OPEN-CIRCUIT VOLTAGE OF THE SOLAR CELL AS PERFORMANCE BENCHMARKS THE LUMINANCE LEVEL

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The literature on photovoltaics, light levels converters are divided into weak, strong, superstrong and intermediate levels of light solar cells. As a criterion for such a gradation accepted ratio of concentration of the generated radiation of nonequilibrium electron-hole pairs and the concentration of the main alloying (acceptor or donor) impurity in the base layer of the converter.

The purpose of research - the use of open-circuit voltage of the solar cell as a criterion for assessing the level of its light.

Materials and methods of research. In practical terms, the above approach the qualitative detection of light levels is complicated by the fact that the impurity concentration of the base area of the inverter, as a rule, the value is not specific enough. It may differ significantly from sample to sample, the concentration of nonequilibrium charge carriers is certainly not constant over the thickness of the base layer, as in planar and in the matrix solar cells. Therefore, you should specifically consider whether, to what quality sub-band radiation of the above areas should be attributed to the illumination level of solar radiation standard AM 1.5 (1,000 W / m2), whose characteristics directive approved by the International Electrotechnical Commission.

The results of research. Simple mathematical calculations based on the emission spectrum of AM 1.5 show that during the lifetime of charge carriers $\tau \approx$ 10 ms, typical of solar grade silicon (Solar Grade Silicon), the density of the photoactive photons postupayushih on the work surface converter, more than 500 times less than the surface density of silicon atoms (Figure 1).

Given the continuity of the electric field lines in the pn junction solar cell at the level of the surface density of the atoms of the semiconductor pn junction saturation for the separation of charges generated by radiation can be estimated as about 0.2% of the theoretical maximum.

Since qualitative assessment of the level of illumination associated with comparing the concentration of nonequilibrium charge carriers with the dominant impurity concentration in the base transmitter is therefore talking about the radiation that penetrated into his base, rather than external radiation, which is clearly greater than the first force in the light losses.

The reasons for the loss of direct light should include three main factors. Firstly, it is the loss caused by shading part of the working surface of the transducer contact grid (10% in planar FEP). Secondly, it is the loss due to reflection of the light flux from the working surface of the transducer. For converters containing a selective coating, the reflection coefficient is estimated at 6-9%, while uncoated quantity of about 32%.

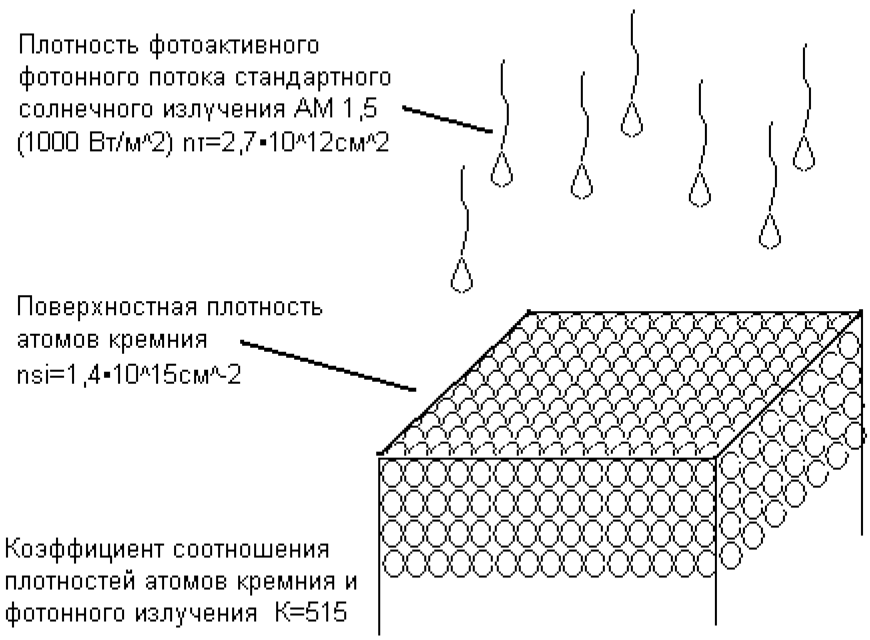

Fig. 1. The calculated data ratio of surface density of silicon atoms and photoactive phototransducer for a photon flux of solar radiation standard AM 1.5 (1,000 W / m2) for the lifetime of τ = 10 ms minority carriers (the value of τ is characteristic of solar grade silicon (S = 1 cm2)

