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Short Communication

Effect of Electron Transporting Layer on Power Conversion Efficiency of Perovskite-Based Solar Cell: Comparative Study

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Recently, photovoltaic energy is growing up rapidly especially in solar cell fabrication. Perovskite-based solar cell technology has been focus of interest from photovoltaic technologies due to its high power conversion efficiency and low processing cost comparing by others. The first step in solar cell fabrication is the simulation, which gives an idea about effect of different parameters on power conversion efficiently with less efforts and costs. There are a lot of software that are used in solar cell simulations, such as GPVDM, SCAPS and Silvaco Atlas. Therefore, several structures are used in perovskite-based solar cells, such as *n-i-p*, *p-i-n*, *n-p-p* and *p-p-n*. Our study is focused on *n-i-p* structure. For the present paper we used Silvaco Atlas software because it contains a lot of physical and recombination models based on solving the Poisson partial differential equation and carrier continuity. Moreover, this paper shows numerical simulations of planar heterojunction solar cell structures that have the following layers: hole transporting layer (HTL) / perovskite absorber layer (PVK) / electron transporting layer (ETL). However, different layer materials of ETL are used, namely cadmium sulfide (CdS) and zink oxide (ZnO) in order to study the behavior of solar cells based on perovskite ($CH_3NH_3PbI_3$). This latter material used in this paper's simulation belongs to organic/inorganic type. The obtained results show that the solar cell structure based on CdS exhibits a better performance in term of power conversion efficiency (PCE) compared to that based on ZnO when using the same layer thickness.

Keywords: IV characteristics, Perovskite, Power conversion efficiency, Solar cell, ZnO, CdS.

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1. INTRODUCTION

In 2009 was the first introduction of perovskite materials in solar cell technology with 3.81 % of power conversion efficiency (PCE) [1]. Later in 2016, PCE of perovskite-based solar cells jumped to 22.1 % [2]. This exponential evolution of PCE attracted researchers attention to investigate in perovskite based solar cells field of research including a lot of aspects, such as but not limited to: stability, hysteresis, production process and methods, materials used as electron transporting layer, materials used as hole transporting layer and materials used for the absorber layer.

One of the most important field of research is the simulation of solar cells using a variety of software, such as GPVDM [3], SCAPS [4], wxAMPS [5] and Silvaco-Atlas [6]. Simulations can help to understand different parameter effects on solar cell characteristics without doing any expensive experimental efforts.

In this work, two planar heterojunction structures of perovskite-based solar cell using different electron transporting layer material, namely CdS and ZnO, are compared in order to study and improve design performances. Our study is made based on numerical simulations using Silvaco-Atlas software [7].

2. SIMULATION PARAMETERS

The general structure of a perovskite-based heterojunction solar cell is presented in Fig. 1a, where we can note three principal layers: electron transporting layer (ETL) / absorber layer / hole transporting layer (HTL). The ETL used two materials alternatively: CdS for the first structure and ZnO for the second one. However, the HTL and perovskite layers are spiro-OMeTAD and $CH_3NH_3PbI_3$, respectively. Both structures are presented in Fig. 1b and Fig. 1c.

The parameters values used for calculation in each structure are mentioned in Table 1. Therefore, they were carefully selected from literature [8-10] and Silvaco database [7].

3. RESULTS AND DISCUSSION

In order to indicate the effect of ETL on power conversion efficiency for different solar cell-based design, the numerical simulations are done and the results are presented.

Fig. 2 shows J-V characteristics of CdS-based solar cell and ZnO-based solar cell with a thickness of 200 nm for both CdS and ZnO materials. It is clear that structure based on CdS exhibits better electrical parameters compared to that based on ZnO. This is due to best transparency of the CdS material than ZnO which improves light absorption in perovskite layer. Thus, the PCE for CdS-based solar cell is better.

Fig. 3 illustrates J-V characteristics of both solar cells based on CdS and ZnO with an ETL thickness of 400 nm for both cases. As seen from Fig. 3, CdS-based

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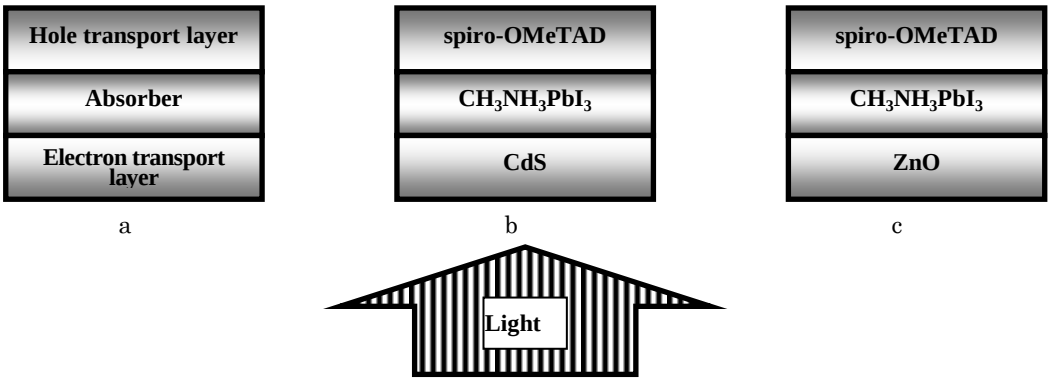
Table 1 – Simulation parameters used for each layer

