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Excitation of Growing Waves in Impurity Semiconductors with Two Current Fluctuations in Two-Valley Semiconductors in Strong Electric and Magnetic Fields

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Abstract: *It is shown that in semiconductors with two types of charge carriers, in the presence of a temperature gradient, taking hydrodynamic motions into account leads to the excitation of growing waves. The frequency and increment of this wave are determined. Expressions are found for the external electric and magnetic fields upon excitation of growing waves. It has been proven that growth occurs in samples with a certain size. It was found that the speed of the rising waves is the same in all directions of the coordinate axes and is proportional to the speed of thermomagnetic waves. The concentration ratio of electrons and holes is found upon the appearance of growing waves.*
Keywords: *valley, energy gap, effective mass, mean free path, instability, critical value, current flux density*

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I. Introduction

In [1-4], current oscillations in multivalley and impurity semiconductors were theoretically investigated. Under the influence of external fields, the excitation of vibrational phenomena in conducting media provides a very important scientific interest. In an oscillatory state, the conducting medium radiates energy from itself and becomes a source of energy. Such unstable states of conducting media create the possibility of converting electromagnetic energy into mechanical energy. Devices that are prepared on the basis of these conductive media work reliably and for a long time. The reason for the appearance of oscillations inside the medium is the generation and recombination of charge carriers (mainly impurity semiconductors) or a kind of energy dispersion law. In two-valley semiconductors, the dispersion law of charge carriers (i.e., the dependence of the energy of charge carriers on the wave vector of an oscillatory wave) is the main reason for the appearance of instability in a conducting medium. The dependences of the current density on the external electric field are mainly described as follows

