ELECTRICAL PARAMETERS OF GOLD-DOPED GALLIUM ARSENIDE

M. A. Krivov, E. V. Malisova, and G. S. Shishkova

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Gold is used in contacts for GaAs devices [1, 2], but no evidence has previously been published on the electrical activity of Au in GaAs. Here we report the properties of Au-doped GaAs, which was made either by alloying (in the melt) or by diffusion from a film deposited on the crystal. The GaAs monocrystals doped from the melt were of n type, but the electron concentration tends to fall towards high Au contents (Fig. 1), so Au in GaAs evidently acts as an acceptor. The ionization energy could not be determined for gold centers produced in this way, probably on account of the high concentration of a donor impurity and of the limited solubility of Au.

Au was diffused into p-type GaAs (initial impurity content $1\text{-}2 \times 10^{16}$ cm^{-3}) at 1100°C under the equilibrium vapor pressure of arsenic; the crystals were cooled at 20 deg/hr. Control specimens cut from the same crystals were treated in the same way.

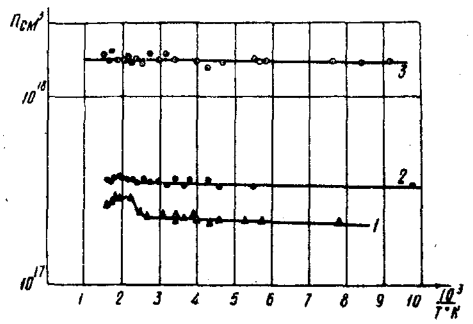

Fig. 1. Au (wt. %) in melt: 1) 2.5, 1) 1.5, 3) 0.5.

The Hall constant and electrical conductivity in the range 100-600°K gave the carrier concentration and mobility (Figs. 2 and 3); the temperature coefficient of the concentration before doping gave the ionization energy of the impurity centers as 0.018 eV at 100-400°K and 0.14 eV at 400-600°K, which points to the presence of copper in the initial material (Fig. 3).

The control showed a somewhat higher hole concentration after heat treatment, perhaps on account of thermal acceptors. The doped specimen had an n-T curve with a part whose slope differs from that of the corresponding part for the control. The new level lies at 0.046 eV, as determined from n (Fig. 3).

If we assume that Au replaces Ga in the lattice, we would expect Au to give two acceptor levels. The 450-600°K range in n against T shows some variation in slope for the doped specimen, but the ionization energy of this second gold

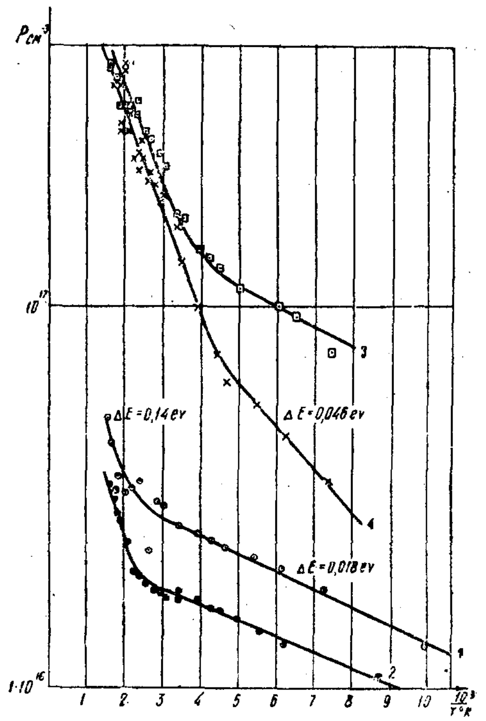

Fig. 2. 1) Control specimen before heat treatment; 2) doped specimen before treatment; 3) control after heat treatment; 4) doped specimen after treatment.

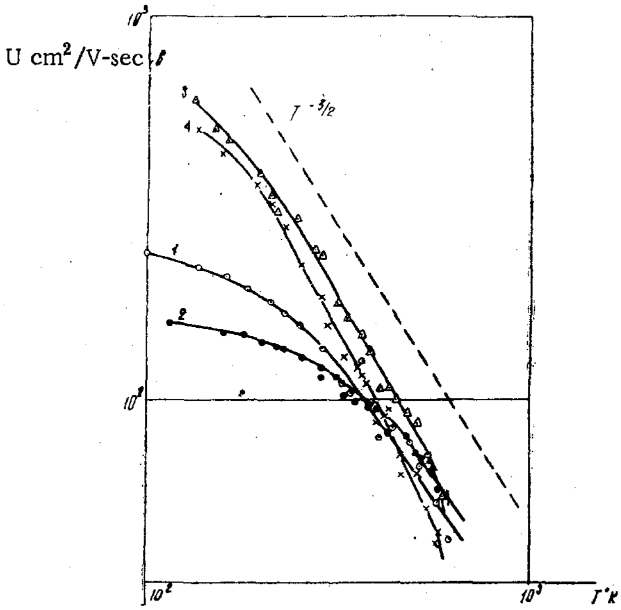

Fig. 3. 1) Control specimen before heat treatment; 2) doped specimen before treatment; 3) control after heat treatment; 4) doped specimen after treatment.