Material Property	CdS	ZnO	Spiro-OMeTAD	$CH_3NH_3PbI_3$
Thickness (nm)	200	200	100	400
E_g, eV	2.4	3.3	3	1.55
χ, eV	4.18	4	2.45	3.9
Nc, cm^{-3}	$2.2 \cdot 10^{18}$	$2.2 \cdot 10^{18}$	$2.2 \cdot 10^{18}$	$2.2 \cdot 10^{18}$
Nv, cm^{-3}	$1.9 \cdot 10^{19}$	$1.9 \cdot 10^{19}$	$1.9 \cdot 10^{19}$	$1.9 \cdot 10^{18}$
N_D, cm^{-3}	$1 \cdot 10^{18}$	$1 \cdot 10^{18}$	–	$2 \cdot 10^{18}$
N_A, cm^{-3}	–	–	$1 \cdot 10^{18}$	–
ε_r	10	9	3	18
μ_n, $cm^2V^{-1}s^{-1}$)	100	100	$2 \cdot 10^4$	3
μ_h, $cm^2V^{-1}s^{-1}$)	25	25	$2 \cdot 10^4$	17



a b c

Fig. 1 – (a) General heterojunction structure, (b) CdS-based solar cell, (c) ZnO-based solar cell

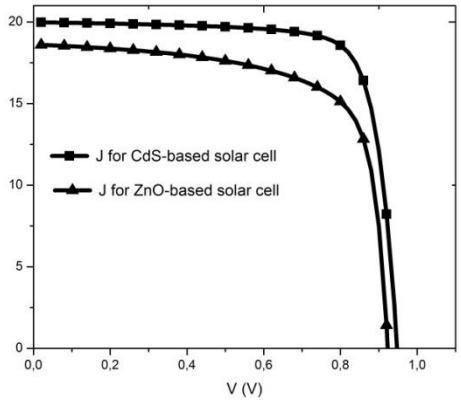


Fig. 2 – J-V characteristic of the CdS-based structure and the ZnO-based structure using a layer thickness of 200 nm

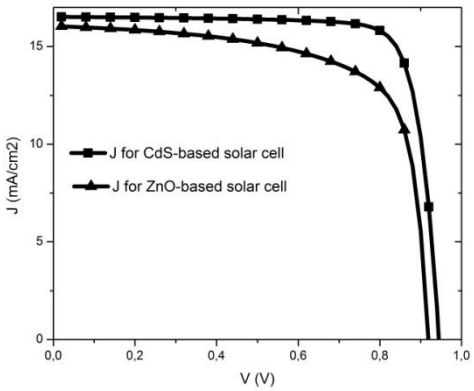


Fig. 3 – J-V characteristic of the CdS based structure and the ZnO-based structure using a layer thickness of 400 nm

Table 2 – Electrical parameters of both structures

Material	Thick-ness, nm	J_{sc}, mA/cm^2	V_{oc}, V	FF, %	PCE, %
CdS	200	19.98	0.95	78.66	14.88
ZnO	200	18.59	0.92	70.48	12.09
CdS	400	16.52	0.94	81.63	12.73
ZnO	400	16.03	0.92	70.01	10.31

solar cell also provides better performances in terms of Jsc, FF and PCE in comparison with that based on ZnO.

The different electrical parameters of both designs with various thickness layers of CdS and ZnO are summarized in Table 2. It is clearly seen that electrical parameters of CdS-based structure are better than of ZnO-based structure for both cases of selected thicknesses. Therefore, the performances with CdS thickness of 200 nm are improved compared to CdS thickness of 400 nm.

4. CONCLUSIONS

In this paper, the effect of different layer materials of ETL for perovskite-solar cells is studied and presented. Simulation results demonstrate that the CdS material is better than the ZnO, when used as ETL in a perovskite-solar cell. Therefore, it is clearly found that CdS-based structure exhibits better electrical parameters compared to ZnO-based structure for both layer thicknesses used in this study. In addition, the enhanced performances of CdS-based solar cell are obtained with CdS thickness of 200 nm. Hence, the obtained results provide guidance for design of perovskite-solar cells for high PCE.

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Вплив транспортуючого шару електронів на ефективність перетворення енергії сонячних елементів на основі перовскіту: порівняльне дослідження

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Фотоелектрична енергія широко застосовується, особливо у виробництві сонячних елементів. Технологія сонячних елементів на основі перовскіту знаходиться в центрі уваги з боку фотоелектричних технологій завдяки високій ефективності перетворення енергії та низькій вартості обробки порівняно з іншими методами. Першим кроком у виробництві сонячних батарей є моделювання, яке дає уявлення про вплив різних параметрів на ефективне перетворення енергії з меншими витратами. Існує різноманітне програмне забезпечення, що використовується у моделюванні сонячних батарей, таке як GPVDM, SCAPS і Silvaco Atlas. Тому в сонячних елементах на основі перовскіту використовують кілька структур, таких як n-i-p, p-i-n, n-p-p і p-p-n. Наше дослідження орієнтоване на структуру n-i-p. У роботі ми використовували програмне забезпечення Silvaco Atlas, оскільки воно містить безліч фізичних і рекомбінаційних моделей, заснованих на розв'язанні рівняння Пуассона з частинними похідними і безперервності носіїв. Крім того, нами представлено чисельне моделювання планарних структур сонячних елементів гетеропереходу, який має наступні шари: шар переносу дірок / шар поглинання перовскіту / транспортуючий шар електронів. Однак використовуються різні матеріали шарів, а саме сульфід кадмію (CdS) і оксид цинку (ZnO), для вивчення поведінки сонячних елементів на основі перовскіту ($CH_3NH_3PbI_3$). Останній матеріал, використаний у моделюванні даної роботи, належить до органічного / неорганічного типу. Отримані результати показують, що структура сонячних елементів на основі CdS демонструє кращу продуктивність з точки зору ефективності перетворення енергії порівняно з такою ж структурою на основі ZnO при використанні однакової товщини шару.

Ключові слова: Вольт-амперні характеристики, Перовскіт, Ефективність перетворення енергії, Сонячна батарея, ZnO, CdS.