Alternative Energy Sources, Materials & Technologies (AESMT'20)

Role of the absorber layer in the thin film solar cells with perovskites

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Introduction

In recent years, the Perovskite solar cells have been developed dramatically, due to their low-cost and simple fabrication, especially the hybrid ones, containing organic and inorganic constituents, such as $CH_3NH_3PbI_3$ for example [1]. For ten years the materials science technology has allowed 6 times increase in the power conversion efficiency. In 2018 has been reported about 23.3% produced from devices with size of 1 cm^2 [2]. Nowadays, the hybrid perovskite solar cells with their electrical and optical parameters are competitive to the well-established thin film technology for photoelectric convertors based on cadmium telluride CdTe and copper indium gallium selenide (CIGS). A lot of researches have been conducted to achieve this goal, related to thin film quality in 2018 it seems that the favorable behavior of these modules is due to the broad absorption of the solar spectrum, because of the presence of lead as a core chemical element in the perovskite material. The new trends worldwide for implementation of environmental friendly materials and technologies, excluding the lead-containing substances have made further development of these solar cells senseless. The focus has been shifted on the synthesis of new, eco-friendly perovskites, in which the lead is replaced by Br, Sb, or I [3]. Because their natural bandgap is narrower in comparison with those of the hybrid solar cells (mostly in the range 450-550 nm), the conversion efficiency has dropped to 2 %. Some of the important results in the field have been published by Jiang et al. in 2018, who has reported greater efficiency when Cl is incorporated as a light absorber in a complex perovskite $(CH_3NH_3)3Sb_2Cl_xI_{9-x}$ [4]. At present, still many challenges must be overcome before the commercialization of the perovskite solar cells, which hinder their broad application. Appropriate materials and designs still have to be proposed to solve the problem with the low power conversion efficiency, toxicity of some solvents and great sensitivity to radiation out of the visible range make their long-term stability under question.

AIM: In this study, we propose to extend the light conversion ability of a solar cell containing perovskite material by inserting sulphide based absorbing films. For this purpose, absorber layers with different thicknesses were introduced and the basic characteristics of the cell were obtained by simulation. For the optimum film thickness, a solar cell was prepared and experimentally tested. The internal quantum efficiency was plotted for both cells.

Experiment

For the device simulation and fabrication device area of 3 cm^2 was used without surface texturing and with front surface barrier of 0.3 eV. Assumption of the front reflection with the used filter 5 % was made. The contacts were set on the top and at 100 µm depth, respectively. Light source with white spectrum and power of 100 W/cm^2 was set.

Results

For the simulation the following assumptions were made (i) the majority carriers' concentration is fixed at its equilibrium value and (ii) the minority-carriers' concentration is related to the minority-carrier current density by a surface recombination velocity.

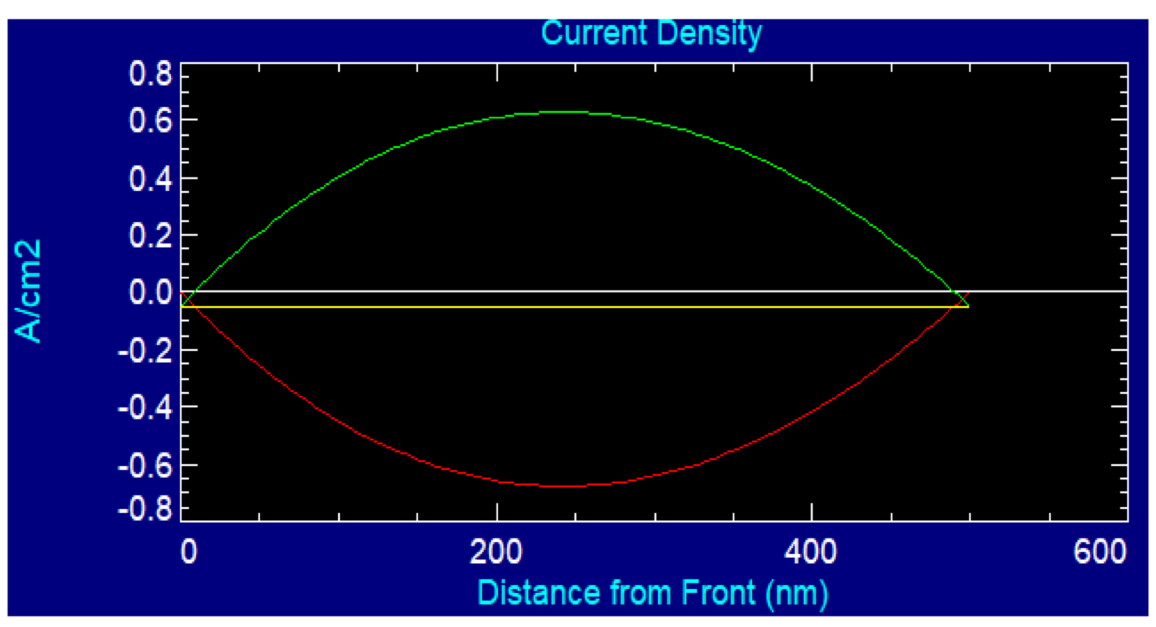

Fig.1. Dependence of the current density on the thickness of the absorbing layer.

