CONNECTION OF THE EFFICIENCY TO THE NON-IDEAL FACTOR OF SOLAR CELLS

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Abstract: In this work, a new expression in simple form for the useful shi coefficient of solar elements has been introduced. It has been shown that the computational results obtained from this expression can explain the results obtained from the experiment. From this formula it is shown that when the efficiency of solar cells is related to the non-ideal coefficient of VAX, the correlation of this parameter to the non-ideal coefficient at the point where the short-circuit current density is determined is linear.

Keywords: Solar cell, useful work coefficient, temperature dependence of useful work coefficient, non-ideal coefficient of VAX.

Introduction One of the most important scientific problems in the world in recent years in the field of semiconductor device physics is to increase the efficiency of semiconductor SC. To increase the efficiency of SC, it is first necessary to study the quality of the *p-n*-transition, which is the basis of the structures, and the dependence of the physical parameters evaluating such quality on the non-ideal coefficient of volt-ampere characteristic (VAX) under illuminated conditions. One of the urgent tasks is to study the basic output parameters of semiconductor cells and their dependence on various factors, taking into account the non-ideal coefficient of VAX and based on experimental data. Targeted scientific research on the creation of high-efficiency energy sources based on semiconductor materials in the world today, including the development of simple and accurate expressions of the basic output characteristics of semiconductor cells; determine the laws of dependence on their non-ideal coefficient; one of the important tasks is to optimize the process of efficient separation of generated charge carriers in the r-p-transition on the basis of theoretical and practical data. However, neither the experimental results nor the results obtained from the calculations, which determined the temperature dependence of the VAX non-ideal coefficient of SE, have been presented in the scientific literature. Since the expressions derived from SE theoretically for FF have a complex and transcendental appearance, the relationship between these parameters and the effective values of SE output voltage and current densities, SC VAX non-ideal coefficient, and other quantities has not been theoretically studied. The available theoretical expressions are not sufficient to explain the effect of temperature on the VAX non-ideal coefficient of SE. It is difficult to determine the effect of the VAX non-ideal coefficient on the electric parameters of SE from the expressions. Therefore, the study of the effect of the nonlinearity coefficient VAX on the electric parameters of SC is one of the current problems in the physics of semiconductor devices.

The laws of dependence of the useful work coefficient of solar elements on temperature and VAX non-ideal coefficient were determined and the experimental results were analyzed using them.

It has also been found that the dependence of the volt-ampere characteristic of solar elements on the non-ideal coefficient under FF illumination conditions is subject to

exponential or linear regularity depending on the point at which the non-ideal coefficient is determined.

It is known that the efficiency of solar cells (SC)

$$\eta = ff \frac{U_{oc} j_{sc}}{P_0 S} \qquad (1)$$

determined from the expression. Here *ff*-is the filling coefficient of SC VAX, U_{oc}-is the operating voltage, j_{sc} - is the short-circuit current density, P_0 - is the intensity of solar radiation falling on the surface of SC, S-is the working surface of SC [1].
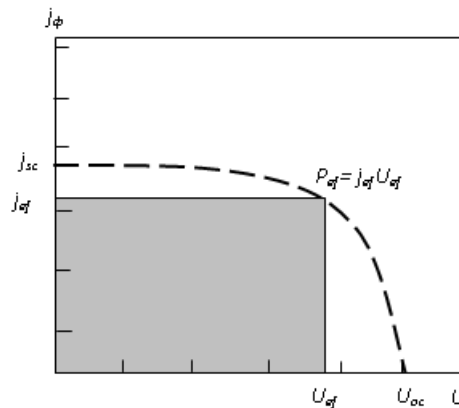

Figure 1. Determination of SC VAX fill factor.

The filling coefficient of the VAX of SC

$$ff = \frac{S_1}{S_0} = \frac{U_{ef} j_{ef}}{U_{oc} j_{sc}} \qquad (2)$$

determined from the formula. Where S_1 - is the right quadrilateral surface determined by the effective values of voltage (U_{ef}) and current density (j_{ef}) of SC, and S_0 - is the right quadrilateral surface determined by the operating voltage and short-circuit current density of SC (Figure 1).

