THE INTERNAL AND EXTERNAL RELAXATION INSTABILITY IN SEMICONDUCTORS.

REZA YAZDANKHAH HOSEYN, MOHAMMED REZA BELGHADR JAMSHİD
(Islamic Azad University, Islam Shahr Branch IRAN).

E.R.GASANOV,
Institute of Physics Azerbaijan National Academy of Sciences of Azerbaijan, Baku. AZ-1143,H.Javid,33

Yük daşıyıcıların relaksasiyasınını nəzərə alaraq elektron-deşik keçiriciliyinə malik yarımkeçiricilərdə daxili və xarici dayanıqsızlıq halında dalğanın rəqs tezliyi hesablanmışdır. Elektrik dayanəqsız halın əmələ gəlməsinə müvafiq olan xarici elektrik sahəsini dəyişmə intervalı müəyyən edilmişdir.

Вычислены частоты колебаний волн при внутренней и внешней неустойчивости в полупроводниках электронно-дырочной проводимости с учетом релаксации носителей заряда. Найдены интервалы изменения внешнего электрического поля, при которых возникает электрическая неустойчивость.

The frequencies of wave oscillations at internal and external instability in semiconductors of electron-hole conductivity with taking under consideration the relaxation of charge carriers have been calculated. The intervals of change of external electric field, at which the electric instability in the sample take place, have been found.

The relaxation of electrons and holes in the semiconductors at the presence of external electric field E_0, can lead to instable state of the crystal. The relaxation times of electrons τ_- and holes τ_+ are different by the values. When field dependencies of coefficients $\beta_\pm = \frac{\mathrm{E}_0^2}{\sigma_\pm^0}\cdot\frac{d\sigma_\pm}{d\left(\mathrm{E}_0^2\right)}$ change, signs, i.e. $\beta_\pm \lesseqgtr 0$, then the number of current carrier changes and that leads to the current decrease with increase of electric field. The main results of theoretic investigations of current oscillations in the semiconductors with the different of relaxation times $\tau_\pm$ and coefficients $\beta_\pm$ are given in the present paper.

The total current in the semiconductors of two types of current carriers has the form:

$$J = \sigma_+\vec{\mathrm{E}} + \vec{\sigma}_- + D_-\vec{\nabla}\rho_- - D_+\vec{\nabla}\rho_+, \quad \rho_\pm = en_\pm \quad (1),$$

where $D_\pm$ are diffusion coefficients, $n_\pm$ are concentrations of current carriers.

$$divE = \frac{4\pi e}{\varepsilon}\left(n_+ - n_- + N_0\right); \quad N_0 = n_+^0 - n_-^0 \quad (2).$$

Taking under the consideration that current oscillations don't take place at internal instability, $J'(t) = 0$, i.e. $n_\pm$ charge carriers redistribute. $J'(t) \neq 0$ and crystal impedance become complex at the external instability:

$$\mathrm{Z} = \mathrm{Re}\,\mathrm{Z} + Jm\mathrm{Z} \quad (3).$$

Taking under consideration that $\mathrm{E} = \mathrm{E}_0 + \mathrm{E}'$, $n_\pm = n_\pm^0 + n'_\pm$

$$\sigma_\pm = \sigma_\pm^0 + \sigma'_\pm \text{ and } \left(E', n'_\pm, \sigma'_\pm\right) \sim e^{iwt} \quad (4)$$

and substituting (4) in (1-2), we obtain the dispersion equations of the following types for the oscillation frequency at internal instability:

$$\left(\mathrm{A}_0 + i\mathrm{A}_1\right)y^2 + \left(\mathrm{B}_0 + i\mathrm{B}_1\right)y + C_0 + iC_1 = 0 \quad (5)$$

$$y = \omega\tau_-$$

The coefficients of internal instability $A_0, A_1, B_0, B_1, C_0, C_1$ depend on equilibrium values $n_\pm^0, \mathrm{E}_0$.

The solving of equation (5) shows that frequency ω_0 and increment ω_1 have the following values at internal instability:

$$\omega_0 = \frac{R\left|\mathrm{N}_0\right|}{2\tau_-}; \quad \omega_1 = -\frac{R\left|\mathrm{N}_1\right|}{2\tau_-}.$$

$$R = \frac{\tau_-}{\tau_+} + \frac{1}{1+r^2}; \quad r = \frac{2k}{\sigma_0\mathrm{E}_0}\left(\rho_+^0 D_+\mu_+ - \rho_-^0 D_-\mu_-^{\varphi_-}\right),$$

where k is wave vector, $\mu_{\mp}^{0}$ are mobilities of electrons and holes, $\varphi_{-}=\frac{d\ln\mu_{-}}{d\ln E_0^2}$, $|N_0|$ and $|N_1|$ are non-dimensional coefficients. The crystal impedance (3)

$$Z(\omega)=\frac{1}{J'(\omega)}\int_0^L E'dx$$

with homogeneous boundary conditions $E'(0,t)=E'(L,t)=0$ (L is crystal length) has been calculated at external instability $J'(t)\neq 0$.

$$\begin{aligned}\operatorname{Re}Z&=1-\Phi\left(E_{0,}n_{+}^{0},n_{-}^{0},\mu_{+}^{0},\mu_{-}^{0}\right)\\ JmZ&=F\left(E_0,n_{+}^{0},n_{-}^{0},\mu_{+}^{0},\mu_{-}^{0}\right)\end{aligned} \quad (6).$$

The analysis of (6) shows that current oscillations takes place with following frequency in external circuit:

$$\omega\geq\sqrt{2}\cdot\frac{1}{\tau_{-}}\cdot\frac{E_0}{E_1} \quad (7)$$

and these oscillations start if the external electric field takes place:

$$E_0=\frac{\pi\sigma_{-}^{0}}{4\sigma_0}E_1,\quad E_1=\frac{4\pi\left(D_{-}-D_{+}\right)}{\varepsilon D_{+}}\cdot len_{-}^{0}\varphi_1 .$$

From (7) it is seen, that frequency ω of current oscillation increases with the increase of electric field E_0, i.e. concentration changes of current oscillations $n_{\pm}$ take place quicker. If the relaxation takes place quickly, i.e. τ_{-} decreases, then frequency ω of current oscillation increases and this is quite naturally.

[1]. *M.I. Iglizin, E.G.Pel, L.Y.Pervova, V.I. Fistul,* FTT. T.8, 12, s.3606 (1966) (in Russian).

[2]. *V.L.Bonch-Bruyevich, I.P.Zvyagin, A.G.Mironov* "Domennaya elektricheskaya neustoichivost v poluprovodnikah" Moskva (1972) (in Russian).

[3]. *E.R.Gasanov, R.K.Qasimova,* "Xabaralar" №5, v.XXVI, s.98-101, (2006) Baku. (in Russian).

[4]. *E.R.Gasanov, M.F..Novruzov* "Fizika" № 1-2, v.XIII, s.134-136 (2007) (in Russian).

Daxil olunub: 01.07.2007