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ELECTRICAL PROPERTIES OF Cd_3As_2 UNDER HIGH PRESSURE

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The measurements of electrical resistivity and Hall coefficient for Cd_3As_2 under hydrostatic pressure up to 12 kbar in the temperature range from 300 to 450°K were performed. The polycrystalline and single crystal samples with the electron concentration ranging from $1.8 \cdot 10^{18}$ cm^{-3} to $7.7 \cdot 10^{18}$ cm^{-3} were used.

It was found that the Hall coefficient was pressure and temperature independent, and electrical resistivity increased linearly with increasing pressure. The changes of resistivity were higher for purer samples, and the character of these changes was temperature independent.

The results obtained for Cd_3As_2 can be explained by assuming a single Kane-type conduction band.

1. Introduction

Cadmium arsenide — Cd_3As_2 is a II–V compound with tetragonal crystal structure. Samples of Cd_3As_2 are always *n*-type with electron concentration $10^{18}-10^{19}$ cm^{-3}; Hall mobility at room temperature is $10000-18000$ cm^2/V.s, effective mass m^* is $0.04-0.08\ m_0$, and $\Delta E_{\mathrm{term}} = 0.14$ eV [1, 2, 3].

At present, results obtained by different authors are explained by two models of band structure. The first model is based on the assumption that Cd_3As_2 has a single Kane-type conduction band [4, 5]. The second model, proposed by Sexer [6] and supported by other authors [7, 8, 9] is assumed to consist of two conduction bands with different effective masses.

In the case of *n*-type extrinsic materials the effect of pressure on electron mobility only is observed; the total concentration of carriers determined by donor concentration is pressure independent. For semiconductors such as *n*-type InSb, it is known that the increase of pressure causes a rise of effective mass and then a decrease of electron mobility When two conduction band minima are close to each other (such as for GaSb) the increase of pressure causes a transfer of carriers from high to low mobility minimum and changes of concentrations in each minimum; nevertheless the total concentration is constant.

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The purpose of the present work was the study of the effect of hydrostatic pressure on the electric properties of Cd_3As_2 and drawing conclusions which could confirm one of the discussed models of band structure.

2. *Experimental methods*

Measurements were performed for polycrystalline and single crystal samples of Cd_3As_2. The single crystals were obtained by the Bridgman method or from vapour phase. For measurements, samples for which their longest dimension was in the *c*-axis direction were chosen. The polycrystalline samples were cut out from homogeneous polycrystalline material.

Measurements were carried in the nonmagnetic beryllium-copper chamber [10]. The mixture of kerosene and mineral oil (50% of each) was used as a medium. Pressure was measured by a manganin wire resistance gauge.

In the present work the Hall coefficient and electrical resistivity were measured for several samples of Cd_3As_2 with electron concentration ranging from $1.8 \cdot 10^{18}$ cm^{-3} to $7.7 \cdot 10^{18}$ cm^{-3}. The measurements were carried out in the pressure range from 1 to 12 000 bar and temperature range from 300 to 450°K. From the sample *P*–4 the measurements of resistivity were performed in a steel chamber at pressures up to 26 000 bar.

3. *Results and discussion*

Fig. 1 shows temperature dependence of specific resistivity for three selected samples: the single crystal sample *M*–1, and two polycrystalline samples *P*–1 and *P*–4 in the temperature range from 77 to 300°K. It can be seen that resistivity increases linearly with increasing temperature.

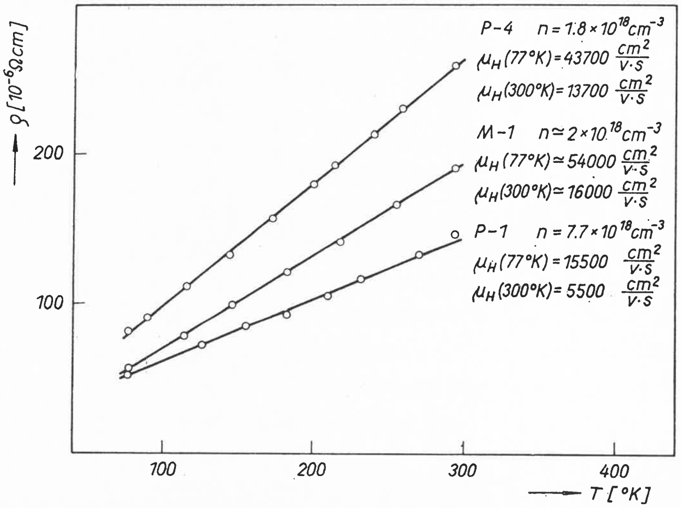

Fig. 1. Temperature dependence of resistivity for polycrystalline samples *P*–1 and *P*–4, and for single crystal sample *M*–1

