SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2018 **Issue:** 10 **Volume:** 66

Published: 30.10.2018 http://T-Science.org

QR – Issue QR – Article

SECTION 1. Theoretical research in mathematics.

Muhammadjon Gulomkodirovich Dadamirzayev
doctor of science (DSc) in physical and mathematical sciences, associate professor,
Namangan engineering-construction institute,
Namangan, Uzbekistan

Mamura Odiljonovna Kosimova
senior teacher,
Namangan engineering-construction institute,
Namangan, Uzbekistan

THE EFFECT OF THE VARIATION OF THE ELECTRIC FIELD OF THE UHF WAVES ON THE CVC OF THE ASYMMETRIC P-N-JUNCTION

***Abstract**: It is revealed that the occurrence of EMF and current at low heating of charge carriers is caused by the deviation of the electric field vector of the UHF wave inside the asymmetric concentration of the p-n-junction and the Frenkel effect, and their increase with strong heating of charge carriers is due to simultaneous perturbation of the potential barrier.*

***Key words**: hot electrons, UHF field, p – n junction, EMF, capture and ionization coefficients.*
***Language**: English*
***Citation**: Dadamirzayev, M.G., & Kosimova, M.O. (2018). The effect of the variation of the electric field of the UHF waves on the CVC of the asymmetric p-n-junction. *ISJ Theoretical & Applied Science, 10 (66),* 401-405.
***Soi**: http://s-o-i.org/1.1/TAS-10-66-52 ***Doi**: crossref https://dx.doi.org/10.15863/TAS.2018.10.66.52

1. Introduction

To date, there are a large number of works devoted to the study of the electrical properties of p-n junctions in strong , UHF fields [1-3]. In [1], the current-voltage characteristics of silicon p – n junctions in strong , UHF fields were studied. It turned out that a change in the current – voltage characteristics of this p – n junctions is already observed in relatively weak fields, when the temperature rise of charge carriers is not yet noticeable. Under these conditions, the behavior of the no ideality coefficient, short-circuit current I_{kz} from the open circuit voltage U_{xx} from the UHF power is investigated. The dependence of I_{kz} on the inverse temperature of charge carriers determines the height of the barrier that carriers need to overcome for recombination. The growth of U_{xx} is not consistent with the change in the temperature of the charge carriers. Possible mechanisms for the appearance of EMF in silicon p – n junctions in strong UHF fields are discussed. In [4] the experimentally study detected effect of the emergence of a mode of negative differential resistance and switching in a tunnel diode under the action of an external UHF signal was theoretically described.The reasons for the existence of the bias voltage ranges on the diode and the UHF signal power levels have been elucidated and in which the effect has been observed.

The electric field strength of the UHF wave inside the sample changes its original direction. The electrical component of the wave inside the diode can be decomposed into perpendicular and parallel components to the sample surface (Fig.1.). The main impact of the parallel component is reduced to the heating of charge carriers. The perpendicular component participates both in the heating of charge carriers and changes the height of the potential barrier of the p – n junction and the magnitude of the surface potential. It was shown that modulation of the barrier height increases the current and the EMF of the p-n junction in a strong UHF field [5]. The distorted wave modulates not only the potential of the p-n junction, but also the surface potential. However, the deviation of the electric field strength of the UHF wave inside an asymmetric p-n junction has not been discussed enough in the literature before.It was only indicated the possibility of such processes [6,7].

The purpose of this work is to construct a quantitative theory of the influence of the deviation of the direction of the electric field strength of a UHF wave and the Frenkel effect on the currents and EMF of an asymmetric p-n junction.

II. Study of the influence of the perturbation of the height of the potential barrier and the Frenkel effect on the current-voltage characteristic of an asymmetric p-n-junction in the UHF field

In [8], the influence of the heating wave distortion on the recombination currents and EMF generated at the p – n junction in a strong UHF field was studied. It is shown that the modulation of the surface potential and the height of the p-n-junction by the heating wave in the short-circuit current mode leads to a decrease in the effective barrier height and in the idling mode to anomalously large EMF values. In addition to these processes, the Frenkel effect also affects, and this can change the EMF and currents in the p-n-junction.

