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 efficiency 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\(_3\)NH\(_2\)Pbl\(_3\)). 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 hetero-junction 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\(_3\)NH\(_2\)PbI\(_3\), 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...
Table 1 – Simulation parameters used for each layer

| Material Property | CdS | ZnO | Spiro-OMeTAD | CH₃NH₃PbI₃ |
|-------------------|-----|-----|--------------|------------|
| Thickness (nm)    | 200 | 200 | 100          | 400        |
| E₀, eV            | 2.4 | 3.3 | 3            | 1.55       |
| X, eV             | 4.18| 4   | 2.45         | 3.9        |
| Nₑ, cm⁻³          | 2.2.10¹⁸| | 2.2.10¹⁸| | 2.2.10¹⁸ |
| Nᵥ, cm⁻³          | 1.9.10¹⁵|1.9.10¹⁵|1.9.10¹⁵|1.9.10¹⁵|
| Nₙ, cm⁻³          | 1.10¹⁸|1.10¹⁸| –            | 2.10¹⁸     |
| Nᵥ, cm⁻³          | –    | –   | 1.10¹⁸       | –          |
| εₑ                | 10   | 9   | 3            | 18         |
| µₑ, cm²V⁻¹s⁻¹     | 100  | 100 | 2.10⁴       | 3          |
| µᵥ, cm²V⁻¹s⁻¹     | 25   | 25  | 2.10⁴       | 17         |

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  | Thickness, nm | Jsc, mA/cm² | Voc, 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 those 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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REFERENCES

1. A. Kojima, K. Teshima, Y. Shirai, T. Miyasaka, J. Amer. Chem. Society 131 No 17, 6050 (2009).
2. M. Saliba, T. Matsui, K. Domanski, J. Y. Seo, A. Uromadisingu, S. M. Zakeeruddin, J. P. Correa-Baena, W.R. Tress, A. Abate, A. Hagfeldt and M. Gratzel, Science 354 No 6309, 206 (2016).
3. A. Hima, A. Khechekhouche, I. Kemerechou, N. Lakhdar, B. Benhaoua, F. Rogti, I. Telli, A. Saadoun, Int. J. Energetica 3 No 1, 37 (2018).
4. G. A. Casas, M. A. Cappelletti, A. P. Cedola, B. M. Soucas, E. L. Peltzer y Blancà, Superlat. Microstr. 107 No 136-143 (2017).
5. Y. Liu, Y. Sun and A. Rockett, Sol. Energ. Mat. Sol. Cells 98, 124 (2012).
6. M. Mehrabian, S. Dalir and H. Shokrvash, Optik 127 No 20, 10096 (2016).
7. I. Silvaco, Atlas user’s manual (2013).
8. W.-C. W. Hui-Jing Du, Yi-Fan Gu, Chin. Phys. B 26 No 2, 28803 (2017).
9. S. Bansal and P. Aryal, 2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC), 0747-0750 IEEE (2016).
10. S. Almosni, L. Cojocaru, D. Li, S. Uchida, T. Kubo and H. Segawa, Energy Technol. 5 No 10, 1767 (2017).