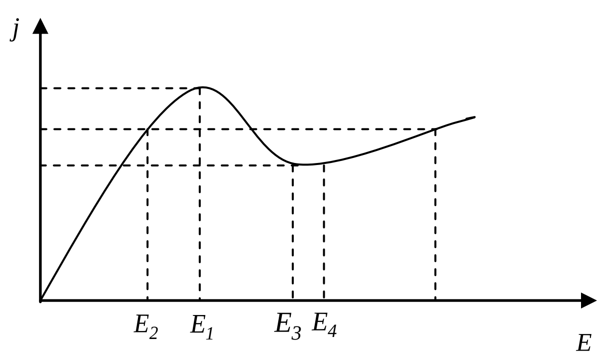

Fig.1. N-shaped current-voltage characteristic

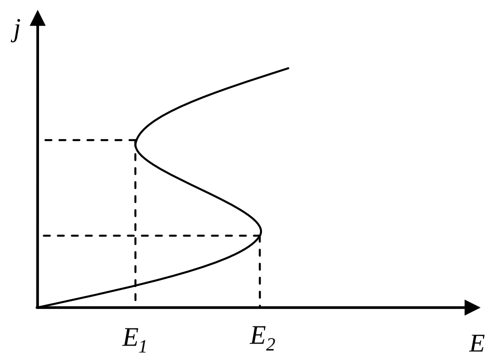

Fig.2. S-shaped current-voltage characteristic

The characteristic differences between these graphs differ as follows. In Fig. 1, the current density is a multivalued function of the electric field strength. In Fig. 2, several values of the current density correspond to one value of the electric field. Figure 1 is mainly observed experimentally in multivalley semiconductors (for example, the Gunn effect). Figure 2 is mainly observed experimentally in impurity semiconductors (for example, in Ge semiconductor doped with gold GeAu). We will further investigate current oscillations in two-valley semiconductors under the influence of external electric and magnetic fields. A random fluctuation of the density of charge carriers at any point in the medium can lead to the formation of an instant charge, which decreases the electric field on the one hand in the direction of the particle current and increases on the other. When the resistance is positive, less current flows into the space-charge region than flows out of it. When resistance is negative, the space charge increases until the field at the boundaries of the space charge region is large enough on one side and small enough on the other side for resistance to become negative. In the end, a stationary state is established, but with a strongly inhomogeneous distribution of the field in the medium. Thus, a high-field phase and a lower-field phase are obtained, and a kind of electric valley structure is formed throughout the crystal. A simplified calculation of the current depending on the field strength made by Hilsum [5], taking into account the type of the band structure of the GaAs semiconductor, showed that the region of negative differential conductivity is read from fields 3*103 V/sm. Hillsum also showed that at low temperatures on the I-V characteristic of GaSb having the same band structure, a region with NDR should also appear. The relationship between current and electric field is complex. Therefore, in all theoretical calculations, it is assumed that the mobility of charge carriers is almost independent of the field. The calculation uses the nonlinear Poisson equation and the continuity equation. When linearizing these equations, the approximation of small fluctuations is used and this is not applicable when an instability with a large amplitude appears. In the scientific literature, there is no theoretical study of the Gunn effect using the Boltzmann kinetic equation. The influence of the magnetic field on the Gunn effect by applying the kinetic Boltzmann equation is also absent. In this theoretical work, taking into account intervalley scattering and based on the solution of the Boltzmann kinetic equation, we investigate the Gunn effect in the presence of electric and magnetic fields.

II. Basic equations of the problem

The processes associated with the use of charge carriers (i.e. kinetic effects) are of great theoretical and practical interest. Electric current density, electric field strength, heat flux, regardless of time, the kinetic effect is stationary. For the current to be stationary, the charge carriers must be scattered on any inhomogeneities of the lattice (vibrations of atoms and crystal defects) and would give the lattice the energy accumulated in the electric field. Nonequilibrium processes substantially depend on the interaction of charge carriers with lattice vibrations or crystal defects.

Solving the Boltzmann equation is the only theoretical approach to transport processes in a strong field. The validity of the Boltzmann equation for strong fields is, of course, not obvious in advance. This issue was studied in [6]. In this work, the application of the Boltzmann equation was used in weak fields. Generally speaking, there is no reason why the Boltzmann equation would be less suitable for strong fields than for weak ones. Under the influence of external forces, the state of charge carriers is nonequilibrium and therefore the distribution function of carriers is nonequilibrium and depends on the coordinates and on the wave vector k $f(\vec{k},\vec{r})$.

Since we are considering stationary processes $f(\vec{k},\vec{r})$, it obviously does not depend on time. The distribution function $f(\vec{k},\vec{r})$ can be found from the kinetic Boltzmann equation based on the following considerations. It is assumed that the distribution function can change under the influence of two reasons: 1) under the influence of external factors, 2) under the influence of collisions of carriers with lattice vibrations (phonons) and lattice defects. Let us denote changes in the distribution function under the influence of external factors by $\left(\frac{\partial f}{\partial t}\right)_{external}$, and collisions by $\left(\frac{\partial f}{\partial t}\right)_{coll}$. Then the considered stationary state, the influence of these two factors mutually compensate each other.

$$\left(\frac{\partial f}{\partial t}\right)_{external}+\left(\frac{\partial f}{\partial t}\right)_{coll}=0 \quad (1)$$

In the presence of external electric and magnetic fields, equation (1) has the form

$$\vec{V}\nabla_r f + \frac{e}{\hbar}\left\{\vec{E} + \frac{1}{c}\left[\vec{V}H\right]\right\}\nabla_k f = \left(\frac{\partial f}{\partial t}\right)_{coll}$$

Here $\vec{V} = \frac{1}{\hbar}\nabla_k a(\vec{k})$ is the velocity of the carriers, e is its charge, and $\nabla_{\vec{r}}$ and $\nabla_{\vec{k}}$ are gradients in the space of coordinates and wave vector $\vec{k}$.

III. Solution of the Boltzmann equation in strong fields.

In GaAs compounds, two spherical energy bands are mixed one with respect to the other by energy, and Δ the external domine (which we will designate "a") the effective mass is much less than in the upper domine ($"b"$) $m_a << m_b$. It is assumed that scattering occurs by longitudinal phonons. We will neglect the perturbation of the phonon distribution by hot carriers. The solution neglects the anisotropy. The fact that, in studies of the Gunn effect on GaAs samples, no orientation dependence was found speaks in favor of this assumption.