level is difficult to determine on account of the thermal acceptors. The acceptor level at 0.018 eV present before doping was absent after doping.

Whelan [3] assigns the copper level at 0.02 eV with a Ga vacancy plus Cu at an internode, in which case it seems that the Au entering the free Ga nodes leads to loss of the Cu level at 0.02 eV and formation of a complex consisting of Au at a Ga node with Cu at an internode, the ionization energy being 0.046 eV.

REFERENCES

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Kuznetsov Siberian Institute of Technical Physics

CALCULATIONF OF THE EDDY CURRENTS PRODUCED IN A CONDUCTING TUBE MOVING IN A MAGNETIC FIELD

R. A. Pavlovskii

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The results given by Kononkov and Sapozhnikov in No. 6 of this journal for 1963 are not of the general character claimed by the authors; they apply only to certain particular cases.

They considered the motion of a rectangular nonmagnetic tube at a speed v in the field of linear magnetic poles of masses m_1 and m_2 per unit length (Fig. 1); these masses were taken as arbitrary, as were the thicknesses Δ_1 and Δ_2 of the horizontal walls and the specific conductivities σ_1 and σ_2 of these. The vertical walls were taken to be ideal conductors.

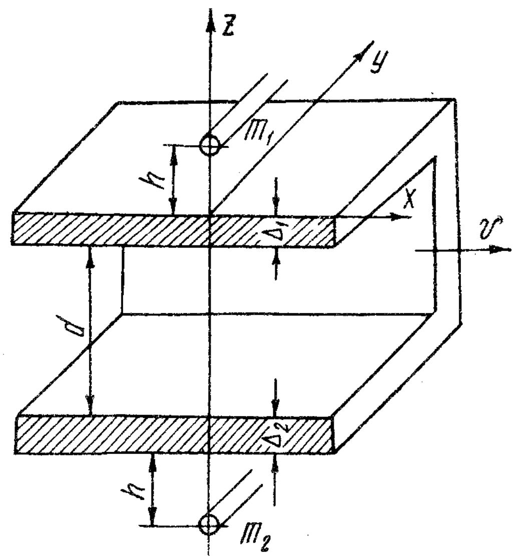

Fig. 1

The magnetic field produced by the eddy currents was found in the two-dimensional approximation (the tube was taken as unbounded along the y axis). It is assumed that the eddy currents have no component along the x axis, so from that point of view the tube may be considered as consisting of mutually insulated transverse frames carrying current G(x). Thus G(x) is taken as the line density of the eddy current, for which purpose they used the relation

$$G(x)\,\frac{\sigma_2\Delta_2\cdot\sigma_1\Delta_1}{\sigma_1\Delta_1+\sigma_2\Delta_2} = 10^8\, v\left(\frac{\partial\varphi}{\partial z}\bigg|_{z=0} - \frac{\partial\varphi}{\partial z}\bigg|_{z=-d}\right), \qquad (1)$$

in which φ is the potential of the magnetic field.

Now (1) is equivalent to the following relation in the three-dimensional case:

$$\boldsymbol{i} = \sigma\,[\boldsymbol{vB}], \qquad (2)$$

in which i is the volume density of the current and B = −grad φ; this involves the assumption that the potential difference per unit length of circuit is exactly equal to the emf induced in that circuit per unit length.

These assumptions are not valid in the general case envisaged in the original paper (i.e., the m, σ, and Δ arbitrary); this may be demonstrated from the following simple example.

Let $k = m_1/m_2 = -1$ (densities of the magnetic masses equal in magnitude but opposite in sign); then (1) may be used with the expression φ they give to show readily that $G(x) \equiv 0$. This is the natural result of their assumptions, because the emf in the upper wall is equal in magnitude to that in the lower one, but is opposite in sign. They thus consider that there are no eddy currents in this case, but it is easy to show that this is not so.

Ohm's law for the general case of a moving conductor (tube) is