

Evidence for Non-existence of Oscillations in Photofield Emission Current in Gallium Arsenide

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Abstract: We have shown here the results of PFEC (photofield emission current) calculated for GaAs (gallium arsenide). We have used the initial state wavefunctions derived using the Kronig-Penney potential model for evaluating the PFEC. We have found that PFEC is not oscillatory as obtained by Modinos and Klient, [Solid State Commun. 50, 651 (1984)], but it is an exponential function.

Key words: Photofield emission, matrix element, Kronig-Penney potential model, density of state.

1. Introduction

In this report, we are presenting the calculated results of PFEC (photofield emission current) in GaAs (gallium arsenide) as a function of applied electric field. PFEC is calculated by using the formula as given by Gao and Reifenberger [1]. We have used the Kronig-Penney potential model to define the initial state wavefunctions as deduced by Thapa and Kar [2] for evaluating the matrix element involved in the formula for PFEC. In the end, with our calculated results, we confirm that PFEC in GaAs is not oscillatory but it THEORY.

The PFEC density as calculated by Gao and Reifenberger is given by Ref. [1]:

$$\frac{dj}{dE} = -\frac{e^3}{2\hbar^4 \omega^3} \frac{n}{\Omega} (\hat{\epsilon} \cdot \hat{z})^2 f(E - \hbar\omega) \int_{-V_0 + \hbar\omega}^E dW \frac{D(W) |M_{fi}|^2}{[W(W - \hbar\omega)]^{\frac{1}{2}}} \quad (1)$$

Matrix element M_{fi} in Eq. (1) due to transition of electrons from the initial state $|\psi_i\rangle$ to the final state $|\psi_f\rangle$ in one dimension along z -axis is given by:

$$M_{fi} = \int_{-d}^0 \psi_f^* A_z \frac{dV}{dz} \psi_i dz + \int_{-d}^0 \psi_f^* \frac{d^2 A_z}{dz^2} \left(-i\hbar \frac{d}{dz} \right) \psi_i dz + \int_{-d}^0 \psi_f^* \frac{dA_z}{dz} \left(-\hbar^2 \frac{d^2}{dz^2} \right) \psi_i dz + \int_{-d}^0 \psi_f^* \frac{dA_z}{dz} \psi_i dz. \quad (2)$$

The transmission tunneling probability $D(W)$ used in Eq. (1) has been calculated by Thapa et al. [4] by solving the Airy's differential equation and matching the wave functions inside and outside the surface at $z = 0.0$. The standard form of Airy's differential equation is:

$$D(W) = \frac{W^4 \sqrt{\pi}}{(\hbar e F)^{\frac{1}{6}}} \left(\frac{2ik_i}{ik_i + \chi} \right) (2m)^{\frac{1}{12}} \exp \left[-i \left(\frac{2W^{\frac{3}{2}} \sqrt{2m}}{3 \hbar e F} + \frac{\pi}{4} \right) \right] \quad (3)$$

We can evaluate the matrix element in Eq. (1) by evaluating the M_{fi} in Eq. (2) with appropriate wavefunctions and by using the above Eq. (3) for $D(W)$, PFEC for GaAs had been calculated as a function of applied field.

2. Results and Discussion

In Fig. 1, we show the experimental results of plot of PFEC as a function of applied electric field in the case of W as obtained by Bagchi and Kar [3]. We find from this figure that oscillations in PFEC are found to increase with the increase in applied field.

In Fig. 2, we show the plots of PFEC as a function of applied electric field (in V/m) in the case of GaAs. Plots have been done for three different kinds of photon