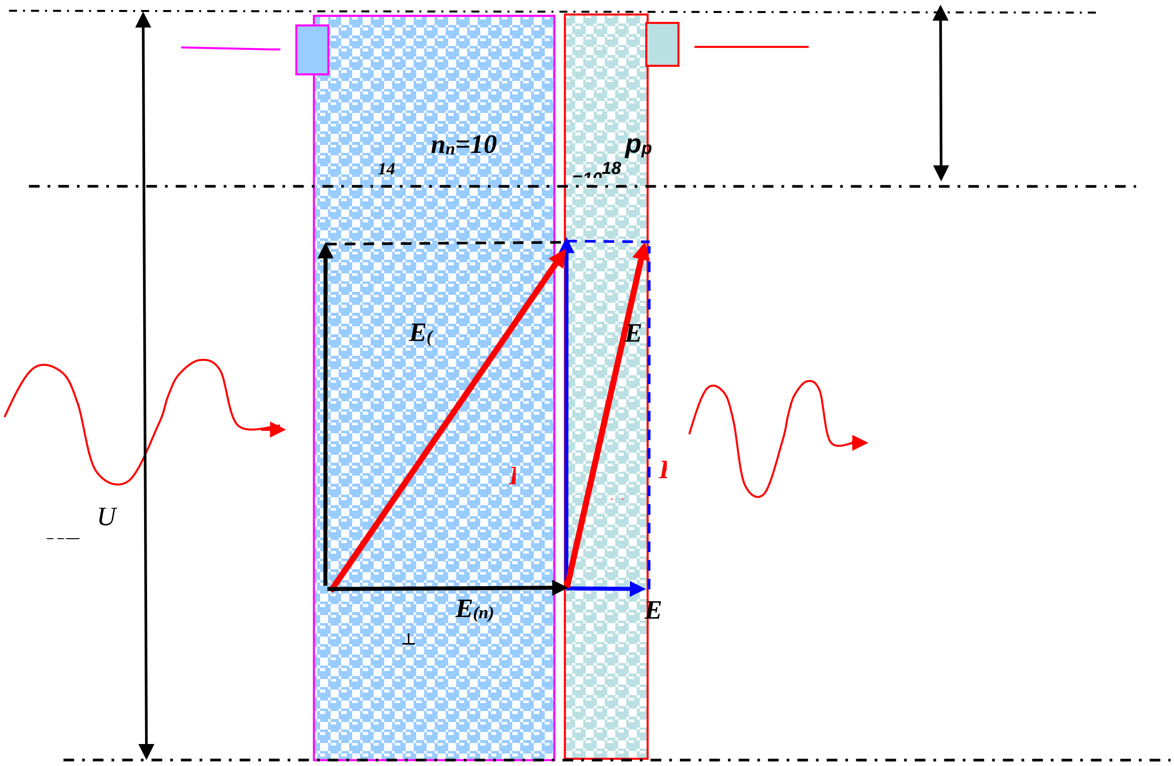

Fig.1. Appearance of the perpendicular component of the electric field strength of a wave to the pn-junction plane due to its distortion. E (n) II and E (p) II is the parallel component of the electric field strength in the n and p regions, respectively. $E_{(n)\perp}$ and $E_{(p)\perp}$ - the perpendicular component of the electric field strength in the n and p regions, respectively.

Now let us consider the influence of the deviation of the direction of the electric field of the UHF wave and the Frenkel effect on the currents and EMF arising in the p-n-junction located in the UHF field. In [9], the dependences of the capture coefficient on the ionization coefficient are given.

$$\beta_1\beta_2 = \gamma_1\gamma_2 n_0 p_0 = \gamma_1\gamma_2 n_i^2 \qquad (1)$$

where β_1 and β capture coefficients, γ_1 and γ_2 ionization coefficients for electrons and holes.

According to the Frenkel mechanism, the ionization coefficients are as follows [10]:

$$\beta_n = \beta_{n0}\exp\left(\frac{\beta_{Fp}}{kT}\sqrt{E}\right),$$

$$\beta_p = \beta_{p0}\exp\left(\frac{\beta_{Fp}}{kT}\sqrt{E}\right) \qquad (2)$$

Where $\beta_{n0} = \gamma_1 n_n$, $\beta_{p0} = \gamma_2 p_p$, β_{FP} - Frenkel-Bullet ratio.

The total current passing through the diode consists of electron and hole currents [11,12]:

$$\bar{I} = \frac{eD_e n_p}{L_e}\left\{\left(\frac{T_e}{T}\right)^{\frac{1}{2}} I(U_B,T_e)\exp\left(\frac{e\varphi_0}{kT} - \frac{e(\varphi_0 - U)}{kT_e}\right) - 1\right\} + \quad (3)$$

$$+\frac{eD_h p_n}{L_h}\left\{\left(\frac{T_h}{T}\right)^{\frac{1}{2}} I(U_B,T_h)\exp\left(\frac{e\varphi_0}{kT} - \frac{e(\varphi_0 - U)}{kT_h}\right) - 1\right\}.$$

here,

$$I(U_B,T_e) = \int_0^{2\pi} \exp\left(-\frac{eU_B\cos(\omega t)}{kT_e}\right)\frac{d(\omega t)}{2\pi} \quad (4)$$

$$I(U_B,T_h) = \int_0^{2\pi} \exp\left(-\frac{eU_B\cos(\omega t)}{kT_h}\right)\frac{d(\omega t)}{2\pi} \quad (5)$$

