Letters to the Editor

INFLUENCE OF THE MAGNETIC FIELD ON GaAs (Cr) DIODES CURRENT-VOLTAGE CHARACTERISTICS DISTINGUISHED BY A SATURATED VOLTAGE

ВЛИЯНИЕ МАГНИТНОГО ПОЛЯ НА ВОЛЬТАМПЕРНЫЕ ХАРАКТЕРИСТИКИ РАЗЛИЧНЫХ ДИОДОВ GaAs (Cr), ОТЛИЧАЮЩИХСЯ НАПРЯЖЕНИЕМ НАСЫЩЕНИЯ

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In paper [1] we have derived and experimentally verified the following formula for the forward d.c. current-voltage characteristic of some diodes with a semi-insulating GaAs (Cr) base:

$$U = U_0 \left[\left(\frac{I}{I_0} + 1 \right) \ln \left(\frac{I + I_0 \exp d/a}{I + I_0} \right) - \frac{d}{a} \right], \qquad (1)$$

where $U_0 = a^2/\mu_p\tau_p$, $I_0 = ep_0aS/\tau_p$, $a = v_n\tau_n$, d is the distance between the electrodes, S is the cross-section of the current channel, p_0 is the hole concentration of the base at low electric fields, μ_p, τ_p are the hole mobility and life-time, respectively, v_n is the electron drift velocity and τ_n is the life-time of the electrons. We assumed that μ_p, τ_p are independent in electric fied.

At a sufficiently high injection of carries, i.e. for $I \gg I_0$, the VA characteristic described by the formula [1] is distinguished by a tendency to reach the saturated voltage

$$U_s = U_0 [\exp (d/a) - 1 - d/a]. \qquad (2)$$

If a magnetic field is applied in a direction perpendicular to the current direction, the character of the VA characteristic is not changed; however, the value of the saturated voltage increases with the increasing value of the magnetic induction B.

The investigated p-i-n diodes were prepared by liquid phase epitaxy in a horizontal apparatus with hydrogen atmosphere. The substrates were Cr doped semi-insulating GaAs slices oriented in the ⟨100⟩ direction. The P-layer, about 100 μm thick, was grown in a Ga rich solution doped by Zn, with an initial teperature 750 °C. The hole concentration in the layer was about 10^{19} cm^{-3} at room temperature. The other side of the substrate was lapped to the preselected thickness and briefly etched. Then Sn doped N-layer was grown with an electron concetration of 2.3×10^{18} cm^{-3}. Mesas with a diameter of 0.75 mm were then etched using a photolitographic technique. The slices with mesas were broken into individual structures. The set of characteristics of the structure H16 (which is of type B described in [1]) with $d = 60$ μm for various values of B is shown in Fig. 1, which was obtained directly by a I-V plotter. In the

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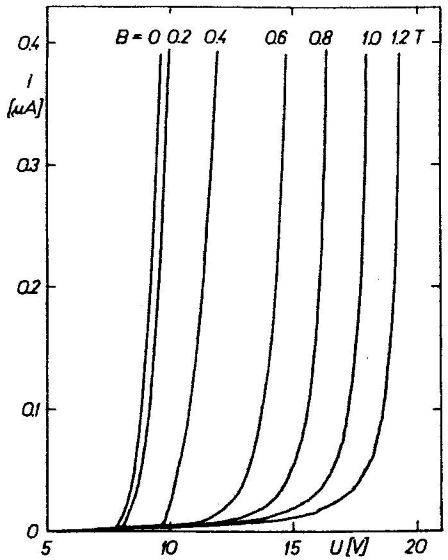

Fig. 1. Plotter record of the current-voltage characteristics of the H16 GaAs (Cr) diode at various magnetic fields.

ohmic range of the characteristics the influence of the magnetic field was negligible. However, in the range of the steep current rise, the magnetic field causes a remarkable change of the voltage. This can be seen in Fig. 2 obtained by the U-B plotter for various values of the current on the same H16 structure. On the basis of these experimental results we suppose that the injected current flows through a channel with the cross-section S smaller than the area of the anode, so that the magnetic field can lengthen the

