THEORY OF INTERNAL INSTABILITY IN THE SEMICONDUCTORS WITH ONE TYPE OF CHARGE CARRIERS

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The frequencies and increase increment of arising waves in homogeneous and impurity semiconductors have been calculated. The change interval of external electric field in the conditions of internal instability has been found.

The theoretical investigation of electric instabilities in the semiconductors forms the possibilities for experimental preparations amplifier and generators, working in high-frequency band. The oscillations, arising inside the sample, can go out increasing and at that the current in the external circuit oscillates, i.e. the external instability arises. At external instability the oscillation frequency ω is real value, and wave vector *k* is complex one. If current oscillations take place in external circuit, then this means, that charge and electric field oscillations inside the sample have already aroused. Thus, the sample, inside of which the charge and electric field distributions take place, is the active circuit element. Firstly, by this reason it is needed the foundations of charge internal oscillation and electric field for theoretical description of current in external circuit. When the charge redistribution arises inside the sample, the possibility of internal instability arises. At internal instability the wave vector is the real one, and oscillation frequency is complex value.

In this paper we will theoretically investigate the conditions of internal instability in the semiconductors with one type of charge carriers. When the semiconductor is pure material (i.e. there aren't impurity atoms in semiconductor), then charge redistribution inside the sample takes place because of external fields. If there are impurity atoms in semiconductor, then current carriers can be captured (recombination), or emitted (generation) by impurity atoms.

The corresponding control system with taking into consideration of recombination and generation of charge carriers has the form:

$$\begin{cases} \dfrac{\partial\rho}{\partial\tau} + div\,\vec{j} = 0 \\ div\vec{E} = \dfrac{4\pi}{\varepsilon}(\rho - \rho_0) \\ \vec{j} = en\mu\vec{E} - D\nabla\vec{n} \\ \dfrac{\partial n_{rec.}}{\partial\tau} = \gamma(0)\left[n(N - n_{rec.})\omega(E) - n_1 n_{rec.}\right] \end{cases}, \quad (1)$$

$\rho=e(n+n_{rec.})$; N is concentration of impurity atoms, $\omega(E)$ is capture frequency of charge carriers by impurity atoms, $n_{rec.}$ is electron recombination concentration, $\gamma(0)$ is coefficient of electron emission by impurity atoms. Linearizing system (1) without taking into consideration with respect to electric field and concentrations of charge carriers

$$E = E_0 + E'(x,t); \qquad E'(x,t) << E_0,$$
$$n=n_0+n'(x,t) \qquad n'(x,t)<<n_0^0$$

and considering, that fluctuation values $\left[E'(x,t)\ \text{k}\ n'(x,t)\right] \sim e^{i(kx-\omega t)}$ from (1), we will obtain the dispersion relation of the following type:

$$i\omega = \varepsilon + DK^2 + ik(U_0 - \frac{8\pi}{\varepsilon}E_0\rho_0\frac{dD}{dE}\Big|_{E=E_0}). \quad (2)$$

From (2) it is seen, that $\omega=\omega_0+ij$; $U_0=\mu_0 E_0$

$$\omega_0 = k(U_0 - \frac{8\pi}{\varepsilon}E_0\rho_0\frac{dD}{dE}\Big|_{E=E_0}). \quad (3)$$

$$\gamma = -\frac{4\pi\tau}{\varepsilon} - DK^2$$

Substituting (3) in $\left[E'(x,t)\ \text{k}\ n'(x,t)\right] \sim e^{i(kx-\omega t)}$, we easily see, that $\sigma<0$, i.e.

$$\sigma = -en_0\left|\frac{d(\mu E)}{dE}\right|_{E=E_0} \langle 0 .$$

The oscillations of charge carriers inside the sample increase and sample state is instable. These oscillations take place with frequency ω_0. However, at $\mu_0 = \frac{8\pi}{\varepsilon}en_0\frac{dD}{dE}\Big|_{E=E_0}$ these oscillations are periodic ones, i.e. $Re\omega=0$. At that the considered fluctuations damp or increase without oscillation. The increase increment of aperiodic oscillations has the form

$$\gamma = \frac{4\pi}{\varepsilon}|\sigma| - DK^2 \quad (4) \quad K = \frac{2\pi}{L}m, \quad m = 0 \pm 1, \pm 2, .$$

From (4) it is seen, that aperiodic oscillations can arise in long samples quickly, than in short ones.

Let's consider the arise conditions of instable fluctuation waves inside sample in impurity semiconductors.