$I_{se} = \frac{eD_e n_p}{L_e}$; $I_{sh} = \frac{eD_h\, p_n}{L_h}$ - saturation currents for electrons and holes; φ_0 – height of potential barrier in the absence of electromagnetic wave; $\varphi=\varphi_0-U$; U – arising voltage on the diode; $U_B = -\int_0^d E_B dx$ - AC voltage of the incident wave cre ted on the barrier diode; T- lattice temperature; k-Boltzmann constant; T_e и T_h - electron and hole temperatures; E_B– electric field strength of the wave; e-electron charge; D_e и D_h – electron and hole diffusion coefficients, L_e и L_h – their diffusion lengths; n_p and p_n – the concentration of minority charge carriers.

Via (3), (1) и (2), and taking into account $p_n = \frac{n_i^2}{n_n}$; $n_p = \frac{n_i^2}{p_p}$ and Einstein relation – $\frac{D_{e,h}}{\mu_{e,h}} = \frac{kT}{e}$, for the CVC characteristics of the p – n junction we have:

$$\bar{I} = \left\{\frac{eD_e n_i^2}{L_e p_p}\left[\left(\frac{T_e}{T}\right)^{\frac{1}{2}} I(U_B,T_e)\exp\left(\frac{e\varphi_0}{kT} - \frac{e(\varphi_0 - U)}{kT_e}\right) - 1\right] + \right.$$

$$\left. + \frac{eD_h n_i^2}{L_h n_n}\left[\left(\frac{T_h}{T}\right)^{\frac{1}{2}} I(U_B,T_e)\exp\left(\frac{e\varphi_0}{kT} - \frac{e(\varphi_0 - U)}{kT_h}\right) - 1\right]\right\} =$$

$$= \frac{\beta_{n_0}\beta_{p_0}}{\gamma_n\gamma_p}\exp\left(\frac{2\beta_{FP}\sqrt{E}}{kT}\right)\left\{\frac{eD_e}{L_e p_p}\left[\left(\frac{T_e}{T}\right)^{\frac{1}{2}} I(U_B,T_e)\exp\left(\frac{e\varphi_0}{kT} - \frac{e(\varphi_0 - U)}{kT_e}\right) - 1\right] + \right. \quad (6)$$

$$\left. + \frac{eD_h}{L_h n_n}\left[\left(\frac{T_e}{T}\right)^{\frac{1}{2}} I(U_B,T_h)\exp\left(\frac{e\varphi_0}{kT} - \frac{e(\varphi_0 - U)}{kT_h}\right) - 1\right]\right\}$$

This shows that the Frenkel mechanism also influences the volt-ampere characteristic of the p – n junction.

In Fig.2. The volt-ampere characteristics of the p – n junction are given taking into account the heating of charge carriers and the change in the direction of the electric field of the super high frequency, which are obtained using the formula (6).