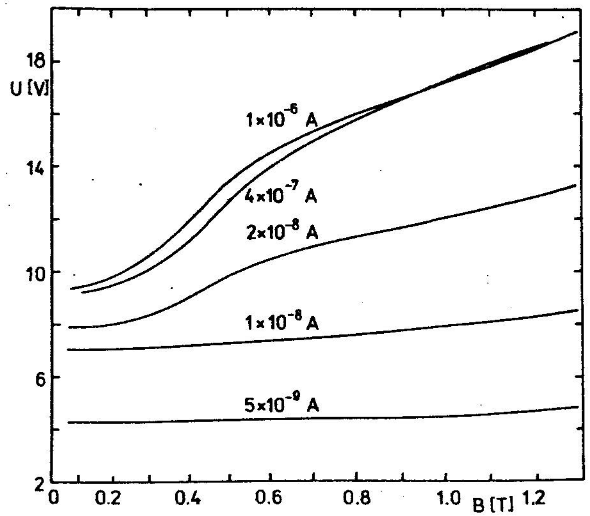

Fig. 2. Plotter record of the voltage-magnetic field characteristics for H16 diode at various currents.

current channel as it is schematically shown in Fig. 3. At a low magnetic field we can approximate the magnetic field dependence of the channel length by the formula

$$d(B) = d[1 + \alpha^2 B^2]. \tag{3}$$

Substituting this relation into the formula

$$U_s(B) = U_0 \exp \frac{d(B)}{a} - 1 - \frac{d(B)}{a} \tag{4}$$

and using the values $U_0 = 12.6$ V, $d/a = 1$, $\alpha = 0.88\ T^{-1}$ we get a good agreement with experimental values of the voltages measured at the current $I = 1\ \mu A$ (in the range of the saturated voltage) up to the

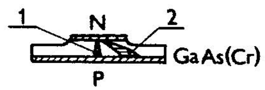

Fig. 3. Schematic picture of the examined P-i-N diode with the supposed influence of the magnetic field on the current channel; 1 — B = 0, 2 — B ≠ 0.

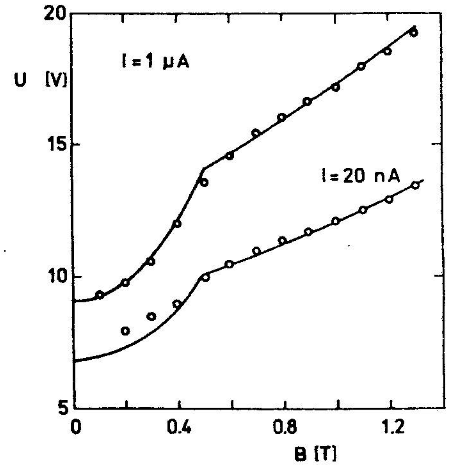

Fig. 4. Computed magnetic field dependences of the voltage corresponding to the currents $I = 1\ \mu A$ and $I = 20$ nA, respectively, together with experimental data (dots).

value $B_k = 0.49$ T, as it can be seen in Fig. 4. For the values of $B > B_k$ the apparent change of the magnetic field dependence of U_s occurs. In this range of magnetic field we can fit the experimental data using the relation

$$d(B) = d[1 + \alpha^2 B_k^2 + \beta(B - B_k)] \tag{5}$$

with $\beta = 0.209\ T^{-1}$ in the formula (4). The change of the magnetic field dependence of the channel length can be attributed to the finite dimensions of the anode. We have calculated the magnetic field dependence of the voltage at the current $I = 20$ nA by the use of the formula (1) with $I_0 = 3.3$ nA, $U_0 = 12.4$ V, and the same magnetic field dependence of d/a as in the case of $I = 1\ \mu A$. Experimental values are taken from the Fig. 2.

We have shown that the formula (1) together with the asumption that the magnetic field can lengthen the injected current channel lead to the satisfactory explanation of the influence of the magnetic field of some GaAs (Cr) diodes.

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