The third factor should include loss of luminous flux in the heavily doped layer of the frontal converter due to rapid recombination radiation generated charges, since this layer their lifetime τ is very small. In the doped layer thickness of 1 micron semiconductor (silicon) lost up to 18% of the photoactive radiation flux.

The indirect cause of the loss of luminous flux is generated by recombination of charge carriers in the base region of the converter in which the lifetime of the charge carriers is much larger than in the doped region, but it is limited to the above order of magnitude of 10 ms. Also plays an important role and drain of the p-n separated by charge transfer across a shunt resistor in the converter.

The final concentration of the generated radiation of nonequilibrium charge carriers in the base region near the pn junction is directly reflected in the value of the open circuit voltage U_{xx}. This physical quantity is a function of the concentration of nonequilibrium charge carriers in the base of the inverter.

In this connection it is possible to perform identification of the level of illumination on the surface of a particular value of the voltage photoconverter idling.

Open circuit voltage of the silicon transducer depends exponentially on the value of the illumination. At zero light converter (temperature 25 ° C) U_{xx0} (ie, the potential at the pn junction) amounts to 0.53 V. In this case, the theoretical limit U_{xx} converter amounts equal to twice the value of the dark potential Uhh0.

Based on the foregoing, light levels can be assessed converters largest open-circuit voltage by dividing the full range of its potential growth in the five respective sub-bands, such as isometric.

The results of solving the problem presented in the table for the two types of silicon transducers planar matrix and, based on the parameters experimentally obtained test specimens. Figure 2 shows the actual current-voltage characteristic, taken at fifty times the concentration of solar radiation.

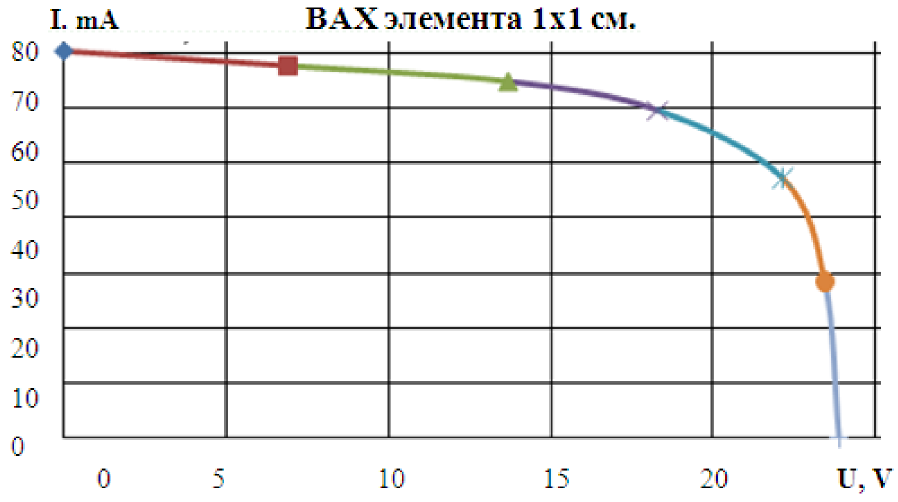

Fig. 2. Current-voltage characteristic of the solar cell of the matrix S = 1cm^2 containing 30 structures with pn junction with concentrated (50-fold) light (open circuit voltage of one structure is 0.727 V).

