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ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ СОЛНЕЧНОГО ЭЛЕМЕНТА НА ОСНОВЕ СТРУКТУРЫ SNO2/CDS/CdTe

Аннотация: В данной работе представлено численное моделирование солнечного элемента на основе структуры SnO2/CdS/CdTe посредством программы AFORS-HET v2.5. Была показана зависимость КПД и ВАХ солнечного элемента от толщины слоев SnO2 и CdS, а также изменение КПД в результате изменения температуры с 300 К до 370 К. В результате моделирования было установлено, что увеличение толщины слоев, а также температуры снижает КПД устройства. Было также установлено, что солнечный элемент на основе структуры SnO2/CdS/CdTe с толщиной слоев 12 нм, 30 нм и 9 мкм и степенью легирования \( N_D=1\cdot10^{17} \text{ cm}^{-3} \), \( N_D=1\cdot10^{17} \text{ cm}^{-3} \), и \( N_A=1\cdot10^{14} \text{ cm}^{-3} \) соответственно, при температуре 300 К позволяет достичь КПД в 16 %.
Abstract: This article presents numerical modeling of a solar cell based on the SnO$_2$/CdS/CdTe structure through the AFORS-HET v2.5 program. The dependence of the efficiency of the solar cell on the thickness of the SnO$_2$ and CdS layers was shown, as well as the change in the efficiency as a result of the temperature change from 300 K to 370 K. As a result of the simulation, it was found that increasing the thickness of the layers, as well as the temperature, reduces the efficiency of the device. It was also found that a solar cell based on the SnO$_2$/CdS/CdTe structure with a layer thickness of 12 nm, 30 nm and 9 μm and a doping level of $N_D=1\cdot10^{17}$ cm$^{-3}$, $N_D=1\cdot10^{17}$ cm$^{-3}$, and $N_A=1\cdot10^{14}$ cm$^{-3}$, respectively, at a temperature of 300 K, allows an efficiency of 16%.

Ключевые слова: солнечный элемент, толщина, степень легирования, КПД, ВАХ.

Key words: solar cell, thickness, degree of doping, efficiency, I-V characteristic.

At present, thin-film solar cells are quite common. they have a number of advantages: they require fewer semiconductor materials, they are easier to manufacture and assemble, they have less weight, they are less expensive than wafer solar cells. At present, there are a number of materials that are used in thin-film solar cells such as cadmium telluride (CdTe), gallium arsenide (GaAs), indium phosphide (InP), amorphous silicon (a-Si), polycrystalline silicon (pc-Si), etc.

For example, cadmium telluride (CdTe) is a typical p-type semiconductor of group II-VI, having a band gap of 1.5 eV, which is the optimum value for photogeneration. Also, CdTe is well suited for large-area deposition and can be used in large-scale production [1]. A typical structure of a solar cell based on SnO$_2$/CdS/CdTe is shown in Fig.1.
In this work, the solar cell was modeled on the SnO\textsubscript{2}/CdS/CdTe structure using the AFORS-HET v2.5 program and the dependence of the solar cell efficiency on the thickness of the SnO\textsubscript{2} and CdS layers was found, and the spectral response of the structure and the dependence of the efficiency on temperature.

The thickness of the CdTe layer was constant and amounted to 9 µm (this layer thickness is optimal for a given solar cell structure, which allows obtaining high efficiency values), and the degree of doping for all layers in the structure was constant and consisted of $N_D=1\cdot10^{17}$ cm\textsuperscript{-3}, $N_D=1\cdot10^{17}$ cm\textsuperscript{-3}, $N_A=1\cdot10^{14}$ cm\textsuperscript{-3} for SnO\textsubscript{2}, CdS, and CdTe respectively.

Fig.2 shows the dependence of the current-voltage characteristics of the solar cell on the thickness of the SnO\textsubscript{2} layer with a band gap of 3.4 eV at a thickness of 12 nm in Fig. 2 (a) and 100 nm in Fig. 2 (b) and a constant CdS layer thickness of 30 nm. It follows from Fig. 2 that with increasing thickness of the SnO\textsubscript{2} layer, the efficiency of the device decreases from 16% to 13.87%, which is due to the fact that the upper SnO\textsubscript{2} layer is responsible for the photogeneration of the charge carriers [1,2].
Figure 2. Dependence of the I-V characteristic on the thickness of the SnO₂ layer a) at a layer thickness of 12 nm, the efficiency is 16% b) at a layer thickness of 100 nm 13.87%

The smaller the thickness of the SnO₂ layer, the higher the probability of passage of the charge carriers to the next layer (the diffusion length of the charge carriers is the average distance from the photogeneration to recombination time).

Further, the dependence of the I-V characteristic and the efficiency of the solar cell on the thickness of the CdS layer (the band gap 2.42 eV) was analyzed. The thickness of this layer was changed from 30 nm to 300 nm (at a constant thickness of the SnO₂ layer of 12 nm), as a result of which the efficiency and the current-voltage characteristic of the solar cell decreased in Fig. 3.

A decrease in the efficiency of the solar cell occurred from 16% of Fig. 3 (a) to 14.85% of Fig. 3 (b). Next, the spectral response of this solar cell was shown and analyzed in Fig. 4.

Figure 3. Dependence of the I-V characteristic on the thickness of the CdS layer a) at a layer thickness of 30 nm 16% b) at a layer thickness of 300 nm 14.85%
Figure 4. Dependence of the spectral response of the structure of a solar cell based on SnO$_2$/CdS/CdTe

It can be seen from the figure that the spectral response of this solar cell lies in the range from 300 nm to 900 nm. The absorption peak occurs in photons with a wavelength of 600 nm. Photons of solar radiation with a wavelength of more than 900 nm are not absorbed by this solar cell.

Further, the effect of temperature on the efficiency (n) of the solar cell in the range from 300 K to 370 K was analyzed. As a result, it was shown in Fig. 5 that the efficiency of the device decreased from 16% to 12.58% under the influence of temperature.

Figure 5. Dependence of the efficiency of a solar cell on the basis of the SnO$_2$/CdS / CdTe structure on the temperature change
Thus, as a result of modeling the structure of a solar cell based on SnO$_2$/CdS/CdTe, it was found that an increase in the thickness of SnO$_2$ films from 12 nm to 100 nm and CdS from 30 nm to 300 nm negatively affects the efficiency of the device, as well as an increase in temperature from 300 K up to 370 K contributes to a reduction in efficiency from 16% to 12.58%.

Thus, the efficiency of a solar cell based on the SnO$_2$/CdS/CdTe structure was 16% at a layer thickness of 12 nm, 30 nm and 9 μm and the doping level of the $N_D = 1 \cdot 10^{17}$ cm$^{-3}$, $N_D = 1 \cdot 10^{17}$ cm$^{-3}$ and $N_A = 1 \cdot 10^{14}$ cm$^{-3}$ respectively. This simulation has shown that by optimizing the thickness of the layers of the solar cell, it is possible to achieve an increase in the efficiency of the device [2,3].

References