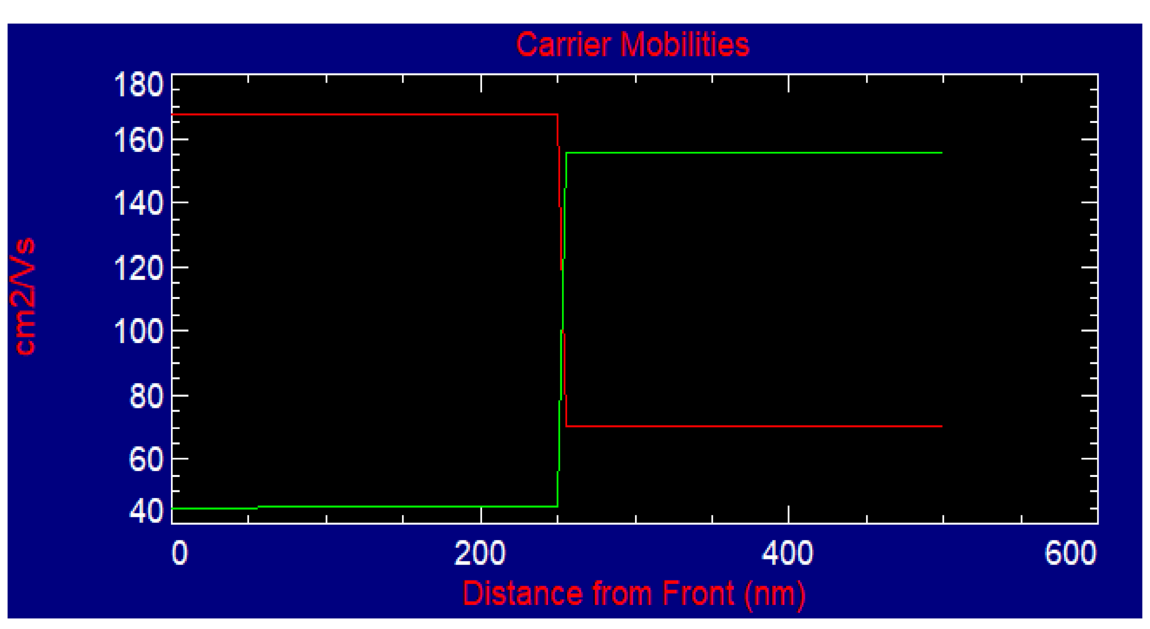

Fig.2. Dependence of the charge carriers' mobility on the thickness of the absorbing layer.