Using these expressions, the FF of SCcan be written as follows.

$$\eta = \frac{U_{ef} j_{ef}}{U_{oc} j_{sc}} \frac{U_{oc} j_{sc}}{P_0 S} = \frac{U_{ef} j_{ef}}{P_0 S} = \frac{P_{ef}}{P_0 S} \qquad (3)$$

Here is the effective value of the power output from the P_{ef} – SC [2].

It can be seen from formula (1) that the main parameters that determine the *ff* of SC are their operating voltage, short-circuit current density and VAX filling coefficients.

[3] for the salt processing voltage of SC empirically in the study

$$U_{oc} = (U_{oc0} - \varphi)\frac{T}{T_0} + \varphi \qquad (4)$$

where $U_{oc\,0}$ - $T_0 = 300$ K is the operating voltage, φ - is the potential barrier height of SC.

[4] in the study theoretically obtained the following equation to relate the current density of SC to temperature:

$$j_{sc} = j_{00} \exp\left[\frac{q(\varphi_0 - \gamma T)}{k}(\frac{1}{T_0} - \frac{1}{T})\right]\left[\exp\left[\frac{q(\varphi_0 - \gamma T)}{n_1 k T_0}(\frac{U_{oc0}}{(\varphi_0 - \gamma T)} - 1 + \frac{T_0}{T})\right] - 1\right] \qquad (5)$$

Where j_{00} - is the saturation current density of SC at room temperature, k-is the Boltzmann constant, q- is the electron charge, n_1 -is the abnormal coefficient at the point where the short-circuit current density of SC is determined, - SC potential barrier height at T=0K, - semiconductors The temperature coefficient of the energy with of the restricted zone. Its value is in the eU/K range for semiconductors.

[5] used SC experimental VAX to find the point corresponding to the effective power in SC for the effective voltage and current density of SC.

$$U_{ef} = \frac{kT}{q} \ln \frac{j_{sc}}{j_0} \frac{kT}{qU_{oc}} \qquad (6)$$

$$j_{ef} = j_{sc}\left(\frac{n_2 kT}{qU_{oc}} - 1 - \frac{j_0}{j_{sc}} \right) \qquad (7)$$

expressions are obtained. Where j_0 -is the saturation current density of SC [4] for this parameter in the study

$$j_0 = j_{00} \exp\left(\frac{q\varphi}{k}\left(\frac{1}{T_0} - \frac{1}{T} \right) \right) \qquad (8)$$

expressed. Using these, the following expression can be obtained for the temperature dependence of the filling coefficient of the VAX of SC:
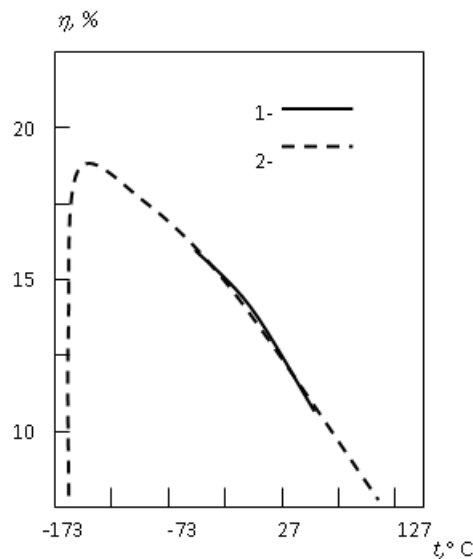

Figure 2. The temperature dependence of homogeneous silicon-based SC ff is the result of experiment 1 [2] and calculation of formula 2 (29).