We will assume that for a domina $"a"$, intervalley scattering prevails in comparison with inside a domina, and for a domina "b", we will assume that intravalley scattering prevails over intervalley scattering. Then the Boltzmann equation for the lower domina can be written in the form

$$\left(\frac{\partial f^a}{\partial t}\right)_{external} + \left(\frac{\partial f^a}{\partial t}\right)_{interdomain} = 0 \qquad (3)$$

For the domina $"b"$, we write the Boltzmann equation in the form

$$\left(\frac{\partial f^b}{\partial t}\right)_{external} + \left(\frac{\partial f^b}{\partial t}\right)_{entraldomain} = 0 \qquad (4)$$

In [7] it was proved that in a strong electric field the distribution function can be expanded in a series as follows

$$f = f_0 + \frac{\vec{P}}{p}\vec{f_1} \quad (5)$$

Then

$$f^a = f_0^a + \frac{\vec{P}}{p}\vec{f}_1^a, \quad f^b = f_0^b + \frac{\vec{P}}{p}\vec{f}_1^b \qquad (6)$$

$\vec{P}$ -is the momentum of an electron. The distribution function f^b was found from equation (4) without a magnetic field in [8]

$$f_0^b = Be^{-\alpha\delta(\varepsilon-\Delta)^2}, \; f_1^b = -\frac{em_b l_b}{p}\vec{E}\frac{\partial f_0^b}{\partial p} \qquad (7)$$

Here

$$l_b = \frac{\pi\hbar^4\rho u_0^2}{D^2 m_b^2 k_0 T}, \alpha_b = \frac{3D^4 m_b^5 k_0 T}{e^2\pi^2\hbar^8\rho u_0^2}\cdot\frac{1}{E^2} \qquad (8)$$

l_b – free path in valley "b"

D – deformation potential

T – grate temperature

k_0 – Boltzmann constant

u_0 – sound speed

ρ – crystal density

For domina "a" without magnetic field

$$\left(\frac{\partial f^a}{\partial t}\right)_{external} = \frac{e}{\hbar}\vec{E}\vec{\nabla}_k f^a = e\vec{E}\nabla_p f^a \qquad (9)$$

$$e\vec{E}\nabla_p f^a + \left(\frac{\partial f^a}{\partial t}\right)_{interdomain} = 0 \qquad (10)$$

In the relaxation time approximation

$$\left(\frac{\partial f^a}{\partial t}\right)_{interdomain} = -\frac{f_1^a}{\tau} = -\frac{p}{l_a m_a} f_1^a, f_1^a = -\frac{e m_a l_a}{p}\vec{E}\frac{\partial f_0^a}{\partial p} \qquad (11)$$

In the case of strong fields, from (10-11) at $f_0^a = Ae^{-\alpha_a \varepsilon^2}$, we easily obtain

$$\alpha_a = \frac{3D^4 m_b^5 k_0 T}{e^2 \pi^2 \hbar^8 \rho^2 u_0^2} \cdot \frac{1}{E^2}$$

A and B can be found from the balance equation

$$n_a + n_b = n \quad (12)$$

$$\frac{dn}{dt} = 0 \quad (13)$$

From (12)

$$A\int_0^\infty e^{-\alpha_a \varepsilon^2} \frac{dP_x dP_y dP_z}{(2\pi\hbar)^3} + B\int_0^\infty e^{-\alpha_b(\varepsilon-\Delta)^2} \frac{dP_x dP_y dP_z}{(2\pi\hbar)^3} = n$$

And from (13) denoting

$$\beta = \frac{\int_1^\infty \left[x(x-1)\right]^{1/2} e^{-\alpha_a \Delta^2 x^2} dx}{\int_0^\infty \left[x(x+1)\right]^{1/2} e^{-\alpha_b \Delta^2 x^2} dx}$$

