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Electrical Properties of CdP_2 Single Crystals

By

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The data on the electric properties and energy structure of traps in the forbidden gap of CdP_2 are very scarce. It was established /1/ that as-grown crystals of CdP_2 reveal p-type conductivity. Acceptor states at $(E_v + 0.25)$eV were found from the dark and photoconductivity studied in the range between 100 and 500 K. From luminescence data an analogous trap was found in /2/. It is also known /1/ that a deep level at $(E_v + 0.65)$eV appears after thermal treatment in vacuum at high temperatures. However, the activation energy equal to 0.88 eV observed in /1/ is explained as being due to the intrinsic conductivity, which is unlikely, since the conductivity of these samples exceeds the intrinsic value of the conductivity. There are no detailed data on donors, carrier mobility, and scattering mechanism.

This paper aims at the investigation of donor and acceptor defect levels and of the Hall mobility of holes and electrons in undoped and doped single crystals of CdP_2.

Single crystals of CdP_2 were grown using Cd KD000 and phosphor B5. The synthesis was carried out in quartz ampoules in 10^{-5} Torr vacuum. Single crystals grown from the vapour phase and by Bridgman's technique have been investigated. The density of intrinsic defects has been varied by thermal treatment in saturated vapour of the initial components. Doping has been carried out during the process of synthesis by adding 1% impurity to the weight of the initial substance. As contacts either indium or gold has been evaporated. The measurements were carried out by the five-probe technique. The apparatus used for measurements is described elsewhere /3/.

Hall effect measurements on the as-grown samples have shown p-type conductivity with hole density p = 10^8 cm^{-3} and Hall mobility $\mu_p' = 3$ to 8 cm^2/Vs at room temperature. The activation energy determined from the slope of the
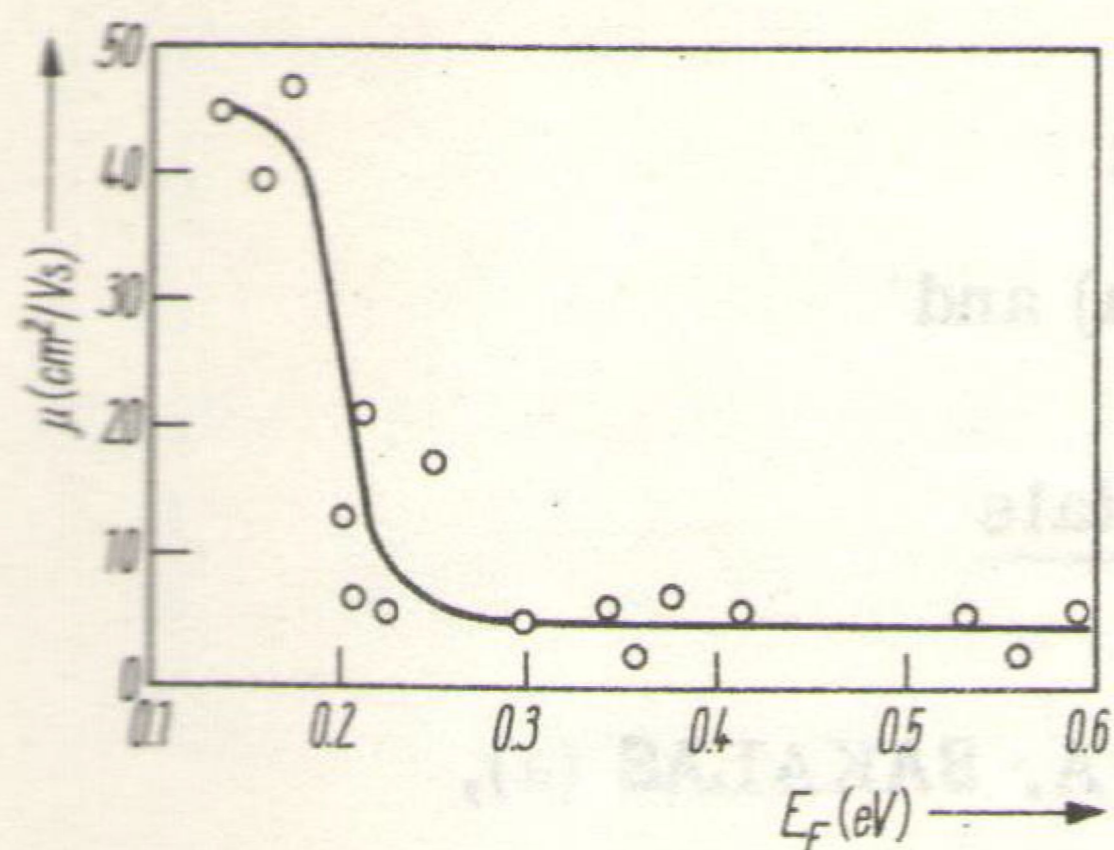
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temperature dependence of the carrier density is equal to (0.83 ± 0.03)eV. As has been mentioned before, this energy is unlikely caused by the intrinsic conductivity of the crystal, since, firstly, it sufficiently differs from the bandgap value (2.02 eV /4/) determined from optical measurements and, secondly, the conductivity measured exceeds the intrinsic conductance by several orders of magnitude. Hence, the level $(E_v + 0.83)$eV is either due to intrinsic defects, or to an uncontrollable impurity.

The thermal treatment in saturated vapour leads to an increase of the hole density by several orders of magnitude and to the reduction of the slope of $\lg p = f(1/T)$ down to (0.47 ± 0.02)eV. The hole mobility also increases. This activation energy is also revealed in single crystals doped by acceptor impurities, which shows that this level may be caused by intrinsic defects like cadmium vacancies.

The annealing of CdP_2 crystals in cadmium vapour leads to inversion of the conductivity type with electrons density n being 10^{15} cm^{-3}. The Hall mobility μ_c of electrons in various samples varied between 12 and 20 cm^2/Vs. From the temperature dependence of the carrier density a donor level at $(E_c - 0.53 \pm 0.05)$eV has been found. Annealing of the single crystals in cadmium atmosphere leads to an increase of the density of intrinsic donor defects, which may be caused either by the evaporation of phosphor or by cadmium on interstitial sites. Since the n-type conductivity is found in single crystals doped by Ga, Bi, Hg during the growth, and their covalent radius provides substitution of cadmium atoms, while in all cases the centre situated at $(E_c - 0.53)$eV is revealed, we may conclude that it is due to phosphor vacancies, rather than to cadmium interstitials.

The temperature dependences of the Hall mobilities are similar in all samples studied, and the carrier mobility decreases with increasing temperature. It is difficult to determine the dominant scattering process and it may only be concluded that it is not lattice scattering, because the carrier mobility depends upon thermal treatment and doping. It should be noted, however, that

with the increase of the hole density their mobility increases (Fig. 1). As seen, the increase of the mobility takes place for the Fermi level at about 0.25 eV, i.e. the level at $(E_v + 0.25)$eV observed in /1, 2/ is caused by a strongly scattering centre, which is responsible for the low Hall mobility when the carrier density p is less than 10^{15} cm^{-3}.

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