$$ff = \frac{\dfrac{kTj_{sc}}{q}\left(1+\dfrac{j_0}{j_{sc}}-\dfrac{n_2 kT}{qU_{oc}}\right)\ln\dfrac{j_{sc}}{j_0}\dfrac{kT}{qU_{oc}}}{\left((U_{oc0}-\varphi)\dfrac{T}{T_0}+\varphi\right)j_0\left[\exp\left[\dfrac{q\varphi}{n_1 kT_0}(\dfrac{U_{oc0}}{\varphi}-1+\dfrac{T_0}{T}))\right]-1\right]} \tag{9}$$

From the results of the calculations performed by substituting the expressions (4), (5) and (8) into expression (9), it was shown that the coefficient of filling of the VAX could not be greater than 0.93 for ideal SC. Therefore, it can be concluded that even in ideal SC, the energy of the absorbed ns is lost by 7%. Experiments for non-ideal SC show that the maximum value of the VAX fill factor is 0.89-0.90, which results in an energy loss of at least 10% of the ns absorbed in non-ideal SC.

The following equation for the ff of secan be obtained by substituting the expressions (6) and (7) obtained for the voltage and current density in the formula (3), which determines the ff of SC.

$$\eta = \frac{\dfrac{kTj_{\kappa m}}{q}\left(1+\dfrac{j_0}{j_{\kappa m}}-\dfrac{n'_2 kT}{qU_{cu}}\right)\ln\dfrac{j_{\kappa m}}{j_0}\dfrac{kT}{qU_{cu}}}{P_0 S} \quad . \tag{10}$$

It can be seen from this formula that if the expressions (4), (5) and (8) are put in the formula (10) of the SC, it will be possible to determine the dependence of this parameter on the temperature and the non-ideal coefficients of the VAX.

The calculation results obtained from (10) for the binding of AlGaAs-GaAs-based SC in [2] to the ff temperature at AM0 ($P_0 = 1353$ W/m^2) at t = 25°C at ff $\eta = 16.4\%$ are given in Table 1.

Table 1

Temperature binding of the main electric parameters of AlGaAs-GaAs-based SC in ff

№	t, °C	T, K	U_{ef}, В	U_{ef}, В	I_{sc}, мА	I_{ef}, мА	η, %
1	-120	153	1,415	1,271	100,0	98,0	18,89
2	-100	173	1,358	1,214	101,3	99,25	18,91
3	-80	193	1,304	1,160	102,525	100,15	18,82
4	-60	213	1,252	1,108	103,835	101,35	18,70
5	-40	233	1,200	1,056	104,25	102,2	18,40
6	-20	253	1,148	1,004	105,5	102,8	17,85
7	0	273	1,096	0,952	106,7	103,3	17,18
8	20	293	1,044	0,990	107,825	103,7	16,59
9	40	313	0,992	0,948	108,95	104,0	15,77
10	60	333	0,940	0,896	110	103,9	15,26
11	80	353	0,888	0,844	111	103,7	14,59

η =16.4% at temperature T=25°C under conditions of AM0 (P_0=1353W/m^2)

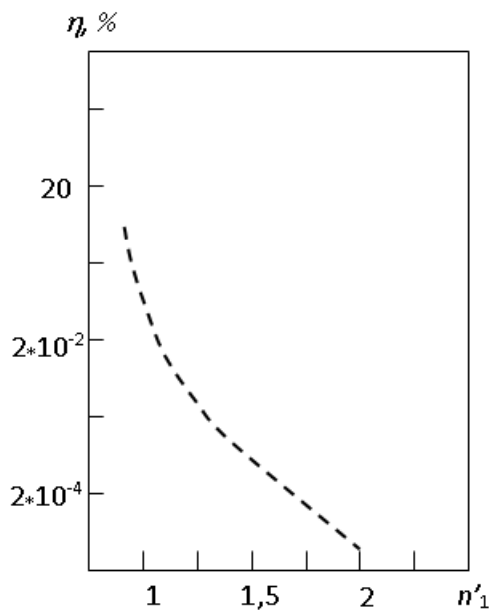| 12	100	373	0,836	0,792	112	103,4	13,92
13	120	393	0,784	0,740	113	102,9	13,26
14	140	413	0,732	0,688	114	102,2	12,59
15	160	433	0,680	0,636	115	101,7	11,92
16	180	453	0,628	0,584	116	101,3	11,26
17	200	473	0,576	0,532	117	101,0	10,59
18	220	493	0,524	0,480	118	109,9	9,93

