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TEMPERATURE DEPENDENCE OF THE EFFECTIVE PHOTOGALVANIC CHARACTERISTICS OF SOLAR ELEMENTS

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Abstract
In this work, expressions for temperature dependence of short-circuit current density, effective voltage, effective current density and effective power of solar cells are presented and theoretically studied.

Keywords: solar cell, short-circuit current density, effective voltage, effective current density, effective power, temperature, potential barrier height, pure operating voltage.

Currently, the research of conversion of solar energy into other energies is being carried out intensively and is included in the long-term scientific programs of many developed countries. For example, one such program has been adopted in the USA, according to which solar energy is primarily used for heating and cooling buildings. Because about 25% of the produced energy is used for these purposes. On the other hand, the use of solar energy for this purpose does not require fundamental physical and technical solutions.
Therefore, an important world problem waiting to be solved in this field is the conversion of solar energy into electricity. After all, it is very easy to convert electrical energy into other energies.
Currently, the creation of photocells and photoconverters made of various amorphous materials leads to a decrease in their cost. This indicates the improvement of the use of solar energy and the reduction of the use of other types of energy in the future.

This work is devoted to the theoretical research of the effective photovoltaic characteristics of solar cells made on the basis of amorphous semiconductors. The purpose of choosing this material was at the end of the last century, after it was possible to reduce the density of electronic states in the mobility gap (forbidden zone) by hydrogenation of amorphous semiconductors, and then it became possible to alloy them. After that, it became possible to create inexpensive large-surface solar cells. But

later it became known that the photogalvanic characteristics of solar cells made on the basis of amorphous semiconductors are resistant to external influences. Therefore, this work is mainly aimed at studying the temperature dependence of the effective photovoltaic characteristics of amorphous semiconductor-based solar cells.
In this work, it is derived for the effective power of QEs

$$P_{эф} = \frac{kTj_{кт}}{q}\left(1 + \frac{j_0}{j_{кт}} - \frac{n'_2 kT}{qU_{cu}}\right)\ln\frac{j_{кт}}{j_0}\frac{kT}{qU_{cu}}$$

It is shown that the expression corresponds to the maximum power value of the ideal QEs determined from the Joule-Lents law. [1; 208 p., 2; 141 p.]
Therefore, in this work, the temperature dependence of the short-circuit current density, effective voltage, effective current density and effective power of QEs is derived.
In our previous works [3; p. 41-44] we obtained the expressions that can be used to determine the effective values of the photovoltaic characteristics of QE. Now our goal is to study the dependence of these parameters on temperature. [4; 405-410] in the work, we obtained expressions that determine the dependence of QE on j0 -saturation and jkt - short circuit current densities, Usi - operating voltage, and temperature [5; pp. 19-25]. Based on the conclusions drawn in this work, we write these parameters in the following forms:

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

$$U_{cu} = (U_{cu0} - \varphi)\frac{T}{T_0} + \varphi$$

$$j_{кт} = j_0\left[\exp\left[\frac{q\varphi}{n'_1 kT_0}\left(\frac{U_{cu0}}{\varphi} - 1 + \frac{T_0}{T}\right)\right)\right] - 1\right]$$

n'1-QE in these expressions VAX is the coefficient of non-ideality VAX at the point where the short circuit current is determined and the value of this quantity does not change almost in the range of temperature 100K<T<500K [6; 148-150 p.] is indicated in the case. φ is the potential barrier height of QE, which for not too low temperatures can be written as:

$$\varphi = \varphi_0 - \gamma T$$

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Here, φ0 is the potential barrier height of QE at temperature T=0, which can be determined by extrapolating the dependence of the operating voltage on temperature ($U_{si}(T)$), at T=0K. g- is the temperature coefficient of the potential barrier height, its value for semiconductors is in the range of 10-3-10-4 V/K. If (4) is added to (1)-(3), only temperature remains as a variable in these photovoltaic characteristics [7; 61-64 b].

According to the conclusions made in the previous chapter, we write the expressions defining the effective voltage, effective current density, and effective power density depending on the temperature in the following forms:

$$U_{эф} = \frac{kT}{q} \ln \frac{j_{кт}}{j_0} \frac{kT}{qU_{си}}$$

$$j_{эф} = j_{кт} \left(\frac{n'_2 kT}{qU_{си}} - 1 - \frac{j_0}{j_{кт}} \right)$$

$$P_{эф} = \frac{kTj_{кт}}{q} \left(1 + \frac{j_0}{j_{кт}} - \frac{n'_2 kT}{qU_{си}} \right) \ln \frac{j_{кт}}{j_0} \frac{kT}{qU_{си}}$$

The results of experiment (curve 1) and calculations (curve 2) obtained from (5) for temperature dependence of effective voltage for AlGaAs-GaAs-based QE are presented in Fig. 1. From the calculations, it was found that the relative error of the compatibility of these results is not greater than the error allowed in the experiments (8%).

The calculation results obtained from (6) for the dependence of the effective current density on temperature are presented in Fig. 2 (curve 1). For comparison, this figure shows the experimental results for the effective current density as a function of temperature (curve 2). From the calculations, it was found that the relative error of the compatibility of these results is not greater than the error allowed in the experiments (8%).

The results of the calculation of the effective power density QE found using (7) as a function of temperature are shown in Fig. 3 (curve 1). For comparison, this figure also shows experimental results for QE effective power density as a function of temperature (curve 2). From the calculations, it was found that the relative error of the compatibility of the results is not greater than the error allowed in the experiments (8%).

