CURRENT-VOLTAGE CHARACTERISTICS FEATURES OF HETEROSTRUCTURES $nGe\text{-}p(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$

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In this report results of experimental studies of continuous solid solution $nGe\text{-}p(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ grown by liquid phase epitaxy using the technology described in [1] was given. As substrates were used monocrystallne Ge washer with diameter 20 mm, thickness - 350 microns and n-type conductivity. Growth of the epitaxial layer was carried out a limited amount of bismuth molten solution in an atmosphere of purified hydrogen palladium. Grown epitaxial layers were n-type conductivity with a thickness ~ 20 microns.

The type of $nGe\text{-}p(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ heterostructure were made for research CVC. Current collector contacts with silver evaporated by the method vacuum evaporation. CVC in the forward direction, shown in fig.1 in a semi-logarithmic scale, were recorded at different temperatures.

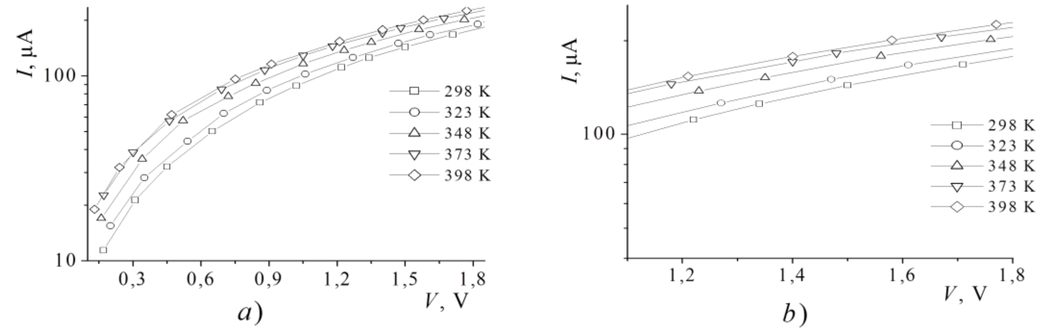

Fig.1. Voltage characteristics of $nGe\text{-}p(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ structures in the forward direction in the semi-logarithmic scale at different temperatures *(a)* and sublinear plots *(b)*.

The initial section of the CVC (fig.1a) for all temperatures can be described by an exponential dependence:

$$J = J_0 \exp\left(\frac{qV}{ckT}\right), \qquad (1)$$

with exponent $c \approx 17{,}75$. This clearly shows that the structures have a sufficiently long base [2], i.e. $d/L_p > 1$, where d - length of the base, L_p - the diffusion length of minority carriers. At the same time on all CVC traced sublinear areas. These plots are shown separately for the investigated temperatures in fig.1, b. Clearly, these areas CVC can be well described by the theory of the effect of the injection depletion, first theoretically predicted in [3]. According to the theory, this effect can be observed in opposite directions of ambipolar diffusion and drift of nonequilibrium carriers in not long diode structures under the condition $Jad > 2$, the CVC is described by:

$$V \approx V_0 \cdot e^{Jad}, \tag{2}$$

where J - the current density, a - parameter. It is known that this type of CVC implemented in semiconductor structures containing high concentration of deep impurities in opposite directions conditions of ambipolar diffusion and drift, in which case the parameter $"a"$ is described by the simple expression [4]:

$$a = \frac{1}{2qD_p N_t}, \tag{3}$$

depends only on the diffusion coefficient of the major carriers (i.e. their mobility - $D_p = \frac{kT}{q}\mu_p$) and the concentration of deep impurities N_t. For implementation of this regime, which was later called the effect of the injection depletion, must be met in terms of $Jad > 2$. In our case, at room temperature $Jad \approx 9.26$, that is, this requirement is satisfied.

Parameter *“a”* can easily be calculated from the relevant sections of sublinear CVC (fig.1(b)):

$$a = \frac{\ln\left(\frac{V_2}{V_1}\right) \cdot S}{(I_2 - I_1) \cdot d}, \tag{4}$$

where S - the cross sectional area, (I_1, V_1), (I_2, V_2) – points, selected sites on the experimental curves of the injection depletion. As follows from the theory, the emergence of such CVC is possible only if the opposite directions of the ambipolar diffusion of nonequilibrium carriers and ambipolar drift, which in this case is determined by the modulation of the charge injection of deep impurities [5].

Since we have a set of different CVC corresponding to different temperatures, according to the formula (4) we can calculate the value of the parameters $"a"$ at different temperatures, which are listed in Table 1.

Table 1. Values of parameter *(a)* and the diffusion coefficient of the majority carriers (D_p) depending on the temperature.

T, K	*298*	*323*	*348*	*373*	*398*
a, (cm/A)	$10{,}4\cdot10^5$	$10{,}16\cdot10^5$	$9{,}87\cdot10^5$	$9{,}34\cdot10^5$	$8{,}8\cdot10^5$
D, (cm²/s)	*9.9*	*10.1*	*10.37*	*11*	*12.8*
$\mu_p\cdot(cm^2/V\cdot s)$	*378*	*360*	*343,6*	*339*	*333*
$\mu_n\cdot(cm^2/V\cdot s)$	*4800*	*5544*	*6614*	*6852*	*8391*

A value of *"a"* allows from the formula (3) determine the concentration of deep impurities, responsible for the appearance of a sublinear section (2), which at room temperature is $N = 3{\cdot}10^{11}\ cm^{-3}$. From table 1, it is seen that μ_p of main carrier in the solid solution $nGe\text{-}p(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ decreases and minority carrier μ_n increases with increasing the temperature. This apparently leads to the conclusion that in this solid solution the prevailing role played the scattering mechanism of the mobility of carriers on deep impurity ions.

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