We easily obtain for A and B the following expressions

$$A = \frac{(2\pi)^2 \hbar^3 \alpha_a^{3/4}}{(2m_a)^{3/2} \Gamma^{3/4}\left[1+\gamma^{-3/2} Z^{3/2}\beta\right]}; \quad B = \frac{(2\pi)^2 \hbar^3 \alpha_b^{3/4} n\beta}{(2m_b)^{3/2} \Gamma^{3/4}\left[1+\gamma^{-3/2} Z^{3/2}\beta\right]}$$

$$\gamma = \frac{m_a}{m_b}; \quad Z = \frac{\alpha_a}{\alpha_b}$$

Вычислим плотность тока

$$j = j_a + j_b = c\alpha_a^{1/4} E \frac{1 + t\gamma^{-1} Z^{-1/2} e - \alpha_a \Delta^2}{1 + \gamma^{-3/2} Z^{-1/4} e^{-\alpha_a \Delta^2}}, t = \frac{l_b}{l_a} \qquad (14)$$

Substituting values α_a in (14) and introducing

$$E_{char}^2 = \frac{3D^4 m_0 m_a^3 m_b k_0 T}{\pi^2 e^2 \hbar^8 \rho^2 u_0^2}$$

we get

$\alpha_a = \Delta^2 = \left(\frac{E_{char}}{E}\right)^2$ and $e^{-\frac{E_{char}^2}{E^2}} == 1 - \frac{E_{char}^2}{E^2}; E_{char} << E$

$$j = E^{1/2} R \frac{1 + t\gamma^{-1} Z^{-1/2}\left(1 - \frac{E_{char}^2}{E^2}\right)}{1 + \gamma^{-3/2} Z^{-1/4}\left(1 - \frac{E_{char}^2}{E^2}\right)} \qquad (15)$$

From (15) we easily obtain $\frac{dj}{dE}=0$ and

$$E_{critical}^2 = 2E_{char}^2 \frac{tZ^{-1/2} j^{-1} + 2,5}{tZ^{-1/2} j^{-1} + 1} \qquad (16)$$

Substituting the values E_{xap}, t, Z, γ from (16) we get:

$$E_{char} \approx 2800 V/sm \qquad (17)$$

It can be seen from (17) that the value of the critical field is consistent with the value of the electric field in Gunn's studies $\left(E_{critical}^{Gunn} \approx 3000 V/sm\right)$. To clarify the effect of a magnetic field on the critical electric field in two-mine semiconductors, it is necessary to solve the Boltzmann equation in the presence of an external magnetic field. In [7] it was proved that in the presence of electric and magnetic fields, the corresponding distribution functions have the form:

$$f_1^b = -\frac{el_a m_b}{P}\frac{\partial f_0^b}{\partial P}\cdot\frac{\vec{E} + \left(\frac{el_b}{cP}\right)\left[\vec{E}\vec{H}\right] + \left(\frac{el_b}{cP}\right)^2 \vec{H}\left[\vec{E}\vec{H}\right]}{1+\left(\frac{el_b}{cP}\right)^2 H^2}, \; f_0^b = Be^{-\alpha_b(\varepsilon-\Delta)^2} \qquad (18)$$

$$\alpha_b = \frac{3D^4 m_b^5 k_0 T\left[1+\left(\frac{el_b}{cP}\right)^2 H^2\right]}{\pi^2 e^2 \hbar^8 \rho^2 u_0^2\left[E^2 + \left(\frac{el_b}{cP}\right)^2\left(\vec{E}\vec{H}\right)^2\right]}$$

Expressions for f_1^a and α_a are easily obtained, you just need m_b to replace with m_a, l_b with l_a, and $f_0^a = Ae^{-\alpha_a\varepsilon^2}$

Let's calculate the total current

$$\vec{j} = \vec{j}_a + \vec{j}_b \qquad (19)$$

$$j_a = \frac{e^2 l_a \alpha_a A}{3\pi^2\hbar^3 m_a^2}\left\{\vec{E}\int_0^\infty \frac{P^5 e^{-\frac{\alpha_a P^2}{4m_a^2}}}{1+\left(\frac{el_a}{cP}\right)^2 H^2}dP + \frac{el_a}{c}\left[\vec{E}\vec{H}\right]\int_0^\infty \frac{P^4 e^{-\frac{\alpha_a P^4}{4m_a^2}}}{1+\left(\frac{el_a}{cP}\right)^2 H^2}dP + \left(\frac{el_a}{c}\right)^2 \vec{H}\left[\vec{E}\vec{H}\right]\int_0^\infty \frac{P^3 e^{-\frac{\alpha_a P^4}{4m_a^2}}}{1+\left(\frac{el_a}{cP}\right)^2 H^2}dP\right\}$$

