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TEMPERATURE DEPENDENCE OF NEGATIVE MAGNETORESISTANCE IN COMPENSATED GALLIUM ARSENIDE

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We have established in [1] that in compensated n-GaAs with a total impurity density $N_i \simeq 5 \times 10^{17}$ cm^{-3} and an electron density $n \leq 5 \times 10^{16}$ cm^{-3} the electrons become localized at low temperatures in potential wells that distort the bottom of the conduction band.

Since an external magnetic field changes the energy states and the conditions of electron motion, we deemed it of interest to study the influence of the field under these conditions.

The measurements were made on the same samples as in [1], and a decrease of the resistance was observed in magnetic fields up to 50 kOe. The relative changes of the resistance, $\Delta\rho/\rho = [\rho(H) - \rho(0)]/\rho(0)$, turned out to approximately the same in a field H parallel to the current as in a perpendicular one.

Figure 1 shows the measured $\Delta\rho/\rho = f(H)$ at 10 values of the temperature from 0.6 to 27°K, in magnetic fields $H \leq 20$ kOe, in which the positive component of the magnetoresistance could be neglected.

In analogy with the interpretation of the negative magnetoresistance (NM) in ferromagnets and in metals with ferromagnetic impurities, it is assumed that NM in semiconductors is due to the magnetization of the medium [3] and that

$$\frac{\Delta\rho}{\rho} = -\alpha^2 M^2 = -\alpha^2 \chi^2 H^2 , \qquad (1)$$

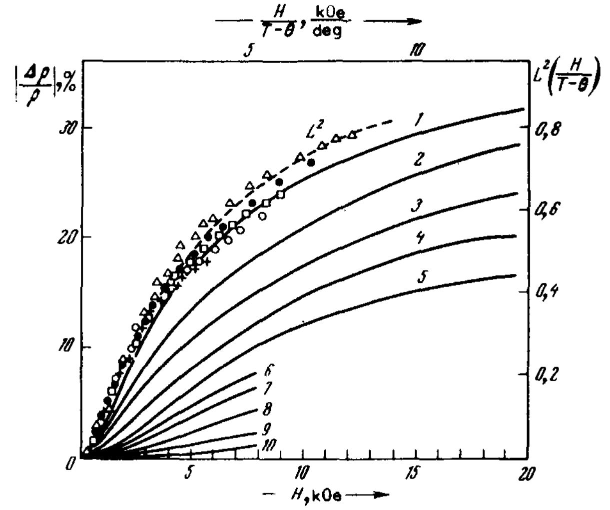

Fig. 1. Dependence of the negative magnetoresistance on the field H and the temperature T: continuous lines - $|\Delta\rho/\rho| = f(H)$ at the following temperatures (°K): 1 - 0.6, 2 - 1.1, 3 - 1.7, 4 - 2.9, 5 - 4.2, 6 - 6.2, 7 - 8.5, 8 - 14.5, 9 - 20.4, 10 - 27. Points: values of $|\Delta\rho/\rho| = f[H/(T - \theta)]$ at the following temperatures: Δ - 0.6, ● - 1.1, □ - 1.7, o - 2.3, × - 4.2. The dashed line is a plot of $L^2(x)$, where $L(x)$ is the Langevin function, $x = (\mu H)/k(T - \theta)$, $\mu = 25\ \mu_B$, $\theta_1 = 1.25$ °K, and $\theta_2 = 2$°K.

where α is a proportionality coefficient, $M = \chi H$ is the magnetization of the medium and χ is the magnetic susceptibility.

Using the results of the measurements, we can obtain from (1) the values of $\alpha\chi$, and from the data obtained in weak fields we can get $\alpha\chi_0$ as $H \to 0$. The results of the measurements and the calculations are shown in Fig. 2 in the form of plots of

$$\zeta = (\alpha\chi_0)^{-1} = \left|\frac{\Delta\rho}{\rho H^2}\right|^{-1/2}_{H\to 0} = F(T)$$

From the results it follows that the temperature dependence of $\alpha\chi_0$ is described by the Curie-Weiss law

$$\alpha\chi_0 = C/(T-\theta) \qquad (2)$$

θ is negative in the region $1 < T < 6$°K and its value is $\theta_1 = -1.3$°K; the interval $6 < T < 9$°K is a transition region, and in the region $9 < T < 20$°K the parameter θ_2 is positive and equal approximately to 2°K.