Linearizing system (1) with taking into consideration of recombination and generation of charge carriers, we easily obtain the following dispersion relations

$$-k^2D(1-i\omega\tau_1)-U_0\left[\frac{D\tau_1}{U^2{}_0\tau_M\tau_c}\frac{d\ell n\omega}{d\ell nE}+1-i\omega\tau_1\right]ik+$$
$$+\frac{1}{\tau_1}\left[(\omega\tau_1)^2+i\omega\tau_1(\frac{\tau_1}{\tau_M}+\frac{\tau_1}{\tau_2})+\frac{\tau_1{}^2}{\tau_M\tau_3}(\frac{d\ell n\omega(E)}{d\ell nE}-1)+\frac{\tau_1}{\tau_M}\right]=0 \quad (5)$$

$\tau_M=\frac{\varepsilon}{4\pi\tau_0}$ is Maxwell relaxation time

$\tau_1=n_{t,0}\left[(j_{10})\omega(E_0)n_0N\right]^{-1}$ is generation time of charge carriers

$\tau_3=\left[(j_{10})\omega(E_0)(N-nt,_0)\right]^{-1}$ is capture time of charge carriers

$\tau_2=\frac{\tau_3\tau_1}{\tau_3+\tau_1}$ is life time of free charge carriers.

Designating $\omega\tau_1=x$ from (5) we obtain

$$a=1+\frac{D\tau_1}{U^2{}_0\tau_M\tau_c}\frac{d\ell n\omega}{d\ell nE};\quad b=\frac{\tau_1}{\tau_M}+\frac{\tau_1}{\tau_2};\quad c=\frac{\tau_1}{\tau_M}+\frac{\tau_1{}^2}{\tau_M\tau_3}(\frac{d\ell n\omega}{d\ell nE}-1)$$

$$x^2+(ku\tau_1+ib+i\tau_1k^2D)x-\tau_1k^2D+ikuk^2\tau^a{}_1+c=0\ . \quad (6)$$

As $\tau_1<\tau_3$ at $\frac{d\ell n\omega}{d\ell nE}=0$

$$a=1;\ b=\frac{\tau_1}{\tau_M}(1+\frac{\tau_M}{\tau_2});\quad c=\frac{\tau_1}{\tau_M}$$

from (6) we obtain

$$x^2+\left\{ku\tau_1+{}_c\left[\frac{\tau_1}{\tau_M}(1+\frac{\tau_m}{\tau_2})+k^2D\tau_1\right]\right\}x-\tau_1k^2D+\frac{\tau_1}{\tau_M}+iku\tau_1=0\ . \quad (6')$$

Considering, that $x=x_0+ix_1$ and $x_1<<x_0$ from solution (6'), we obtain

$$x_0=-r,\qquad x_1=\frac{\frac{\tau_1}{\tau_M}-k^2D\tau_1}{(ku\tau_1)^2}r-1\ . \quad (7)$$

From (7) it is seen, that recombination fluctuation is increasing one, if $k^2D\geq\frac{1}{\tau_m}$ i.e. $\frac{\varepsilon}{4\pi}\frac{k^2D}{\sigma}\geq 1$ with frequency $\omega_0=\frac{1}{\tau_m}(1+\frac{\tau_m}{\tau_2})+k^2D$, when electric field changes in next interval.

$$E_0\geq(\frac{D}{\tau_1})\frac{1}{\mu}\cdot$$

Thus, the emergences of electric instability in impurity semiconductors essentially depend on recombination and generation frequencies of charge carriers. This process (i.e. sample instable state) leads to wave radiation from sample with definite frequency ω_0.

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BİR TİP KEÇİRİCİLİYƏ MALİK YARIMKEÇİRİCİLƏRDƏ DAXİLİ DAYANIQSIZLIQ NƏZƏRİYYƏSİ

Bircins və aşqarlı yarımkeçiricilərdə daxili dayanıqsızlıq şəraitində artan dalğaların tezlikləri və inkrementləri hesablanmışdır. Dayanıqsızlığa uyğun elektrik sahəsinin dəyişmə intervalı tapılmışdır.

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ТЕОРИЯ ВНУТРЕННЕЙ НЕУСТОЙЧИВОСТИ В ПОЛУПРОВОДНИКАХ С ОДНИМ ТИПОМ НОСИТЕЛЕЙ ЗАРЯДА

Вычислены частоты и инкременты нарастания возникающих волн в однородных и в примесных полупроводниках. Найден интервал изменения внешнего электрического поля в условиях внутренней неустойчивости.

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