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IONIZATION OF DONOR ATOMS IN n-InSb BY A MICROWAVE ELECTRIC FIELD

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We have investigated the effect of a microwave electric field of wavelength λ = 10 mm on the electric conductivity of several samples of n-InSb, and observed that the microwave field ionizes the donor impurities. Owing to the small effective mass of the electrons, $m^* = 0.013\ m_0$, and owing to the large dielectric constant, $\epsilon = 16$, the wave functions of the donor-atom electrons in n-InSb overlap even at relatively low impurity concentrations, $\sim 5 \times 10^{14}$ cm^{-3}, and impurity conductivity comparable with the free-electron conductivity is observed at helium temperatures [1-3]. The experiments were therefore carried out with highly purified samples at temperatures down to 1°K. For two fixed temperatures, 4.2 and 1.1°K, at which the impurity conductivity is respectively comparable with the free-electron conductivity and is much larger than the latter, we plotted the Hall constant and the resistivity as functions of the microwave field power (Figs. 1 and 2). The measurements were made in a 3 kOe magnetic field. Samples measuring 2 x 0.5 x 10 mm were placed in front of a cylindrical waveguide, and the magnetic field was perpendicular to the plane of the sample. The sample parameters are shown in the table.

Sample Nos.	2	3	4	7	10	11
$N_D - N_A$, cm^{-3}	1.1×10^{13}	1.5×10^{13}	$3. \times 10^{13}$	4.4×10^{13}	$1. \times 10^{14}$	1.1×10^{14}
μ_H, cm^2/V-sec	2.6×10^5	1.6×10^5	8.4×10^4	2.9×10^5	3.7×10^5	$6. \times 10^3$

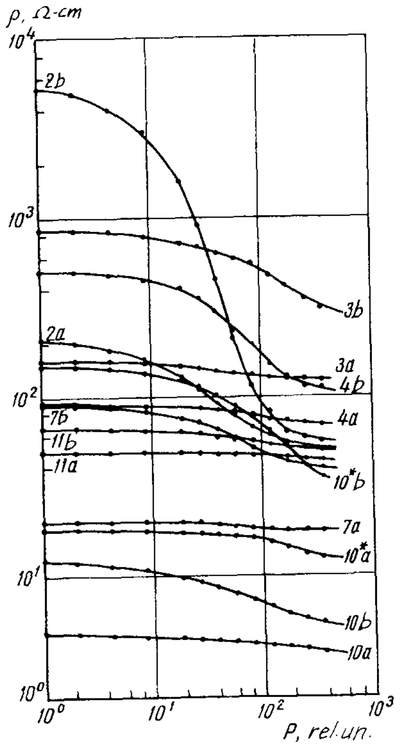

Fig. 1. Specific resistivity ρ of the samples vs. relative radiation power in a magnetic field H - 3 kOe; a - T = 4.2°K, b - T = 1.1°K. The asterisk denotes that the measurement was made in a magnetic field H = 8 kOe.

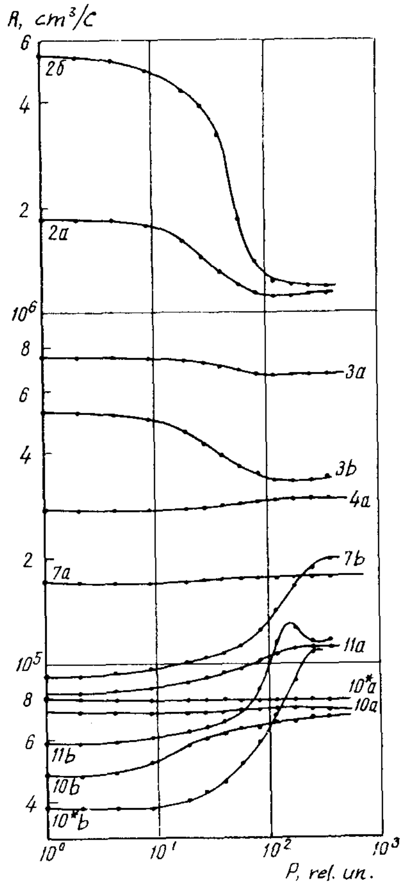

Fig. 2. Hall constant R vs. relative radiation power: a - T = 4.2°K, b - T = 1.1°K.

In all samples except No. 2, the Hall constant passes through a maximum near T = 3 - 4°K, approaching the value obtained at 77°K [3]. This indicates that at temperatures below 3°K the conductivity of the samples is due to impurity conductivity.

It is seen from Figs. 1 and 2 that in sample No. 2, which has a low value of $N_D - N_A$, and which has low impurity conductivity, that the Hall constant decreases rapidly when the radiation power exceeds a certain limit. The magnitude of this jump increases strongly with decreasing temperature, and the limit to which the Hall constant tends with increasing power is close to the value at 77°K. It must also be noted that the increase in the electric conductivity with increasing microwave power begins simultaneously with the decrease of the Hall constant, long before the critical power is approached. The change in the electric conductivity under the influence of the radiation is thus accompanied by a change in the number of free electrons. This is connected with the reduced recombination of the electrons on the donor atoms, and appears also in the case of direct current [3]. Additional measurements have shown that the sample temperature does not change under the influence of the radiation.

The Hall constant in samples with large impurity conductivity, to the contrary, increases with increasing incident radiation power, as in the case of direct current [2,3]. This change is all the more noticeable the lower the temperature. Using a simple two-band model [1], it can be shown that when the impurities are ionized the Hall constant increases when the impurity conductivity increases. At 4.2°K the change in the Hall constant, due to the increased number of the free electrons, is offset by the change due to the change in the number of electrons participating in the impurity conductivity. It can also be shown [3] that at sufficiently low temperature $T = 1°K$, the observed change in the electric conductivity and in the Hall constant under the influence of the radiation cannot be attributed to the change in the ratio of the mobilities of the free electrons and the impurity electrons, since the effect increases with decreasing temperature. Thus, the change in the electric conductivity of the samples following irradiation by an electromagnetic wave with $\lambda = 10$ mm is connected with the change in the recombination of the electrons at the donor levels under the influence of the electric field and the subsequent change in the number of carriers at the impurity levels and in the conduction band [3,4].

The field intensity corresponding to the abrupt change in the electric conductivity and in the Hall constant ranges from 0.2 to 0.4 V/cm, although these figures may be overvalued, since we do not know the penetration of the field in the samples. The independence of the Hall constant on the radiation power when n-InSb is irradiated by millimeter waves, observed in [5], may be connected with insufficiently low temperatures and insufficiently pure samples.

In conclusion, the author considers it his duty to thank N. G. Basov for stimulating discussions, V. D. Burmistrov for help during the measurements, and Yu. P. Zakharov for preparing the samples.

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LEPTON DECAY OF VECTOR MESONS

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The matrix element for the probability of the decay of a vector meson (ρ^0, ω, or φ) into an e^+e^- or $\mu^+\mu^-$ pair is determined by the same diagram as its proper energy. In a recent paper [1] it was proposed to use this circumstance to determine the nonrenormalized mass of