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Efficiency of CIGS PV under normal sunlight conditions when on a lawn

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ABSTRACT: The study of the load current-voltage characteristics of a solar photovoltaic module based on a polycrystalline semiconductor binary compound $Cu(In,Ga)Se_2$ under normal sunlight P_{rad}=(800±5) W/m^2, in a temperature range of (32÷60) ºC. It was found that with an increase in temperature, the efficiency of the solar photovoltaic module first decreases from 10.77% to 10.65%, and then increases to 10.97%, and the coefficient of temperature dependence of the efficiency in these regions differs and have values K_{Eff1}≈-0.18 %/ºK and K_{Eff2}≈+0.13%/ºK.

KEY WORDS: solar photovoltaic module, polycrystalline semiconductor, $Cu(In,Ga)Se_2$, solar radiation, efficiency, short-circuit current, open circuit voltage.

I.INTRODUCTION

Currently, the share of solar photovoltaic modules based on crystalline silicon in solar energy is 92% [1,2]. Despite this, there are a number of reasons that limit the widespread implementation of crystalline silicon photovoltaic panels. The main ones are: (a) the high cost of the base material, which is ~50% of the total cost of the solar cell; (b) the complexity of the production chain, (c) high material costs due to the indirectness of the semiconductor material and strict requirements for the purity of the material, as well as the toxicity of the manufacturing process, problems associated with the disposal of toxic waste [3,4]. It is possible to get rid of the above disadvantages by creating thin-film solar. One of the promising and environmentally friendly materials is the semiconductor binary compounds of copper-indium-gallium and selenium – $Cu(In,Ga)Se_2$ (CIGS). The advantages of CIGS solar cells are as follows:

1. CIGS layers are synthesized at relatively low temperatures (~450 °C). This makes it possible to create solar cells and photovoltaic modules on glass, flexible polyamide and metal substrates of large area (100x120 cm^2), in a single technological cycle;
2. Low material consumption due to the high light absorption coefficient (104 - 105 cm^{-1}), makes it possible to reduce the thickness of the photoactive region (<5 μm);
3. Energy intensity, the cost of producing panels of similar power is several times less than for the production of crystalline silicon panels.

II. METHODOLOGY

In this article, studies were conducted on the influence of green space, such as a lawn, on the output energy parameters of PV modules based on CIGS solar cells. The studies were conducted under normal sunlight conditions in July 2024 in Tashkent. The solar illumination power Prad incident on the solar cell was 800 W/m^2. Under the influence of sunlight, the temperature T of the solar cell changed in the range from 32°C to 60°C, at an ambient temperature of T=32°C. The studied solar cell consisted of 36 series-connected solar cells with an effective area of 27.8×27.8 cm^2. The incident solar radiation power was measured using a wireless analyzer Solmetric Sol Sensor. The temperature on the surface of the solar cell was measured using a Fluke 62 MAX infrared thermometer. The load I-V characteristics of the solar cell were studied using a PROVA-210 Solar Module Analyzer.

III. EXPERIMENTAL RESULTS

Fig. 1 and Fig. 2 show the experimental results of the temperature dependence of the short-circuit current I_{sc} and the open-circuit voltage V_{oc} of CIGS photovoltaic modules. It follows from the experiment that I_{sc} increases linearly with temperature, from 0.46 A to 0.54 A, with two slopes. In the temperature range of 305–315°K, the temperature coefficient

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of the short-circuit current I_{sc} of CIGS photovoltaic modules was $K_{sc1}\approx0.19\%/°K$, and in the temperature range of 315–335°K, it was $K_{sc2}\approx0.77\%/°K$ [5-7]. The open-circuit voltage V_{oc} of the FEM.

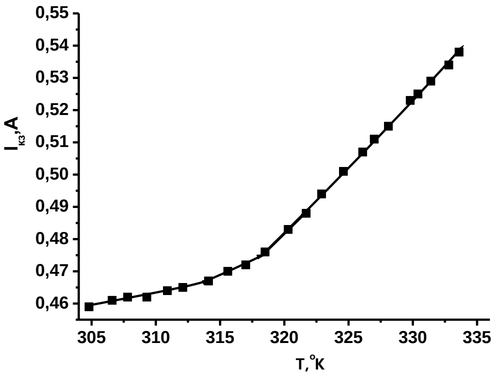

Fig. 1. Temperature dependence of I_{sc} of CIGS photovoltaic module

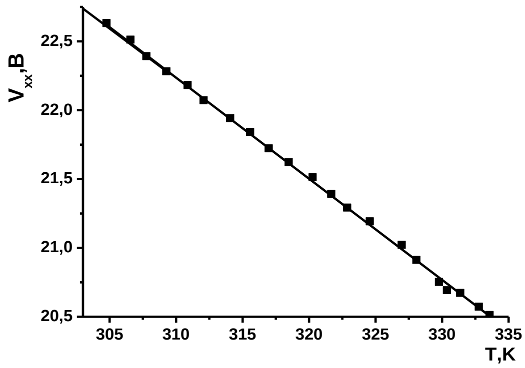

Fig. 2. Temperature dependence of V_{oc} CIGS photovoltaic module

Fig. 2 decreases linearly with increasing temperature, from 22.6 V to 20.54 V. It follows from the experiment that V_{oc} decreases linearly, with one slope, in the entire studied temperature range of 305–333°K, and the temperature coefficient of the open-circuit voltage V_{oc} has a value of $K_{oc}\approx-0.033\%/°K$