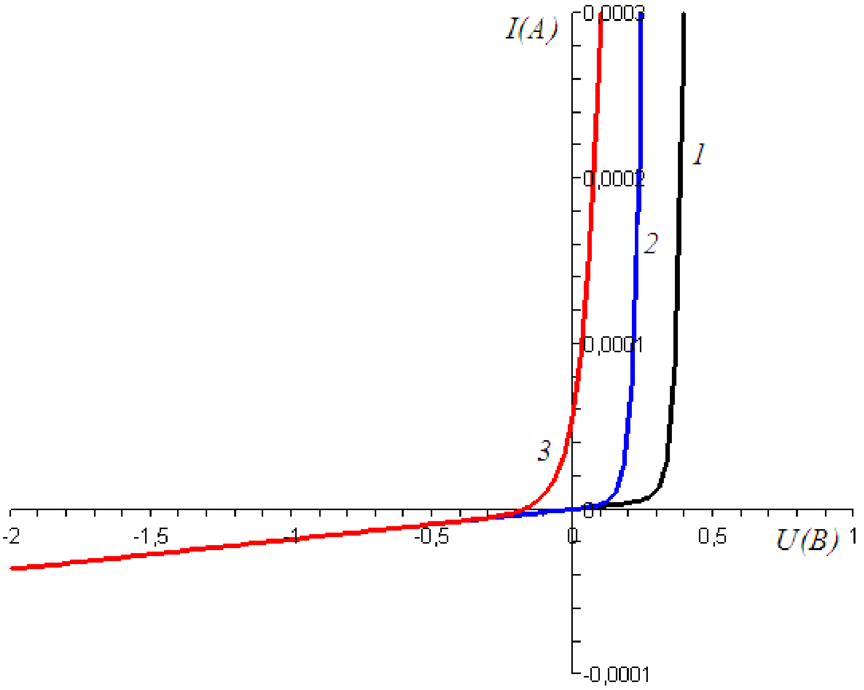

Fig.2. ***CVC p-n-transition under the condition:***
1- without UHF field. 2- at low UHF power, ($T_e = T_h = T$; $U_B \neq 0$) when only a perturbation of the height of the potential barrier occurs, which occurs due to the deviation of the electric field strength vector of the UHF wave inside the p-n junction. 3- at high UHF power ($T_e \neq T_h > T$; $U_B \neq 0$), when charge carriers and perturbations of the height of the potential barrier are heated due to the deflection of the electric field vector of the UHF field inside the pn-junction, and the Frenkel effect.

From the graphs it can be seen that heating up charge carriers, perturbations of the potential barrier height, and also the Frenkel effect increase the direct currents of the diode.

III. Conclusion

Based on the conducted research, we can draw the following conclusion: Deviation of the electric field strength of the UHF wave inside the pn junction and the Frenkel effect will lead to the appearance of EMF and currents, even with a weak heating of the charge carriers. The total current appears due to the heating of charge carriers, disturbance of the height of the potential barrier, as well as the Frenkel effect, and this is the cause of the large voltages generated by the pn-junction.

References:

1. Ablyazimova, N.A., Veynger, A.I., & Pitanov, V.S. (1988). Elektricheskie svoystva kremnievix p-n-perexodov v silnix SVCH polyax. *FTP, tom 22, vipusk 11*, 2001-2007.
2. Veynger A.I. (1988). N-obraznost VAX kremnievix p-n-perexodov v silnix SVCH polyax. *FTP, 1988, tom 22, vipusk 11*, 1972-1978.
3. Usanov, D.A., Skripal, A.V., & Ugryumova, N.V. (1998). Vozniknovenie otritsatelnogo soprotivleniya v strukturax na osnove p–n-perexoda v SVCH pole. *Fizika i texnika poluprovodnikov*, *tom 32, № 11*, 1399-1402.
4. Usanov, D.A., Skripal, A.V., Ugryumova, N.V., Venig, S.B., & Orlov, V.E. (2000). Vozniknovenie rejima otritsatelnogo differentsialnogo soprotivleniya i pereklyucheniya v tunnelnom diode pod deystviem vneshnego SVCH signala. *Fizika i texnika poluprovodnikov, 2000, tom 34, vip. 5*, 567-571.
5. Gulyamov, G. (1996). Elektrodvijuoshaya sila kremnievix p-n-perexodax v silnix SVCH polyax. *Fizika i texnika poluprovodnikov.- Sankt-Peterburg, t.30. №7*, 1279-1284.

6. Gulyamov, G. (1996). Vliyanie poverxnostnoy rekombinatsii na volt-ampernuyu xarakteristiku p-n-perexoda v silnom SVCH pole. *Fizika i texnika poluprovodnikov. – Sankt-Peterburg, tom 30, №3*, 569-574.
7. Gulyamov, G., & Xamidova B. (1996) Vliyanie geometrii obraztsov na VAX p-n-perexoda v silnom SVCH pole. *Fizika i texnika poluprovodnikov. Sankt- Peterburg, t.30, №.5*, 769-777.
8. Gulyamov, G., Dadamirzaev, M.G., Boydedaev, S.R. (2000). EDS goryachix nositeley, obuslovlennaya modulyatsiy poverxnostnogo potentsiala v silnom SVCH pole. *Fizika i texnika poluprovodnikov – Sankt Peterburg, t.34, №5*, 572-575.
9. Pikus, G.E. (1965). *Osnovi teorii poluprovodnikovix priborov*. Moscow: Nauka, pp.1-448.
10. Gulyamov, G., & Dadamirzaev, M.G. (1998). Vliyanie effekta Frenkelya na koeffitsient neidealnosti p-n-perexoda v silnom SVCH pole. *Uzbekskiy Fizicheskiy Jurnal, Tashkent, № 3*, 48-50.
11. Dadamirzaev, M.G. (2011). Heating of Charge Carriers and Rectification of Current in Asymmetrical *p–n* Junction in a Microwave Field. *Semiconductors, USA, vol. 45, No.3*, 288-291.
12. Dadamirzaev, M.G. (2015). Influence of Deformation on CVC p-n-Junction in a Strong Microwave Field. *Journal of Modern Physics, USA, Vol. 6*, 176-180.