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МОДЕЛИРОВАНИЕ ОСНОВНЫХ ЭКСПЛУАТАЦИОННЫХ ХАРАКТЕРИСТИК СОЛНЕЧНЫХ ЭЛЕМЕНТОВ НА ОСНОВЕ ГЕТЕРОПЕРЕХОДОВ ZnTe/CdSe И ZnSe/CdSe

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MODELING OF THE MAIN WORKING PARAMETERS OF SOLAR CELLS BASED ON ZnTe/CdSe AND ZnSe/CdSe HETEROJUNCTIONS

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В данной работе было проведено моделирование основных параметров солнечных элементов, таких как: напряжение холостого хода V_{oc}, плотность тока короткого замыкания J_{sc}, фактор заполнения FF, коэффициент полезного действия (КПД) η солнечных элементов на основе гетеропереходов ZnTe/CdSe и ZnSe/CdSe, в зависимости от внешних условий: эксплуатационная температура, толщины поглощающего и оконного слоев. Были найдены начальные характеристики для получения солнечных элементов с оптимальной эффективностью преобразования энергии светового излучения.

Ключевые слова: солнечный элемент, SCAPS-1D, коэффициент полезного действия.

In this paper a modeling of the main working parameters, such as: open-circuit voltage V_{oc}, short-circuit current density J_{sc}, fill factor FF, efficiency η of solar cells based on ZnTe/CdSe and ZnSe/CdSe hetero-junctions (HJ) depend on the external conditions: operation temperature, absorption and window layers thickness. Were

determined a basic parameters for obtaining solar cells with optimal efficiency of light irradiation conversion.

Key words: solar cell, SCAPS-1D, efficiency.

Nowadays a solar energy usage pays a higher attention of researchers as a perspective way of global energy crisis solution. Among the different methods of a conversion of solar energy into electric a photo-electrical transition is most reviewed.

In recent time for solar cells (SC) manufacturing used single-crystal, polycrystalline and amorphous Si, semiconductor thin films, etc [1]. II-VI semiconductor compounds, such as cadmium selenide (CdSe), zinc selenide (ZnSe), zinc telluride (ZnTe), are considered as a promised materials for economically effective unijunction and tandem photo-convertors because of their band gap (1.70 eV – CdSe, 2.67 eV – ZnSe, 2.26 eV – ZnTe). They may be used as absorber and window layers in solar cells applications. Therefore un-doped CdSe and ZnSe layers have *n*-type conductivity, ZnTe layer have a *p*-type [2-3].

For modeling SC characteristics are present several programmable packages: AMPS-1D, ASA, PC-1D, SCAPS-3200. The last software due to its convenience and development is most powerful for our improvement [4]. Abilities of this software allow to consider own properties of semiconductor layers as a recombination processes, which took place in interface boundaries and to determine the main SC characteristics: dark and light I-V curves, spectral distributions of quantum efficiency etc. The optimization of CS construction parameters based on ZnTe/CdSe and ZnSe/CdSe heterojunctions by modeling their main working characteristics using the SCAPS-3200 software package caused the aim of study.

In table 1 is present the input parameters for modeling solar cells in SCAPS software.

The main construction parameters which affect to the CS efficiency are window and absorber layers thickness. Therefore in this work an influence of these values on CS characteristics was investigated and their optimal values were determined.

Table 1

Basic parameters used at modeling of SC characteristics based on HJ ZnTe/CdSe and ZnSe/CdSe

Parameters	Compounds		
	n-CdSe	*p*-ZnTe	*n*-ZnSe
Wide band gap (300 K) E_g, eV	1.74	2.39	2.70
Electron affinity c, eV	4.95	3.53	4.09
Dielectric permittivity e	6.10	7.28	5.70
Effective density of states of the conduction band N_c, cm^{-3}	$1.75 \cdot 10^{18}$	$2.24 \cdot 10^{18}$	$2.40 \cdot 10^{18}$
Effective density of states of the valence band N_v, cm^{-3}	$2.10 \cdot 10^{19}$	$1.60 \cdot 10^{19}$	$1.80 \cdot 10^{19}$
Electron mobility μ_n, cm^2/Volt·c	650	340	500
Hole mobility μ_p, cm^2/Volt·c	-	100	30

Modeling was carried out in the range of the absorber layer thickness CdSe d = 1 – 3 mm, window layer ZnTe (ZnSe) thickness d = 0.1 – 0.6 mm, operation temperature T = 280 – 320 K.

On fig.1 shown light I-V curves of SC based on ZnTe/CdSe and ZnSe/CdSe HJ modeled at different absorber layers thickness.

As a result of a modeling it was carried out, that in case of HJ ZnTe/CdSe at the increasing of the absorber layer thickness from 1.0 to 3.0 mm observed some increasing of h of about 1 % in borderline cases. It may be explain by the presence of larger crystallites in ZnTe film by the increasing of the window layer. During the exploitation solar cell may heat, this factor may significantly impact on their working characteristics. Therefore we investigated an operational temperature influence on I-V curves ZnTe/CdSe and ZnSe/CdSe heterojunctions.