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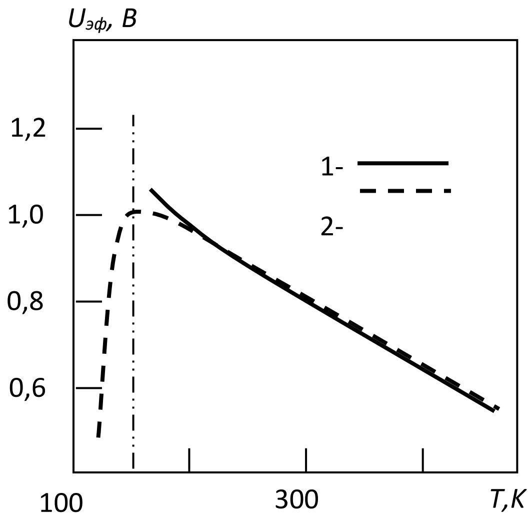

Figure 1. Temperature dependence of the effective voltage of QEs. 1 - the results obtained from the experiment [2; 141 p.], calculation results from the formula (3.13).

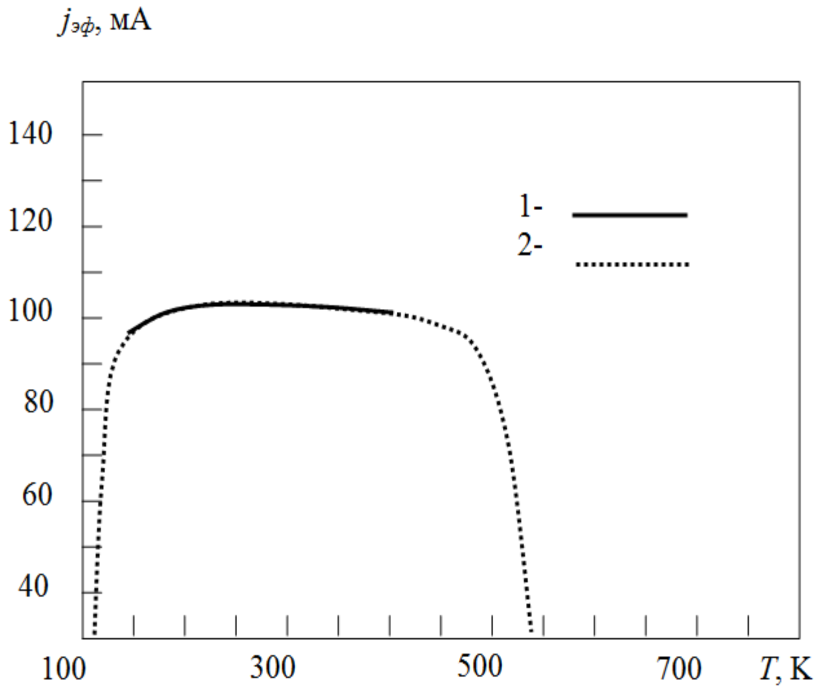

Figure 2. Dependence of effective current of QEs on temperature Experiment 1 [2; 141 p.] and calculation results obtained from formula 2- (3.14). Calculations n=2.5; Done for φ0=1.42 V and g=2*10-4 V/K.

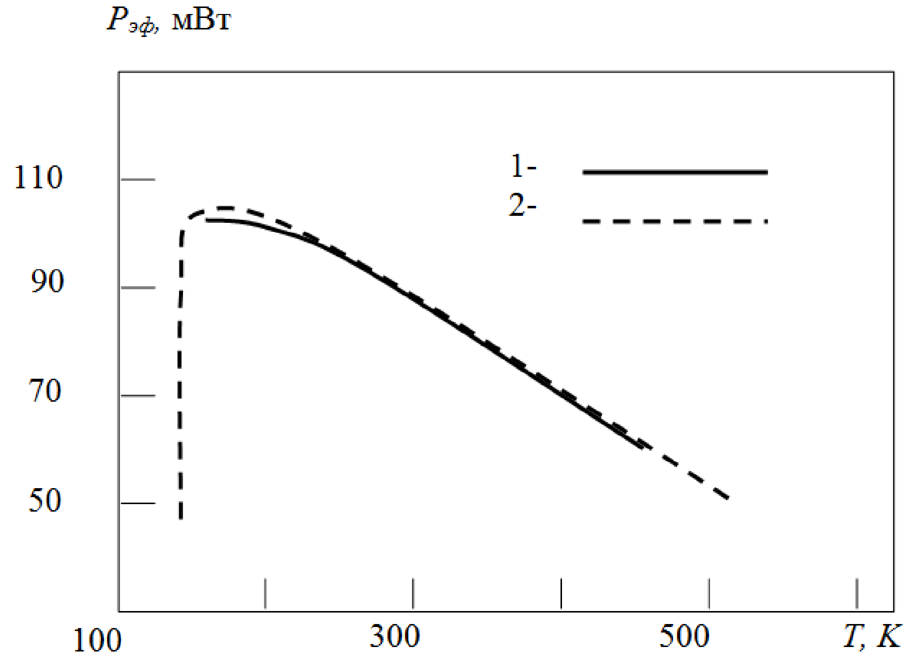

Figure 3. Dependence of effective power of QEs on temperature (1) experiment [6; 148-150 p.] and the results of calculation (2) obtained from the expression (3.15).

Based on the results obtained in this work, it is possible to study the temperature dependence of the effective photovoltaic characteristics of amorphous semiconductor-based solar cells. The obtained results serve to study the stability of effective photogalvanic characteristics of semiconductors in practice. In addition, all the results obtained in this work can be applied to crystal semiconductors.

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