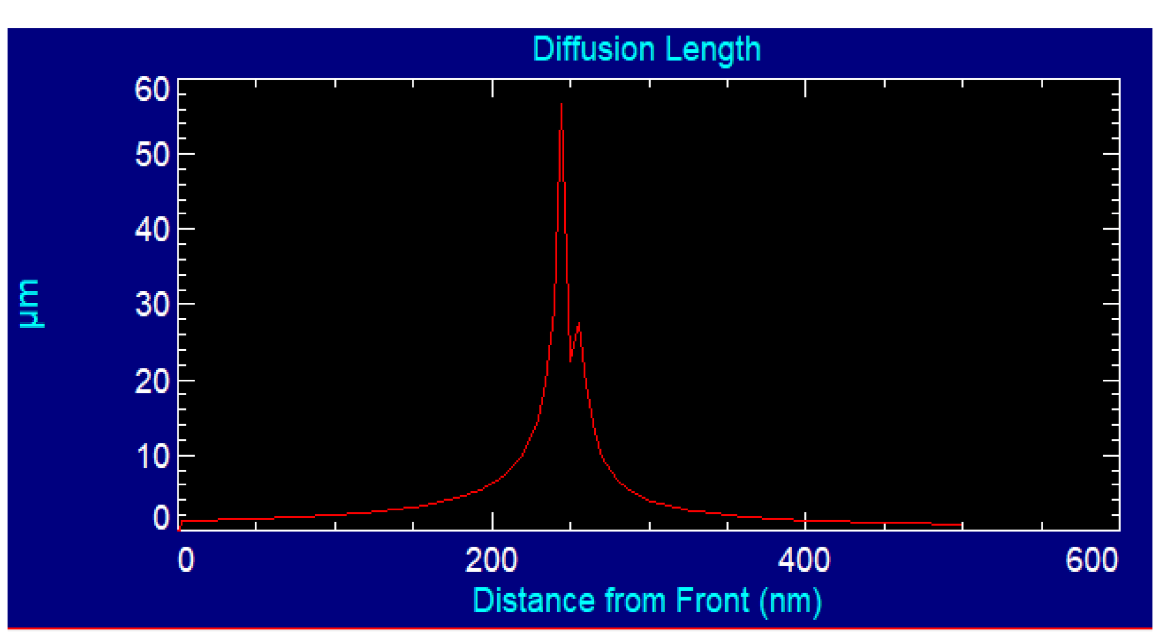

Fig.3. Dependence of the diffusion length on the thickness of the absorbing layer.

As can be seen from the fig. 1, maximum short circuit current density of 600 mA/cm^2 was achieved for thickness of the absorbing layer of 300 nm (green line if the absorber is considered as a hole transporting layer). For comparison, without absorber, the current density is ~ 50 mA/cm^2. The difference in the charge carriers mobility is negligible for 300 nm (fig. 2), showing that the layer can be used not only as a front absorbed, but also as a back buffer for balancing the charges path. Maximum diffusion length is also achieved at ~ 300 nm (fig. 3). In the real structure, 10 times enhancement of the efficiency cannot be expected due to the presence of absorbing layer, because if the films defects, irregularities and interface imperfections, causing electrical and optical losses. The real change of the efficiency is shown in fig. 4.

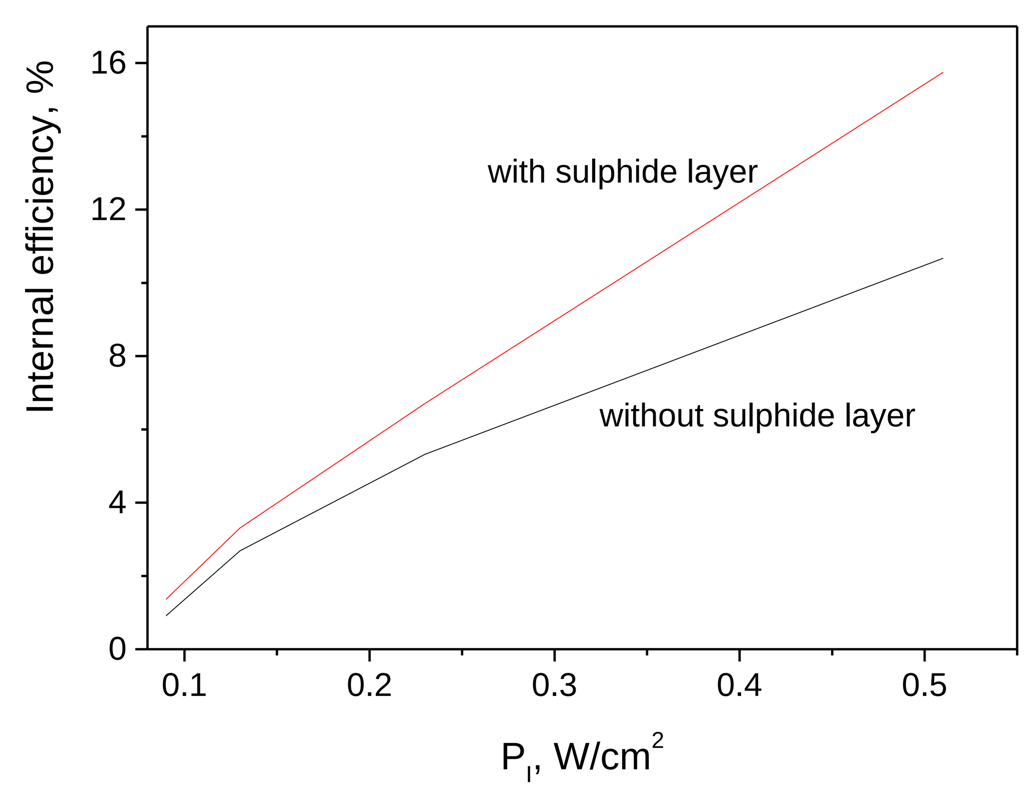

Fig.4. Comparison between the efficiency of the solar cell without and with buffer absorbing layer.

Conclusions

300 nm is the optimal thickness for the sulphide absorbing layer. This layer is suitable for interfacing the perovskite cells as an anode, or as a cathode.

References

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ACKNOWLEDGEMENTS
This work has been supported by the joint project for bilateral cooperation in science and technology Bulgaria - India – КП06-India-6.