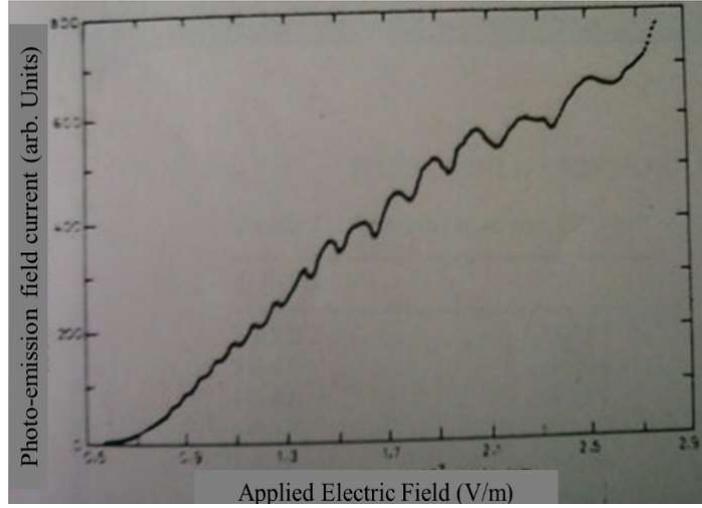


Fig. 1 Variation of oscillatory type of PFEC plotted as a function of applied electric field in the case of tungsten [3].

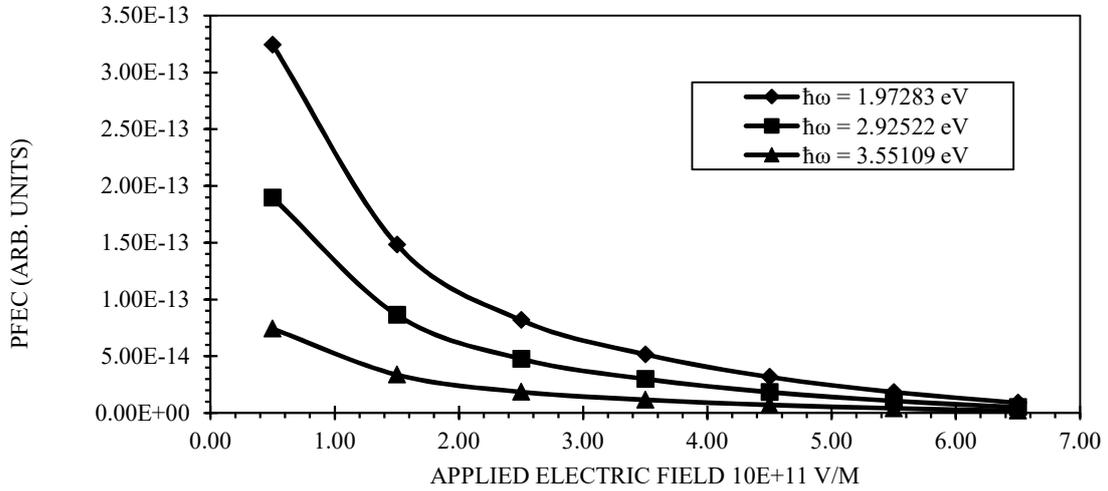


Fig. 2 Plot of variation of PFEC against the applied electric field for three values of photon energies. The angle of incident photon radiation is $\theta_i = 45^\circ$.

energies. In all the three cases it has been found that PFEC shows an exponential decrease with the decrease of applied electric field.

The exponential decrease in PFEC is due to presence of an exponential term in the formula of transition probability $D(W)$ given by Eq. (3). Also, we have found that a maximum peak in PFEC for low photon energy $\hbar\omega = 1.97283$ eV whereas minimum peak of PFEC for large photon energy is $\hbar\omega = 2.92522$ eV. This is due to the reason that PFEC given in Eq. (1) is inversely proportional to frequency of incident photon radiation. However, the variation of PFEC in all the cases of three different values of photon energies are similar in nature.

3. Conclusions

We find that the plots of PFEC showed an exponential decrease in PFEC with the increase in applied electric fields. It did not show the occurrence of oscillatory type of PFEC as shown by Modinos and Klient [3] in W. However, few drawbacks are still existing which must be addressed for better accuracy. We have used same initial state wavefunction for both the surface and the bulk region of the solid. This is in fact not correct and we should have wavefunctions to be well defined for surface and the bulk regions of the solid. Vector potential used should be expressed in the

context of density functional theory. However, our study showed that there are no oscillations in PFEC.

References

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