In weak magnetic fields, when $\mu H/kT \gg 1$, we can assume, in accordance with the rules of Langevin or Brillouin, that

$$M = \frac{N\mu^2 H}{3k(T-\theta)},$$

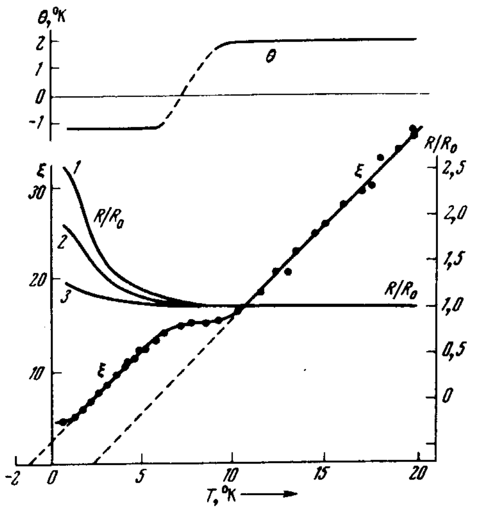

Fig. 2. Points: temperature dependence of $\zeta = |\Delta\rho/\rho H^2|^{-1/2}_{H\to 0}$ (H is in kOe). Solid and dashed line: the parameter θ. Continuous curves: relative values of the Hall coefficient R/R_0, where R_0 is the value of R at 300°K for samples with electron densities 6×10^{15} cm^{-3} (1), 8×10^{15} cm^{-3} (2), and 1.3×10^{16} cm^{-3} (3).

where N is the number of particles per cm^3 having a magnetic moment μ. In strong fields, $\mu H/kT \gg 1$, the magnetization tends to saturation and $M_{sat} \approx N\mu$.

It follows from Fig. 2 that in weak fields $\alpha N\mu^2 \approx 2 \times 10^{19}$ erg/Oe, and in strong fields, according to the data of Fig. 1, $\alpha N\mu \approx 0.6$. It follows therefore that the magnetic moment of the particles is $\mu \approx 3 \times 10^{-19}$ erg/Oe $\approx$ 30 Bohr magnetons (μ_B).

Using the obtained values of θ_1 and θ_2 we can express the entire set of results, at different H and T, in the form

$$\left|\frac{\Delta\rho}{\rho}\right| = f\left(\frac{H}{T-\theta}\right)$$

and thus all the data shown on curves 1 - 10 of Fig. 1 can be reduced to a single curve, shown dashed in Fig. 1.

Taking into account the normalization factor, this line represents the square of the Langevin function of argument $x = \mu H/[k/(T-\theta)]$, where $\mu = 25\mu_B$. The individual results of the calculations of

$$\left|\frac{\Delta\rho}{\rho}\right| = f\left(\frac{H}{T-\theta}\right)$$

are shown by points, which, as seen from Fig. 1, cluster near the dashed line, with accuracy ±10%.

From the fact that the straight lines in the plot of $\zeta = F(T)$ (Fig. 2) have equal slopes both at $T < 6°K$, where $\theta_1 = -1.3°K$, and at $T > 9°K$, where $\theta_2 \simeq 2°K$, we see that the constants C in the Curie-Weiss law (2), and hence the product $N\mu^2$, remain the same in both temperature intervals.

As is well known, the temperature dependence of the susceptibility, in the form $\chi = C/(T - \theta)$, is related to the action of the internal fields. In particular, a positive value of θ corresponds to ferromagnets and a negative one to antiferromagnets. In our case the change of the sign of θ corresponds to the temperature region in which delocalization of the electrons sets in - the smeared "dielectric - metal" transition [4].

Further investigations should show whether this transition is accompanied by a Wigner correlation of the electrons [5].

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PLASMA-JET CO_2 LASER

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We report in this article the first case of plasmotron excitation of a CO_2 laser by injecting into the laser volume plasma jets produced in capillary plasmotrons.

It is known that pre-ionization of all or part of the working volume of the laser is an important factor in the production of a high-pressure active medium for a gas-discharge CO_2 laser. For pre-ionization of the entire working volume, it turned out to be convenient to use ionizing-radiation sources [1 - 2], which increase the extent to which the energy of the current flowing through the gas is utilized, and prevent formation of an arc discharge. If part of the active laser volume is pre-ionized by introducing into the laser a third electron that produces a local overvoltage, then plasma cathodes are produced and contribute to a relatively homogeneous breakdown of large gas volumes at high pressures [4]. An important factor here is that main discharge is initiated in the presence of plasma-filled cathode regions.

A further development of this method is to force plasma formations not into the cathode region, but into the entire laser volume. This can be done with plasmotrons.

The experiment was performed in a transversely-excited laser system similar to that described earlier in [5]. The separate cathodes of the system were replaced by a row of 25 capillary plasmotrons simultaneously injecting plasma jets into the laser volume. We investigated mainly the mixture CO_2-N_2-He with a component ratio 1:2:3 at a pressure of 30 Torr. The supply of interelectrode gap of the working volume was different from that of the capillaries. The gap was 2 cm long, the capillary diameter 1 mm, the length 5 mm, and the distance