Figure 3 The relationship of SC to the non-ideal coefficient of photoVAX at the point where the short-circuit current of fotoVAX is determined. The calculations were performed for the values $T_0 = 273K$, $T=300$ K, $j_0=1.5*10^{-10}$ A, $U_{oc}=0.65V$, $\varphi_0=1.12V$, and $\gamma=5*10^{-4}$ V / K.
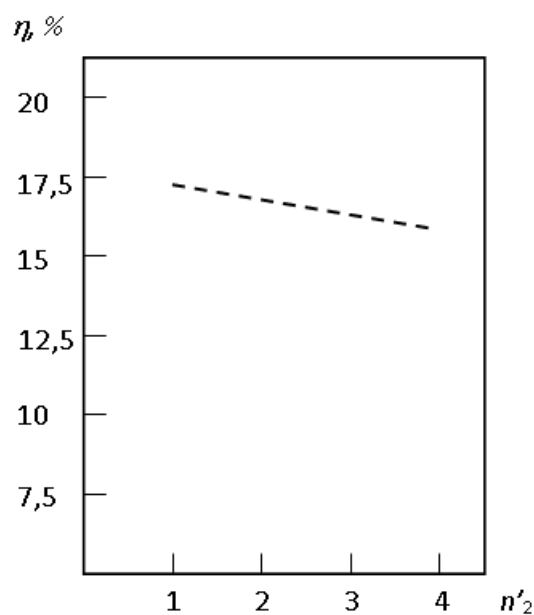
Figure 4. Correlation of QEs with ff to the non-ideal coefficient of VAX.

Calculations $T_0 =273$ K, T =300 K, $j_0=9*10^{-9}$A, $\varphi_0=1.12V$, $U_{oc}=\varphi_0/2$ V, $\gamma=5*10^{-4}$V/K and Completed for $n_1'=1,00239$ values.

The table shows that the ff of AlGaAs-GaAs-based SE increase at very low temperatures (t <-100 ºC) and decrease with increasing temperature. It was found that these results were consistent with the results obtained from experiments and calculations of formulas obtained by other theoretical methods.

To explain the experiments for the temperature dependence of homogeneous silicon-based SC ff, the calculation results obtained from formula (10) are shown in Figure 2. These results are consistent in the temperature range -73 ºC <T <77 ºC, and the calculations complement the experiment and are unsuitable for operation at silicon-based SC T <-160 ºC and T> 120 ºC.

Figure 3 shows the calculation results obtained from formula (10) to relate the FF of the SC to the non-ideal coefficient of the VAX at the point where the short-circuit current of the VAX is determined. This correlation was also very strong, and it was found that as the non-ideal coefficient increased, the ff of the SE exponentially decreased, and the value of the non-ideal coefficient changed from 17.5% to 8 * 10-5% when the value changed between 1 and 2.

Figure 4 shows the relationship between the FF of SC and the non-ideal coefficient of VAX at the point where the effective power of VAX is determined from formula (10). The figure shows that this relationship is also linear, and when the non-ideal coefficient increaSC from 1 to 4, the effective power of SC decrease in the range $\eta =(17.5 - 15.4)\%$.

Thus, in this study, a new formula with a simple appearance was developed to relate the ff of SC to temperature and the non-ideal coefficient of VAX. It has been shown that the calculations obtained from the formula given for this parameter can explain the experimental results. From the dependence of SC on the nonlinearity coefficient of ff fotoVAX, it was shown that this parameter is linearly related to the nonlinearity coefficient at the point where the short-circuit current density of fotoVAX is determined exponentially and the effective force at the point of determination.

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