acta physica slovaca 42 (1992), No. 1, 52–54

# SURFACE PHOTO-EFFECT IN SEMICONDUCTORS

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A theoretical investigation of surface photo-effect is made using the expression of the normalized surface potential obtained through the solution of the Poisson-Boltzmann equation at the semiconductor surface. In the derivation, the expression for the charge in surface traps has been assumed to follow the Brattain - Bardeen model. Variation of the normalized surface photo-voltage with surface potential has been calculated numerically.

## I. INTRODUCTION

During the illumination of the semiconducting surface, the change in the surface potential due to the total charge, both the space charge and the traps, has been calculated by Garret and Brattain for the evaluation of the surface photo-voltage [1]. Various successful attempts have been made so far for the estimation of photo-electric phenomena on different semiconducting materials [2—8]. From an approximate analytical solution of Poisson's equation, De et al. [9] deduced an expression of normalized photo-voltage which is useful for semiconducting materials.

The present paper deals with the calculation of the normalized surface photo-voltage of semiconductors utilizing the expression for the normalized surface potential together with the expression for the charge in surface traps based on the Brattain and Bardeen model. The method is devoid of any approximation. The numerical analysis of the results is presented graphically.

## II. MATHEMATICAL DEDUCTION

The total charge in both space charge and traps can be written as

$$\Sigma = Q_S + \sigma_{tr} = 2en_iL_DF(U_S,U_B) + e[N_b\exp(P-Y) - N_a\exp(Y-N)] \quad (1)$$

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(the symbols have the same meaning as in the previous papers [1, 10, 11]). After some alebraic manipulation, (1) can be written as

$$\Sigma = 2\sqrt{2}en_iL_D[\sinh U_B(U_B-U_S)-(\cosh U_B-\cosh U_S)]^{1/2}+2L\sinh(U_B-U_S), \quad (2)$$

where $L = eN$ = the light current, i.e., the density of the surface states generated per second owing to illumination.

The normalized photo-voltage can be obtained by differentiating equation (2) with respect to $L$ and then by setting the result equal to zero. This yields

$$\begin{aligned}\frac{\partial U_S}{\partial L} = &\frac{\exp(U_B-U_S)-\exp(U_S-U_B)}{L[\exp(U_B-U_S)+\exp(U_S-U_B)]}+\\ &+en_iL_D[\exp(U_B)-\exp(-U_B)-\exp(U_S)+\exp(-U_S)]\times \\ &\times[(U_B-U_S)\{\exp(U_B)-\exp(-U_B)\}-\\ &-\{\exp(U_B)+\exp(-U_B)-\exp(U_S)+\exp(-U_S)\}]^{1/2}.\end{aligned} \quad (3)$$

When $U_S < 0$ and for a large value $U_B$, the equation (3) can be approximated as

$$\frac{\partial U_S}{\partial L} \cong \frac{1}{L}\left[1 - \frac{en_iL_D}{L\exp(U_B-U_S)}\frac{\exp\left(\frac{U_B}{2}\right)}{(U_B-U_S-1)^{1/2}}\right]. \quad (4)$$

## III. RESULTS AND DISCUSION

Equation (4) has been used to investigate the nature of variation of a normalized photo-voltage due to illumination of the surface with normalized surface potential through numerical analysis. The results are presented in Fig. 1, where

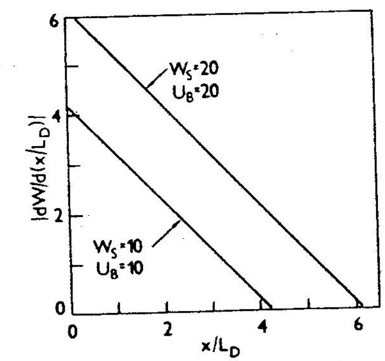


Fig. 1. Variation of normalized photo-voltage with normalized surface potential. The set (a) gives the variation for $L = 1$ with the origin as $(-7.999990 \times 10^{-6})$ and the set (b) depicts the corresponding changes for $L = 2$ with origin as $(-7.499990 \times 10^{-6})$.

two sets of graphs are obtained for $L = 1$ and $L = 2$. For each set, three graphs have been drawn for $U_B = 15, U_B = 20$ and $U_B = 25$. From the graph it is apparent that for higher negative values of the normalized surface potential, there is a limit in the generation of photo-voltage even at different values of the bulk potential. This is in agreement with the physical state. In the case of III—V semiconductors, similar observations can be made [3—6].

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Received August 21st, 1989
Accepted for publication June 13th, 1990


## ИССЛЕДОВАНИЕ ПОВЕРХНОСТНОГО ФОТОЭФФЕКТА В ПОЛУПРОВОДНИКАХ


В работе исследуется фотоэффеккт на поверхности полупроводника приведенного потенциала поверхности основанном на уравнении Поасон—Больцмана. С применением модели Браттейн—Бардена, в выводах учтены выражения учитывающие заряд в ловушках поверхности.

Нумерически анализируется изменение фото-напряжения на приведенной поверхности с потенциалом поверхности.