(20)

Expressions for j_b can be easily obtained if in (20) we carry out the following replace

$$m_a \to m_б, \alpha_a \to \alpha_б, l_a \to l_б$$

After integration from (20) we get:

$$\vec{j}_a = \frac{e^2 l_a \alpha_a A}{3\pi^2\hbar^3 m_a^2}\left\{\vec{E}\cdot\frac{1}{4}\left(\frac{4m_a^2}{\alpha_a}\right)^{3/2}\Gamma\left(3/2\right) + \left[\vec{E}\vec{H}\right]\frac{1}{4}\left(\frac{4m_a^2}{\alpha_a}\right)^{5/4}\Gamma\left(5/4\right)\frac{el_a}{c} + \vec{H}\left(\vec{E}\vec{H}\right)\frac{e^2 l_a^2}{c^2}\frac{m_\alpha^2}{\alpha_a}\right\} \qquad (21)$$

Replace $\alpha_a \to \alpha_b, l_a \to l_b, A \to B$ from (21) we get for $\vec{j}_b$. From $\vec{j} = \vec{j}_a + \vec{j}_b$ легко получим

$$\vec{j} = \sigma\vec{E} + \sigma_1\left[\vec{E}\vec{h}\right] + \sigma_2\vec{h}\left[\vec{E}\vec{h}\right] \qquad (22)$$

$\vec{h}$ is unit vector in direction H.

$$\sigma = \frac{4e^2 l_a \alpha_a^{1/4} n}{3(2m_a)^{1/2}}\cdot\frac{\Gamma\left(3/2\right)}{\Gamma\left(3/4\right)}\cdot\frac{1+t\gamma^{-1}Z^{1/2}\beta}{1+\gamma^{-3/2}Z^{3/4}\beta}$$

$$\sigma_1 = \frac{3e^3 l_a^2 \alpha_a^{1/4} n}{3cm_a} \cdot \frac{\Gamma\left(5/4\right)}{\Gamma\left(3/4\right)} \cdot \frac{1+t^2\gamma^{-1/2} Z^{1/4}\beta}{1+\gamma^{-3/2} Z^{3/4}\beta} H$$

$$\sigma_2 = \frac{2e^4 l_a^3 \alpha_a^{3/4} n}{3\sqrt{2} c^2 m_a^{3/2}} \cdot \frac{H^2}{\Gamma\left(3/4\right)} \cdot \frac{1+t^3}{1+\gamma^{-3/2} Z^{3/4}\beta}$$

When deriving expression (22), we used the conditions of a weak magnetic field

$$\left(\frac{cP}{el_a}\right) = H_{1a}, \left(\frac{cP}{el_b}\right) = H_{1b}, H << \left(H_{1a}, H_{1b}\right)$$

We direct the electric field along the axis Z , then $E_z = E, E_x = E_y = 0$ from (22) we get:

$$j_z = \frac{4e^2 l_a \alpha_a^{1/4} n \Gamma\left(3/2\right)}{3\left(2m_a\right)^{1/2}\left(1+\gamma^{-3/2} Z^{3/4}\beta\right)\Gamma\left(3/4\right)}\left[1+t\gamma^{-1} Z^{1/2}\beta + \left(1+t^3\right)\frac{H^2}{H_{1a}^2}\Delta\alpha_a^{1/2}\cos\theta\right] \qquad (23)$$

$\vec{E}\vec{H} = EH\cos\theta$

Considering that $t^3 << 1, H^2 << H_{1a}^2, \Delta\alpha_a^{1/2} : \frac{E_{xap}}{E}$ and $\sigma E >> \sigma_2 E\cos\theta$ we see that in the case of weak magnetic fields the dependence of the current on the electric field remains the same, that is, a weak magnetic field does not affect the current fluctuations. This was to be expected, since the magnetic field does not change the mean free path (does not affect the relaxation time), but only slightly twist the trajectory between collisions without changing their velocity.