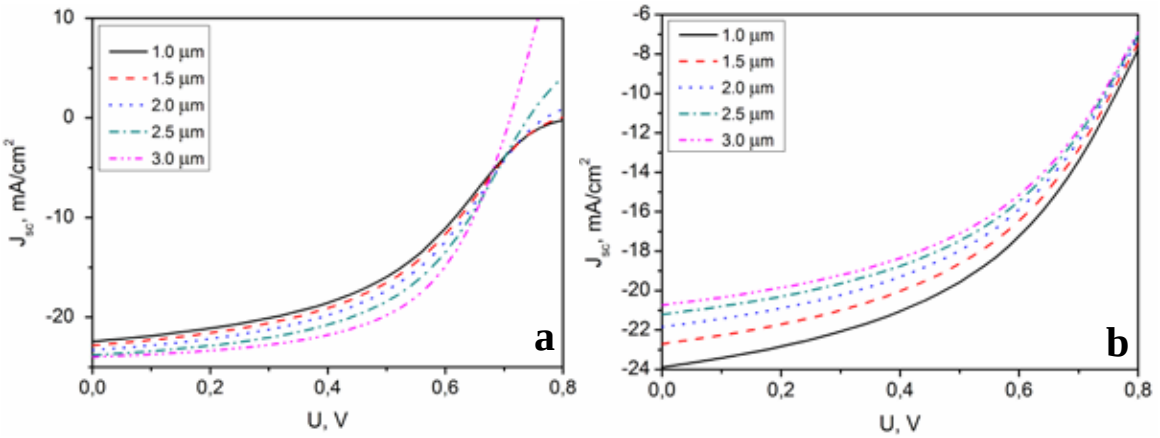

Fig. 1. Light I-V curves simulation of solar cells based on ZnTe/CdSe (a) and ZnSe/CdSe (b) hetero-junction depend on absorber layers thickness

In both cases solar cells modeling was estimated in the range of temperature T =280-320 K. It was determined that at increasing of operation temperature value V_{oc} of SC ZnSe/CdSe decreased that may be explain by temperature dependence of current saturation.

A comparison of the photo-convertors characteristics based on ZnTe/CdSe and ZnSe/CdSe heterojunctions shown on table 2.

Table 2

Solar cell modeling parameters with optimal constructional conditions (d_{CdSe} = 3 mm, $d_{ZnTe(ZnSe)}$ = 0.1 mm, T = 320 K)

Heterojunction	V_{oc}, Volt	J_{sc}, mA/cm^2	FF, %	η, %
ZnTe/CdSe	0.87	24.91	71.02	17.36
ZnSe/CdSe	0.61	15.83	42.34	4.06

The results of quantum efficiency modeling of both hetero-junctions presented on fig. 2.

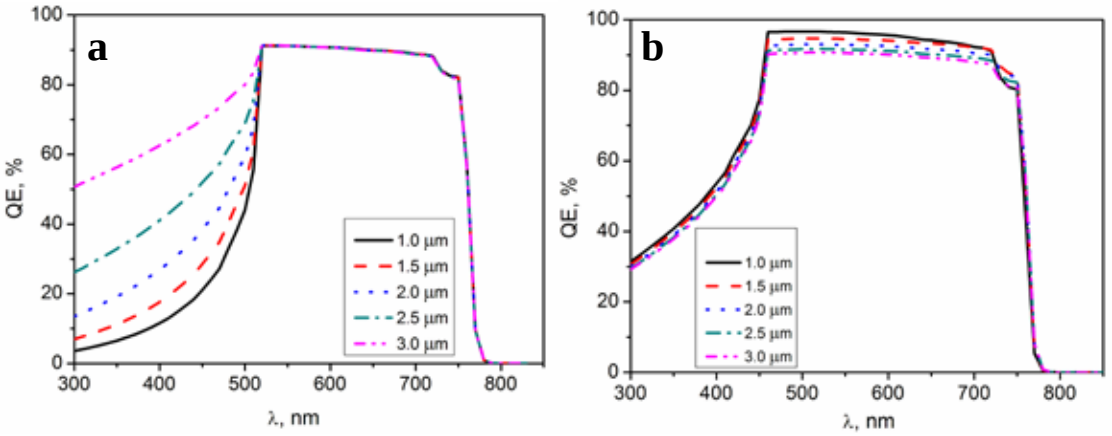

Fig. 2. Numerical modeling of solar cells quantum efficiency based on ZnTe/CdSe (a) and ZnSe/CdSe (b) hetero-junction depend

As fig. 2 shown, the results of modeling are well correlated with theoretical study. In case of HJ ZnTe/CdSe value of QE at increasing of the absorber layer is bigger at the "red boundary" destination point and the maximal value of QE is about 95 %. In case of HJ ZnSe/CdSe the dependence of QE on the thickness of absorber layer is more difficult and is present at the lower values of the wavelength ($\lambda \sim 300$ nm).

At the increasing of the ZnTe (ZnSe) layer thickness an absorbance of photons with energy of hν $>E_g$ has a bigger value. Decrease of the photons in absorber layer, which have an energy, bigger than E_g value for ZnTe, leads to decreasing of quantum yield of CS in the range of the wavelength $\lambda > 680$ нм.

An analysis of the light I-V curves and quantum efficiency modeling results of SC based on ideal HJ ZnTe/CdSe and ZnSe/CdSe occurs to make the next conclusions:

SC efficiency based on ideal anisotropic HJ *p*-ZnTe/*n*-CdSe at optimal device construction (absorber layer thickness was d_{CdSe} = 3 mm, window layer thickness was d_{ZnTe} = 0.1 mm) at the operation temperature T = 320 K may to increase on value h = 17.36%. This photo-cell has a wide photo-sensitivity area, which is present in the

range of λ = (516 – 732) nm. SC efficiency based on ideal isotopic HJ *n*-ZnSe/*n*-CdSe is generally less and not bigger than h = 5%.

Given the fact that the lattice mismatch in *p*-ZnTe/*n*-CdSe HJ is less than 1%, it provides an obtaining of the interface near to ideal, is a possibility to obtaino real high-efficiency photo-converters. This fact makes the perspective of their usage as a base (first) element of tandem solar cells.

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