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EFFECTIVE VALUES OF PHOTOGALVANIC CHARACTERISTICS OF SOLAR ELEMENTS AND TEMPERATURE

Alinazarova Mahfuza Alisherovna,
Regional Center for Retraining and improvement of professional skills of personnel's of public education at Namangan State University.
Uzbekistan

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Abstract: The semi empirical method is received expressions defining dependency of efficient importance photo galvanic characteristics of solar elements from the temperature. It is shown that these expressions wholly can explain the warm-up dependency of efficient importance photo galvanic characteristics of solar element reception from experiment. From calculation of these expressions is shown that efficient importance of the voltage do not belong to the coefficient quality photovoltaic characteristics of solar elements.

It is also shown that solar elements, prepared on base of arsenide-gallium, will not work in temperature bottom T=150 K.

Key words: Solar elements, photo galvanic characteristics, efficient voltage, efficient current, efficient power, coefficient quality photovoltaic characteristics.

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It is known from experiments that the effective values of photovoltaic characteristics of solar elements (SE) depend on temperature [1]. However, in the literature, expressions have not yet been obtained that establish these dependencies. Therefore, in this paper, semi empirical methods are used to derive expressions that determine the dependence of the effective photovoltaic characteristics of the solar element on temperature. It is shown that these expressions are in good agreement with the experimental results.

As is known, one of the main photovoltaic characteristics of SE is the effective power, which is determined by the following expression [1]

$P_{ef} = J_{ef} U_{эф}$, (1)

where J_{ef} is the effective value of the current and U_{ef}- is the effective voltage of the solar element.

On the 1-fig. a method for determining the effective power, along a tangent point, using the experimental photovolta-ampere characteristic (PVAC) of a solar element. To determine this point, a straight line (1-straight line) between the points determining the open-circuit voltage and short-circuit current, i.e (U_{xx}; 0) and (0; J_{kz}), is usually drawn from the pho VAC. Then this line is transferred to the touch of the photo VAC (2-straight line) SE [2]. From the point of contact determines the effective power of the solar element. Based on this method, you can identify the formula that determines the effective power.

It is known that the equation of a straight-line passing between two points is written as follows

$$\frac{J - J_1}{J_2 - J_1} = \frac{U - U_1}{U_2 - U_1}. \qquad (2)$$

From this expression for the 1st line we obtain (1 - Fig.)

$$J = \frac{J_{кз}}{U_{xx}} U + J_{кз} \qquad (3)$$

where $J_{кз}$ - short-circuit current, U_{xx} - open circuit voltages.

In this formula, $a = \frac{J_{кз}}{U_{xx}}$ the value of the slope of this straight line.

It is possible to determine the equation of a straight line, which will be parallel to the 1-straight line and touching on the experimental curve of the photoVAC SE, which has the form

$$J = aU + b. \qquad (4)$$

Taking this into account, we determine the coal coefficient 2-straight from the expression photoVAC SE

$$J_{ф} = J_0\left(\exp\left(\frac{eU}{nkT}\right) - 1\right) - J_{кз} \qquad (5)$$

where Jφ is the photocurrent, J_{0}- is the electric current, e- is the electron charge, k- is the Boltzmann constant, and *T*- is the temperature [3]. To this end, from (5) we obtain the derivative with respect to the voltage. As is known, the coefficient of non-ideality (n) of the photovoltaics of solar elements is determined by the type of electric current. Therefore, it can be assumed that the output voltage of the SE is independent of this parameter [4]. Since the intersection point 2 is a straight line and a 3-curve is U = U_{ef}, bearing in mind this for the angular coefficient *a*, we obtain

$$a = J'_{ф}(U_{эф}) = J_0 \frac{e}{n_1 kT} \exp\left(\frac{eU_{эф}}{n_1 kT}\right) \qquad (6)$$

As is known, the coefficient of non-ideality of the photovoltaic cells of a solar element depends on the type of electric current. Therefore, in (6), n1 is the non-ideality of the photovoltaic photovoltaics of the SE at the point of determining the effective power. From the condition of parallelism of straight lines, their angular coefficient must be equal to [2], taking into account the negative value of the short-circuit current, we obtain

$$\frac{J_{кз}}{U_{xx}} = J_0 \frac{e}{n_1 kT} \exp\left(\frac{eU_{эф}}{n_1 kT}\right). \quad (7)$$

From the formula (7) for the effective value, the voltage (U_{ef}) SE we obtain

$$U_{эф} = \frac{n_1 kT}{e} \ln \frac{J_{кз}}{J_0} \frac{n_1 kT}{eU_{xx}}. \quad (8)$$

When the voltage of the SE is equal to its effective value (U_{ef}) then, and the photocurrent is equal to its effective value

$$U_{эф} = \frac{n_1 kT}{e} \ln \frac{J_{кз}}{J_0} \frac{n_1 kT}{eU_{xx}} \quad (9)$$