Consider the case of strong magnetic fields, i.e.

$$H >> \left(H_{1a}, H_{1b}\right)$$

Then after calculating the integrals we get:

$$\vec{j} = \sigma'\vec{E} + \sigma_1'\left[\vec{E}\vec{h}\right] + \sigma_2'\vec{h}\left[\vec{E}\vec{h}\right] \qquad (24)$$

$$\sigma' = \frac{8nc^2 m_a^{1/2}\alpha^{-1/4}}{3\sqrt{2} l_a \Gamma\left(3/4\right)} \cdot \frac{1}{H^2} \cdot \frac{1+t^{-1}\gamma^{-2} z\beta}{1+\gamma^{-3/2} z^{3/4}\beta}$$

$$\sigma_1' = \frac{4enc}{H} \cdot \frac{\Gamma\left(7/4\right)}{\Gamma\left(3/4\right)}$$

$$\sigma_2' = \frac{4e^2 n l_a \alpha_a^{-1/4}}{3\sqrt{2} m_a^{1/2}} \cdot \frac{\Gamma\left(3/2\right)}{\Gamma\left(3/4\right)} \cdot \frac{1+t\gamma^{-1} z^{1/2}\beta}{1+\gamma^{-3/2} z^{3/4}\beta}$$

At $E_z = E, E_x = E_y = 0$ from (24) we get easy:

$$j_z = \frac{8nc^2 m_a^{1/2}}{3\sqrt{2} l_a \Gamma\left(3/4\right)} \cdot \frac{E}{H^2} \cdot \frac{\alpha_a^{-1/4}}{1+\gamma^{-3/2} z^{3/4}\beta}\left[1+t\gamma^{-2} z\beta + \frac{e^2 l_a^2 \alpha_a^{1/2}}{2c^2 m_a}\Gamma\left(3/2\right) H^2\left(1+t\gamma^{-1} z\beta^{1/2}\right)\right]$$

notice, that $\frac{e^2 l_a \alpha^{-1/2} H^2}{2c^2 m_a} \approx \frac{H^2}{H_{1a}^2} \cdot \frac{E_{char}}{E}, \gamma^{-3/2} \cdot z^{3/4}\beta >> 1$, then $j_z : E^{1/2}$ and in this case, the instability is removed. Suppose $\theta = 90^{\circ}$

$$j_z : E^{1/2}\frac{1+A'e^{-\frac{E_x^2}{E^2}}}{1+B'e^{-\frac{E_x^2}{E^2}}}, A' = \left(\frac{m_b}{m_a}\right)^{7/2}, B' = \left(\frac{m_b}{m_a}\right)^{9/4}\left(\frac{H_{1a}}{H_{1b}}\right)^{1/2}$$

$j_z \sim E^{1/2}$ and in this case the instability is removed.

The disappearance of instability in strong magnetic fields is due to the fact that the mean free path increases (the time of intervalley relaxation increases) due to the fact that between two successive collisions, the electron has time to make several turns.

Consider the values of the magnetic field

$$H_{1a}^2 << H^2 << H_{1b}^2 \qquad (25)$$

If (25) is fulfilled, we get

$$\vec{j} = \sigma''\vec{E} + \sigma_1''\left[\vec{E}\vec{h}\right] + \sigma_2''\vec{h}\left[\vec{E}\vec{h}\right] \qquad (26)$$

$$\sigma'' = \varphi\alpha_a^{1/4}\Gamma\left(3/2\right)\cdot\frac{1+\frac{1}{\Gamma\left(3/2\right)}t\gamma^{-1}z\frac{H_{1b}^2}{H^2}\frac{E}{E_x}\beta}{1+\gamma^{-3/2}z^{3/4}\beta}$$

