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Pressure and Temperature Dependence of the Hall Coefficient in $Cd_{3-x}Zn_xAs_2$ Solid Solutions

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In the previous paper /1/ the results of pressure investigations of $Cd_{3-x}Zn_xAs_2$ alloys in the whole composition range at room temperature were reported. The obtained data were interpreted on the basis of Lin Chung's theoretical work /2/ and the pressure coefficient of the energy gap for x = 1.35 was estimated to 4.5 meV/kbar.

The purpose of the present work was to extend the pressure study of the Hall coefficient above room temperature in order to check the conclusions given in /1/ and to determine values of pressure coefficients by fitting theoretical curves to experimental data.

Measurements were performed for the most compensated $Cd_{3-x}Zn_xAs_2$ alloys of good homogeneity obtained with the aid of an ultrasound shaker /3/. The characteristics of the samples studied are shown in Table 1.

Table 1

sample No.	composition x	carrier concentration in the exhaustion region (10^{16} cm^{-3})	energy gap[a] E_g (eV)	electron effective mass[a,b] m_e^*/m_o	pressure coefficient dE_g/dP (meV/kbar)
1a	1.2	$n_{exh} = N_d - N_a = 4.0$	0.27	0.039	5.4
1b	1.2	$n_{exh} = 0.88$	0.27	0.039	5.4
1c	1.2	$n_{exh} = 0.32$	0.27	0.039	5.4
2	1.35	$n_{exh} = 1.5$	0.34	0.045	5.8
3	1.5	$p_{exh} = N_a - N_d = 8.9$	0.41	0.050	5.5
4	1.95	$p_{exh} = 8.3$	-	-	-

a) Values at 300 K and at normal pressure. b) Taken from /4/.

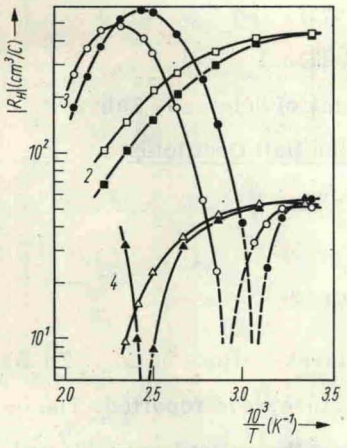

Fig. 1. Temperature dependence of the Hall coefficient at normal pressure (full symbols) and at P = 6 kbar (open symbols) for n-type sample 2 with x = 1.35, and p-type samples 3 and 4 with x = 1.5 and x = 1.95, respectively

The temperature and pressure dependences of the Hall coefficient R_H for the investigated alloys are shown in Fig. 1 and 2. It can be seen that the temperature range in which the studied samples exhibit intrinsic conductivity depends on composition and degree of compensation; curves 1b and 1c show the presence of intrinsic conductivity at 300 K, whilst in samples 2 and 3 the intrinsic carriers are dominant above 400 and 440 K, respectively. Thus, the rise of R_H with pressure, as shown in Fig. 2, is due to a decrease in the intrinsic carrier concentration resulting from an increase of the energy gap with pressure. From the $R_H(T)$ dependences for p-type sample 3 the electron-to-hole mobility ratio b can be estimated (see, e.g. /5/): at normal pressure and at P = 6 kbar b is equal to 41 and 35, respectively. The temperature dependence of R_H for p-type sample 4 at normal pressure shows a change of its sign at 410 K, whilst at P = 6 kbar R_H is positive in the investigated temperature range. Thus, also in this case, the energy gap increases with pressure.

The results obtained for all investigated alloys can be explained by assuming a single s-like conduction band model, as was made for n-type alloys ($0 \leqq x \leqq 1.35$) in /1/. When comparing the results of this work with those of /1/ for p-type samples it is seen that the interpretation given in the latter and based on Lin Chung's two conduction band model /2/ was erroneous; the character of pressure dependences of resistivity and R_H obtained in /1/ at 300 K was due to changes of extrinsic but not intrinsic conduction, and there was no transfer of electrons from one conduction band to the other under the influence of pressure.

The quantitative analysis of the obtained Hall data (dashed lines in Fig. 2) was made under the following assumptions: linear dependence of the energy gap E_g with pressure and temperature, electron effective mass m_e^* proportional to E_g, Fermi

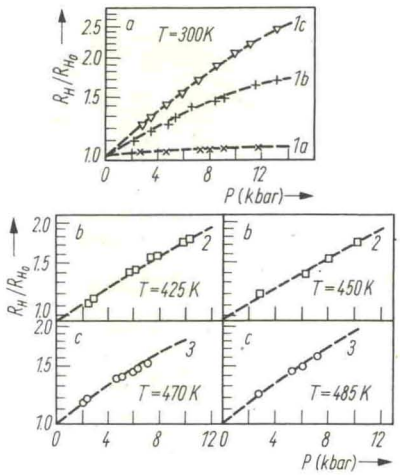

Fig. 2. Pressure dependence of the Hall coefficient at different temperatures for a) x = = 1.2, b) x = 1.35, and c) x = 1.5. The dashed lines represent calculated dependences

statistics, parabolic shape of conduction and valence bands, permanent ionisation of donors (of concentration N_d) and acceptors (of concentration N_a). The values of the hole effective mass m_h^* and the temperature coefficient of the energy gap dE_g/dT were taken from /4/: $m_h^* = m_o$, $dE_g/dT = -3.3 \times 10^{-4}$ eV/K, and they were assumed to be independent of composition and pressure.

The carrier concentrations follow from the electrical neutrality equation of a crystal

$$n + N_a = p + N_d \,. \tag{1}$$

The normalised Hall coefficient R_H/R_{H_o} was calculated from the following formulas:

for n-type samples 1a, 1b, 1c, and 2

$$R_H = -\frac{r}{n\,e} \,, \tag{2}$$

for p-type sample 3

$$R_H = \frac{r}{e}\,\frac{p - nb^2}{(p + nb)^2} \tag{3}$$

with the average and pressure independent value of $b \approx 38$; the scattering factor r was also assumed to be independent of pressure. All other parameters used in the calculations and values of pressure coefficients obtained from the fit are listed in Table 1. It can be seen that the pressure coefficients are approximately equal in the investigated alloys; hence, according to the empirical rule (see, e.g. /6/), it may be expected that the value of the pressure coefficient for the end-point compound Cd_3As_2 is of the same order.

References

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