An estimate of the concentrated radiation at the boundaries of a conditional jump from one to the other sub-band carried out taking into account the individual parameters of the samples according to expression (1).

$$U_{xxi} = U_{xx0}\left[2 - exp\left(-\frac{(R_i/R_0)^{0.5}}{k_0}\right)\right], \qquad (1)$$

where U_{xxi} - calculated value of the open circuit voltage converter according to the selected algorithm, V; U_{xx0} - the potential of the pn junction converter at zero illumination (dark), V; - The concentration of solar radiation, providing the production estimated value of the open circuit voltage converter; Parameter of the exponential loss factors of light and charge in the converter. The values for the test converters found according to the expression (1) for k = 1, taking into account the respective current-voltage characteristics.

The payment information of illumination levels of silicon solar cells and planar matrix types on the basis of experimental values U_{xx}.

Open circuit voltage, V	Illumination level (qualitative assessment)	$K = \frac{U_{xxmax}}{U_{xx0}}$	Illumination in AM 1,5	
			Plan. PEC	Matr/PEC

			П $К_0$ =7	$К_0$ =17
0,53	Zero	1	0	0
0,53-0,636	Hyperweak	1.2	2,6	15,355
0,636-0,742	Weak	1.4	12,816	74,96
0,742-0,848	Moderate	1.6	41,628	243,36
0,848-0,954	Strong	1.8	127,69	751,811
>0,954	Superstrong	2.0	>127,69	>751,811

Figure 3 shows the calculated dependence of the open circuit voltage converters silicon studied by light in the transition from one qualitative level to the other two types: planar and matrix. The same figure shows the experimentally obtained one point in light of the sun (AM 1.5) and some (about 50-fold) of the concentrated radiation.

The calculated data agree well with the experimental results.

Noticeable lag in increasing the open circuit voltage with voszrostaniem light level for the matrix with respect to planar solar cells can be explained by the design features of this type

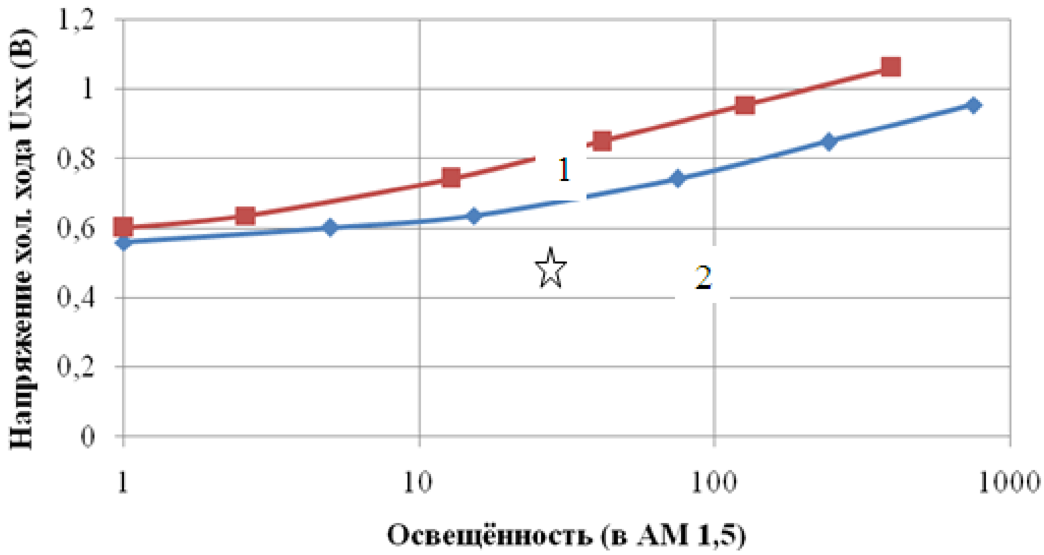

Figure 3. Expected depending on the open circuit voltage of silicon solar cells by light exposure:

1 - for planar solar cells; 2 - for the matrix of solar cells (experimental value Uhh according to Figure 2.)

Conclusions

From the analysis presented in the table in Figure 3 and data that the standard AM 1.5 solar radiation (ie, one sun) for silicon transducers should be classified as super- weak.

The proposed division of the range of possible values of the open circuit voltage converter in comparison with the experimental value of this parameter allows you to quickly assess both the quality of the illumination surface of various objects and its quantitative value.