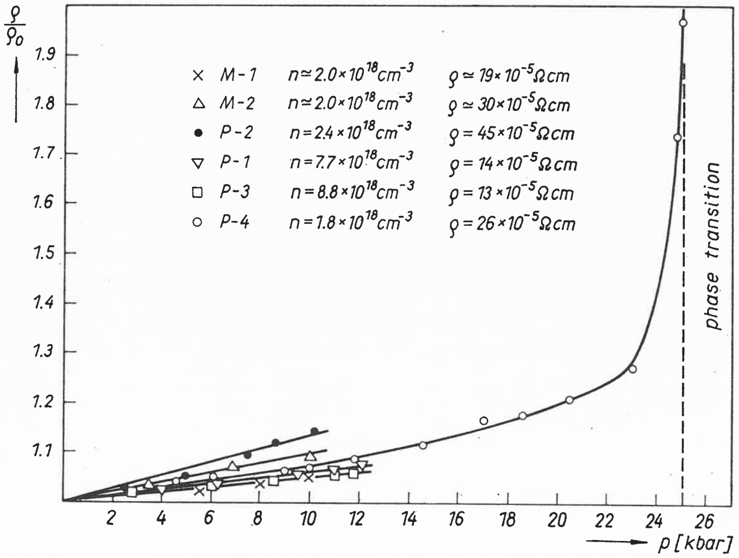

Fig. 2. Pressure dependence of resistivity at 300°K for several Cd_3As_2 samples

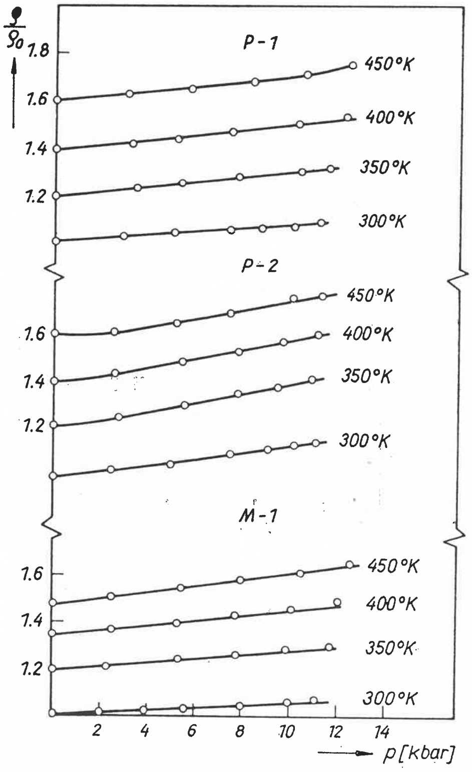

Fig. 3. Pressure dependence of resistivity for three Cd_3As_2 samples at temperatures 300, 350, 400 and 450°K

In the whole investigated pressure and temperature ranges the Hall coefficient is practically constant for all samples except the single crystal sample *M*–1. For this sample the Hall coefficient at 450°K is about 8% less than that at 300°K; this is caused by the increase of intrinsic concentration.

On Fig. 2 the dependence of $\frac{\varrho}{\varrho_0}$ on pressure at room temperature for all samples is shown. The resistivity increases linearly with increasing pressure; the changes of resistivity are higher for samples with smaller electron concentration. The rapid increase of resistivity for sample *P*–4 about 25 kbar is caused by a phase transition [11].

Fig. 3 shows the dependence of $\frac{\varrho}{\varrho_0}$ on pressure at the temperatures 300, 350, 400 and 450°K for three samples of Cd_3As_2. It can be seen, that the character of this dependence is the same for different temperatures.

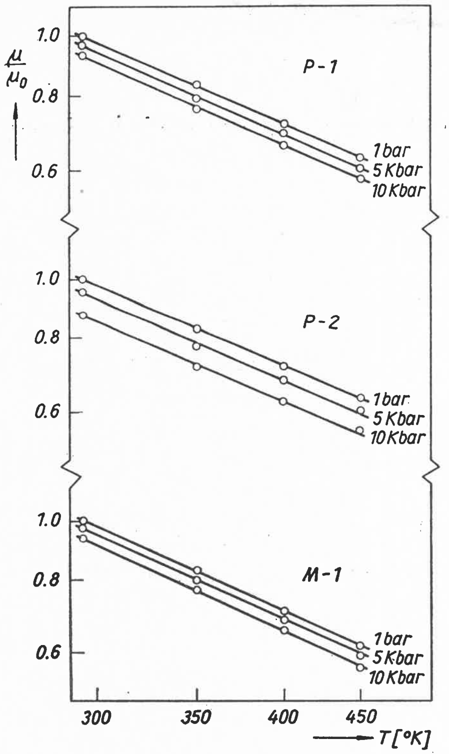

Fig. 4. Temperature dependence of Hall mobility for three Cd_3As_2 samples at pressures 1, 5 000 and 10 000 bar

Fig. 4 shows the dependence of Hall mobility on temperature at the pressures 1, 5000 and 10000 bar. This dependence can be described as:

$$\mu = A \cdot T^{-\alpha}$$

where A depends on pressure and α depends on sample and changes from 1 to 1.2.

It is known that Cd_3As_2 has very similar properties to those of InSb (small energy gap, high electron mobility); moreover the electron effective mass increases with carrier concentration according to Kane's formula [4, 5]. Since Lin-Chung's theoretical calculations (in which the crystal structure of Cd_3As_2 has been taken into account) also show [13] that Cd_3As_2 has a band structure similar to that of III–V compounds, it is reasonable to assume the Kane model for this semiconductor.

Since the Hall coefficient is pressure-independent (in the investigated pressure and temperature ranges) one can assume that Cd_3As_2 has a single conduction band. The rise of resistivity with pressure is caused by the increase of effective mass and hence decrease of electron mobility and increase of resistivity.

The results obtained for Cd_3As_2 are similar to those obtained for InSb with the same electron concentration [12].

Thus, it can be assumed that another minimum of conduction band lies high enough from the first (over 0.4 eV) and does not take part in the transport phenomena.

The possible transfer of carriers from one minimum to the other would take place after using a very high pressure; in this case, however, phase transition occurs [11].

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