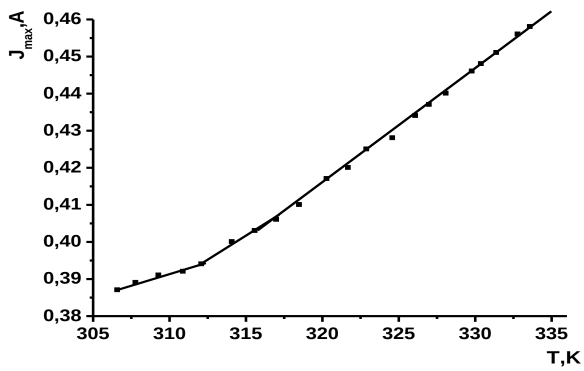

Fig.3. Temperature dependence of I_{max} CIGS photovoltaic module

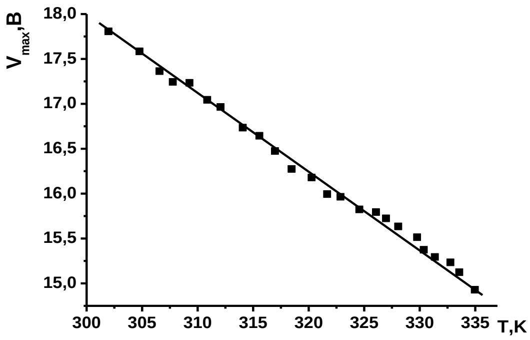

Fig.4. Temperature dependence of V_{max} CIGS photovoltaic module

Fig. 5 shows the experimental result of the temperature dependence of the fill factor of the I-V characteristic FF CIGS PV. The filling factor FF of CIGS photovoltaic cells in the temperature range of 302–314°K increases slightly, reaching a value of 0.652 up to the temperature of T=318°K has a constant value of FF≈0.652, and then drops to T=333°K, reaching a value of FF=0.651, where it has a temperature coefficient of $K_{FF}\approx-0.019\%/°K$. Fig. 6 shows the experimental results of the temperature dependence of the efficiency of CIGS photovoltaic module. As can be seen, the efficiency of photovoltaic cells decreases linearly with increasing temperature in the range of 305–311°K, from 10.8 to 10.65%, and has a temperature coefficient of efficiency of $K_{Eff2}\approx-0.23\%/°K$.

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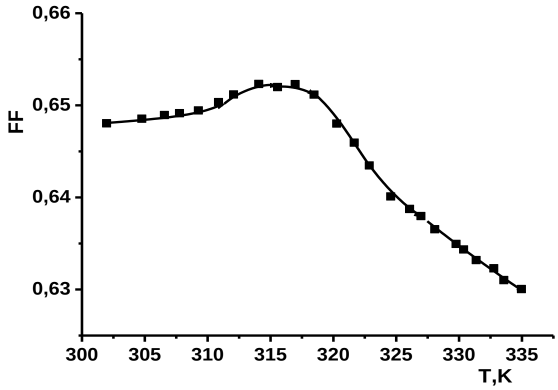

Fig.5. Temperature dependence of FF CIGS of the photovoltaic module

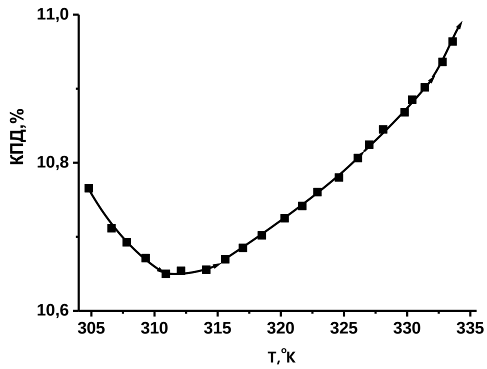

Fig.6. Temperature dependence of the efficiency of CIGS of the photovoltaic module

In the temperature range of 316–333°K, an increase in the efficiency of the photovoltaic cells with a positive temperature coefficient of efficiency $K_{Eff1} \approx$ 0.17%/°K is observed. The experimental studies have shown that the photovoltaic cells based on CIGS solar cells layers under normal illumination conditions $P_{rad} \approx$800 W/m^2, when located on the lawn surface, in the temperature range of 44–60°C, have a positive temperature coefficient of efficiency $K_{Eff1} \approx$0.17%/°K. For silicon Si solar cells, this parameter is equal to 0.45%/°K.

IV. CONCLUSION AND FUTURE WORK

That is, in the studied CIGS photovoltaic cells, this coefficient is actually 2.5 times less than in crystalline silicon solar cells. The coefficient observed in Fig.1 temperature dependence of short-circuit current I_{sc}, with two slopes, in the second section the current increases sharply with temperature, which is associated with a decrease in the recombination of photogenerated minority charge carriers in the region of relatively high temperatures, which is observed during recharging of defective states [8-10]. The temperature dependence of the open-circuit voltage V_{oc} of CIGS PV, by analogy with standard silicon and other solar cells, decreases with increasing temperature, due to a decrease in the height of the potential barrier of the transition.

Comparison of the experimental results indicates that such output parameters of PV as I_{sc}, V_{oc}, I_{Max}, V_{Max} behave in the same way as in the case (Fig. 1 and Fig. 2). However, the parameters FF and efficiency behave anomalously, which may be associated with the influence of the radiation spectrum reflected from the lawn surface, as a result of which even the temperature on the PV surface decreases.

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