Then from (8) and (9) for the effective value of the photocurrent we obtain

$$J_{эф} = J_{кз}\left(\frac{n_2 kT}{eU_{xx}} - 1 - \frac{J_0}{J_{кз}}\right) \quad (10)$$

and from (8) and (10) for the effective power of the SE we obtain

$$P_{эф} = J_{кз}\left(\frac{n_2 kT}{eU_{xx}} - 1 - \frac{J_0}{J_{кз}}\right)\frac{n_1 kT}{e} \ln \frac{J_{кз}}{J_0} \frac{n_1 kT}{eU_{xx}}. \quad (11)$$

In [2, 4], for the temperature dependence of the current saturation (J_0), short-circuit current (J_{kz}), and open-circuit voltage (U_{xx}), the following expressions are obtained

$$J_0 = J_{00} \exp\left(-\frac{e\varphi}{k}\left(\frac{1}{T_0} - \frac{1}{T}\right)\right), \quad (12)$$

$$J_{кз} = J_{00} \exp\left[\frac{e\varphi}{k}\left(\frac{1}{T_0} - \frac{1}{T}\right)\right]\left[\exp\left[\frac{e\varphi}{nkT_0}\left(\frac{U_{0xx}}{\varphi} - 1 + \frac{T_0}{T}\right)\right] - 1\right], \quad (13)$$

$$U_{xx} = (U_{0xx} - \varphi)\frac{T}{T_0} + \varphi, \quad (14)$$

where J_{00} is the saturation current and U_{0xx} is the open circuit voltage at room temperature, φ- is the height of the potential barrier, *n*- is the non-ideality coefficient of the photovoltaic cells SE of the solar element, at the point of detection of the short circuit.

The dependence of the height of the potential barrier (φ) on the temperature of the SE has the same form from the temperature dependence of the forbidden band of the semiconductor [5]. Therefore, this dependence can be written as follows

$$\varphi = \varphi_0 - \gamma T , \quad (15)$$

where φ_0 is the height of the potential barrier of the SE at temperature T = 0 K.

The value of φ_0 can be determined from (14) by extrapolating the dependence of the idling voltage on the temperature *(U_{xx} (T))* by T → 0 K. γ-temperature coefficient of the potential barrier height. It is shown in [6] that its values lie in the range 10^{-3}-10^{-5} V / K.

It was shown in [2, 4] that the non-ideality coefficient *(n)* of the photo-VAC SE is almost independent of temperature in the temperature range 100 K <500 K. Therefore, from the expressions (8), (10) and (11) values of photovoltaic characteristics of solar elements.

Now we pass directly to the calculation of the temperature dependence of the effective values of photovoltaic characteristics of solar elements. It should be noted that all calculations were performed for T_0 = 273 K, φ_0 = 1.42 V, $\gamma = 5 \cdot 10^{-5}$ V / K, U_{0xx} = 1.076 V, $J_{00} = 1.75 \cdot 10^{-18}$ A.

Substituting in (8) formula (12) - (15) we obtain the expression that determines the temperature dependence of the effective voltage of the solar element SE.

In Fig. 2 shows the temperature dependence of the effective value of the voltage SE obtained by the formula (8). These calculations also showed that the effective value of the voltage of the solar element does not depend on the non-ideality of the photovoltaic, or it will be equal to one (n_1 = 1). This figure also shows the experimental results of the temperature dependence of the effective voltage of SEs obtained based on *AlGaAs-GaAs* [1]. It can be seen that these results are in good agreement in the temperature range 200 *K* <*T* <450 K. At the same time, below the temperature T = 200 K, the effective stress of the SE decreases strongly.

Substituting in (10) formula (12) - (15) we obtain the expression determining the temperature dependence of the effective value of the current SE.

In Fig. 3. Shows the temperature dependence of the effective value of the current SE obtained by the formula (10). These calculations also showed that the effective values of the SE current depend very strongly on the non-ideality coefficient of the photovoltaic cells. The agreement between the calculation results and the experiment [1], for the temperature dependence of the effective values of the current of a solar element based on AlGaAs-GaAs, are obtained on n_1 = 2,4.

It can be seen that these results are in good agreement in the temperature range 155 $K < T <$ 400 K. It can be seen from the figure that below T = 150 K, the effective value of the current of SEs prepared on the basis of gallium arsenide is equal to zero. This is to say that such solar elements will not work at low temperatures.

Substituting formula (12) - (15) in (11), we obtain the expression determining the temperature dependence of the effective power of the SE.

In Fig. 4. shows the temperature dependence of the effective power of the solar elements obtained by the formula (11). Here also, the experimental results of the temperature dependence of the effective power of solar elements obtained on the basis of *AlGaAs-GaAs* are presented [1]. It can be seen that these results also agree well in the temperature range 200 $K < T <$450 K.

Thus, in this paper we obtain expressions that establish the temperature dependence of the effective values of photovoltaic characteristics of solar elements based on *AlGaAs-GaAs*. It is shown that these expressions can fully explain the temperature dependence of the effective values of the photovoltaic characteristics of the solar elements obtained from the experiment. The calculations also showed that the effective value of the voltage does not depend on the non-ideality coefficient of the photovoltaic cells of the solar element.

Solar elements, based on gallium arsenide, will not work at temperatures below T = 150 K

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