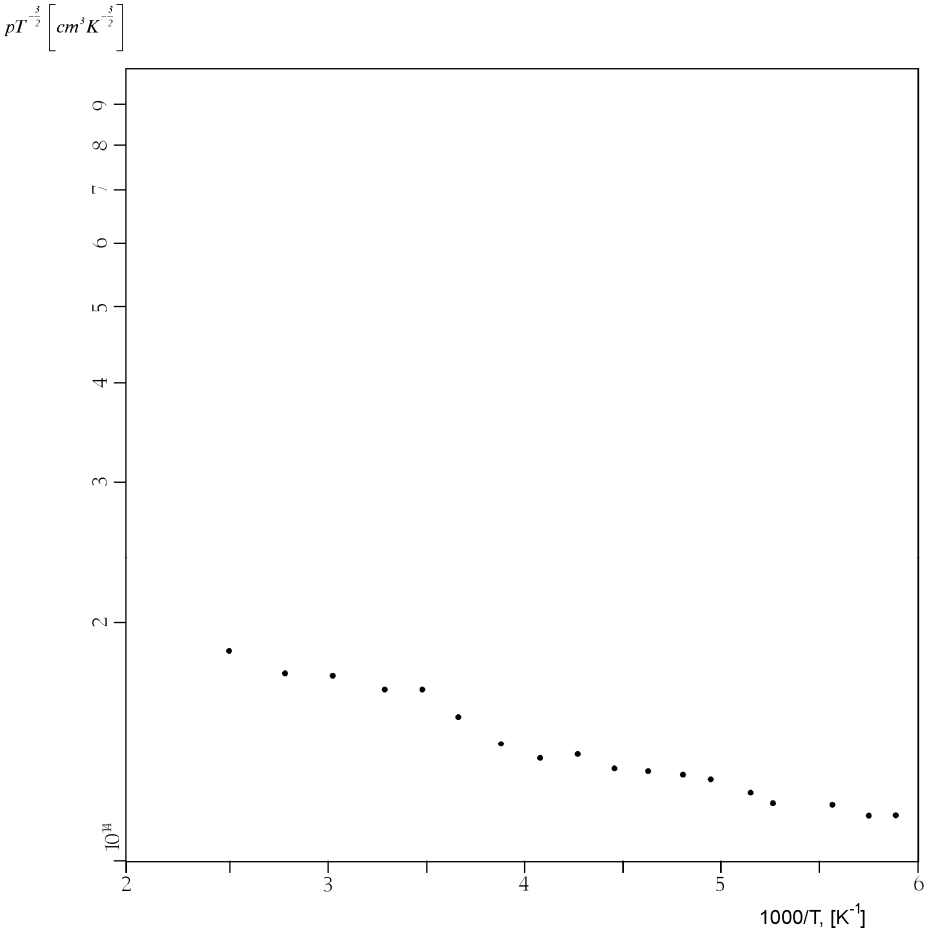

Figure 3. Plot of $pT^{-3/2}$ versus 1/T.

The acceptor states with ionization energy of 15 meV have been also reported in [5]. Fig.3 was also used to the estimation of compensation degree N_A / N_D of the p-$CuInTe_2$ crystals from $pT^{-3/2}$ value at 1/T = 0. Using experimental data of mobility μ_p and the estimated concentration p of holes, the concentration N_I of total ionized impurities was calculated by the Brooks – Herring formula [6].

$$\mu_I = \left(\frac{2}{300}\right)\frac{2^{7/2}\varepsilon_0^2\left(K_0 T\right)^{3/2}}{\pi^{3/2}e^3\left(m_p^*\right)^{1/2}N_I f\left(x\right)} \qquad (2)$$

where N_I is the ionized impurities and f(x) = ln(1+x)-x(1+x).

Here

$$x = \frac{6\varepsilon_0 m_p^* (K_0 T)^2}{\pi e^2 h^2 p}$$

Because at low temperature $N_I = 2N_D + p$, it was also possible to estimate the donor concentration N_D, which together with N_A / N_D value let us obtain the value of acceptor concentration N_A. The calculated values of N_I, N_A / N_D, N_D, N_A and E_A for p-$CuInTe_2$ crystals are presented in Table 1. For the calculations effective mass ratio of holes $m^* = 0.78$ [7], the static relative dielectric constant $\varepsilon_8 = 11$[8] were taken.

Table I. The parameters of p-$CuInTe_2$ crystals.

	N_I [cm^{-9}]	N_A/N_D	N_D [cm^{-9}]	N_A [cm^{-9}]	E_A [meV]
p-$CuInTe_2$	$1{,}63 \times 10^{18}$	1,08	$7{,}14 \times 10^{17}$	$7{,}72 \times 10^{17}$	15

In conclusion it should be underlined that temperature dependence of hole concentration and mobility is controlled by acceptors with ionization energy of

E_A=12 meV.

After other authors [5] we suggest that the shallow acceptor identified in our crystals can be connected with complex native defects.

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