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THE EFFECT OF UNILATERAL COMPRESSION ON THE ELECTRICAL PROPERTIES OF p-TYPE GERMANIUM AT LOW TEMPERATURES

M. A. IL'INA and I. A. KUROVA

Moscow State University

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The resistance, Hall constant, and the variation of resistance in a magnetic field were measured at temperatures between 4.2 and 3.7° K for p-type Ge subjected to unilateral compression. The change in conductivity of hole type Ge caused by the pressure is due both to a variation in the number of carriers in the band and to a change in their mobility. The sign of the deformation potential is determined from the ratio of the mobilities for different crystallographic directions.

UNDER a unilateral deformation the valence band in germanium, which is fourfold degenerate in the normal state, is split into two doubly degenerate bands and is deformed. This produces a change in the electrical properties of p-type germanium. Several works[1-6] have been devoted to a study of the effect of unilateral deformation on the electrical properties of p-type germanium. The problem has been most fully considered theoretically by Pikus and Bir.[5] Smith[1] and Morin et al[2] studied the change of resistivity on deformation and its temperature dependence down to 20° K.

The purpose of the present work was to study the electrical properties at lower temperatures, where the effects should be greater and should have some features pointed out by Pikus and Bir. After this investigation had started, we heard of the work of Koenig and Hall[6] in which the electrical properties of p-type germanium under unilateral compression in the [111] and [100] directions were studied down to 4.2° K. Our results are in general agreement with their data and the sign of the deformation potential d agrees with the sign determined by Koenig.

We measured the resistance, Hall constant, and the variation of resistance in a magnetic field for unilateral compression, on p-type germanium having $\rho = 20$ ohm-cm at room temperature. The measurements were carried out at temperatures from 4.2 to 3.7° K. In this temperature range the conductivity of such specimens is due to holes in the valence band, and the impurity band conductivity does not show up, as is indicated by the exponential variation of the resistivity and Hall constant with decreasing temperature. The temperature range is limited by the value of the resistivity of the specimen: for $T < 3.7°$ K we have $R > 10^{12}$ ohm, and measurement becomes difficult. Measurements were made in the direction of the deformation, [110], and perpendicular to it, along $[\bar{1}10]$. The load varied from zero to 600 kg/cm^2 and was produced by beryllium bronze springs.*

The measurements were carried out in an apparatus thoroughly shielded from radiation, since the magnitude of the measured effects decreases in the presence of radiation and becomes zero for a large amount of radiation. All measurements were made with such electric field strengths in the specimen that Ohm's law was obeyed. The magnetic field was ~ 1,500 oe.

Figure 1 shows the variation of conductivity with pressure for the conductivity parallel to the pressure direction and perpendicular to it. It can be seen that the conductivity changes by more for the $[\bar{1}10]$ direction than for the [110] direction. If we assume that the scattering is little anisotropic, then according to Pikus and Bir[5] the sign of the product dD can be deduced as negative, from the value of the ratio of mobilities $\mu_\perp/\mu_\parallel = \sigma_\perp/\sigma_\parallel > 1$; d is the deformation potential and D is the matrix element of the spin-orbit coupling.

Figure 2 shows the ratios of the mobilities μ/μ_0 and of the concentration of carriers $n/n_0 = R_0/R$ (where R is the Hall constant) with and without deformation, as a function of pressure, when these are measured in the direction of deformation, [110], at 4.2° K. It can be seen from these curves that the conductivity of germanium changes on deformation not only because of an increase in hole mobility,

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*The apparatus for producing the unilateral compression was developed by N. B. Brandt.

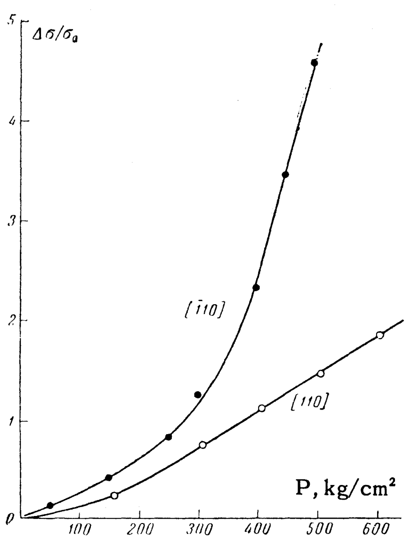

FIG. 1

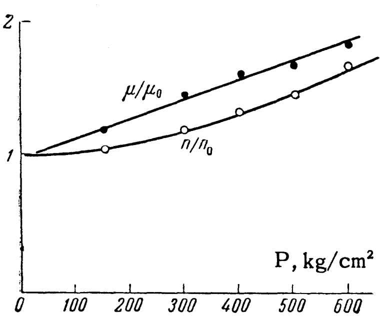

FIG. 2

but also because their number increases. Measurement of the temperature dependence of the Hall constant at zero and at the maximum deformation for these experiments, showed that the ionization energy of the holes changed by 5×10^{-4} ev, which represents 5% of the ionization energy, and is close to the accuracy of measurement in our experiments (~3%). However, the increase in the number of carriers with pressure, found in these experiments, gives the same change of ionization energy.

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