$$\sigma_1'' = \frac{4e^3nl_a^2\alpha_a^{1/2}}{3cm_a}\cdot\frac{\Gamma\left(5/4\right)}{\Gamma\left(3/4\right)}H\cdot\frac{1+\frac{\Gamma\left(3/4\right)}{\Gamma\left(5/4\right)}tz\left(H_{1a}H_{1b}\right)H^{-2}\frac{E}{E_x}e^{-\alpha_a\Delta^2}}{1+\gamma^{-3/2}z^{-1/4}e^{-\alpha_a\Delta^2}}$$

$$\sigma_2'' = \frac{4e^4nl_a^3\alpha_a^{3/4}H^2}{3\Gamma\left(3/4\right)c^2\left(2m_a\right)^{3/2}}\cdot\frac{1+\Gamma\left(3/2\right)t\gamma^{-1}z^{-1/2}\left(\frac{H_{1a}}{H}\right)^2\frac{E}{E_x}e^{-\alpha_a\Delta^2}}{1+\gamma^{-3/2}z^{-1/4}e^{-\alpha_a\Delta^2}}$$

Consider the case $\theta = 0, \vec{E} \parallel \vec{H}$ then from (26) we obtain

$$j_z = \frac{1}{E^{1/2}}\cdot\frac{1+A''\left(\frac{E}{E_x}\right)e^{-\left(\frac{E_x}{E}\right)^2}}{1+B''e^{-\left(\frac{E_x}{E}\right)^2}} \qquad (27)$$

Equating the derivative $\frac{dj_z}{dE}$ to zero we get $E_{critical} = \frac{E_{char}}{u}, u > 1$. Therefore $E_{critical} < E_{char} \approx 1800 V/sm$, i.e. the critical field decreases at $\theta = 0$. Consider the case $\theta = 90^o, \vec{E} \perp \vec{H}$, then we get

$$j_z \sim E^{1/2}\frac{1+A'''\frac{E}{E_x}e^{-\frac{E_x^2}{E^2}}}{1+B'''e^{-\frac{E_x^2}{E^2}}} \qquad (28)$$

$$A''' = \frac{1}{\Gamma\left(3/2\right)}t\gamma^{-1}\left(\frac{H_{1б}}{H_{1a}}\right)^2 > 1, B''' = \gamma^{-3/2}z^{-1/4} >> 1$$

At $\frac{dj_z}{dE} = 0$ from (28) we get

$$E_{critical} = E_{char}\frac{1+\sqrt{1+48\left(A'''\right)^2}}{8A'''}$$

$$E_{critical} \approx 1500 V/sm$$

Those. in this case, the value of the critical field decreases.

IV. Discussion

The application of the Boltzmann kinetic equation is used to obtain the critical value of the external electric field, at which current oscillations (i.e., instability) in two-valley semiconductors of the GaAs type begin. The estimated value of the obtained formulas for the critical field based on the data of the Gann experiment $E_{critical} : 2800 V/sm$ is close to the value $E_{critical}(Gunn) : 3000 V/sm$. This proves that the application of the Boltzmann equation is quite justified. In the presence of an external magnetic field, the value of the critical electric field does not change in the presence of a weak magnetic field. In this case, the magnetic field does not change the mean free path of charge carriers. The trajectory of charge carriers is twisted slightly. In each domina, characteristic magnetic fields H_{1a} and H_{1b} are introduced. The values of these characteristic magnetic fields are inversely proportional to the mean free paths l_a and $l_б$. If the magnetic field changes in the interval

$$H_{1a} < H < H_{1b}$$

at certain values of the external electric field, instability begins (i.e. current fluctuations). In this case, the estimated value of the critical electric field is less than the critical field obtained by Gunn's experiment in GaAs. Thus, in a magnetic field, instability (current fluctuations) begins at lower values of the electric field compared to the presence of only an electric field. The same result was obtained in [1-4], in which the instability is analyzed by solving the Poisson equation and the continuity equation. This will justify the application of the Boltzmann kinetic equation in strong electric and magnetic fields.

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