DEVELOPMENT OF A METHOD FOR PRODUCING SOLAR CELLS BASED ON IODINE PEROVSKITE WITH n-i-p-STRUCTURE ON SnO_2

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Abstract

The article tested methods for producing solar cells based on iodide perovskite with an n-i-p structure on SnO_2 and measured the current-voltage characteristic (CVC) of these cells. The theoretical and experimental studies carried out are important for the creation of efficient 3rd generation solar energy converters based on perovskites.

Keywords: perovskite, solar cells, absorber, tin oxide, current-voltage characteristic.

Introduction

It is known that among the most important tasks in the development of modern alternative energy, the search and study of materials that are promising from the point of view of their use in the developed efficient solar energy converters is especially relevant. Hybrid perovskite materials, in particular $CH_3NH_3PbX_3$ (X = Cl, Br, I), have the advantages of an ideal absorber of solar radiation with an appropriate and adjustable band gap, high absorption coefficient and long diffusion length of photoexcited charge carriers [1–4]. Using thin-film electronics technologies, perovskite solar cells have achieved very high energy conversion efficiency [5-6]. Significant efforts have been devoted to studying the origins of the unique properties of perovskite materials, as well as developing advanced technologies for manufacturing high-performance devices.

One of the ways to increase the conversion performance of cells is to select materials for electronic and hole-conducting layers. Tin dioxide SnO_2 is currently considered as one of the most promising electronically conductive materials [7-9]. We have conducted research into the possibilities of creating efficient perovskite converters with SnO_2 as an electronically conductive layer. As the basis for creating cells, a technique similar to that presented in [9] was chosen, but during the synthesis of SnO_2 it combines thermal heating with heating during UV treatment, as well as the addition of an antisolvent (toluene) during the formation of a perovskite absorber.

Synthesis of layers SnO_2.

The synthesis of SnO_2 sol-gel was carried out according to the method [9-11]. $SnCl_2*2H_2O$ was dissolved in ethanol to form a solution with a concentration of 0.1 M, and the precursor solution was spinned on an ITO/glass substrate at 3000 rpm at room conditions. The mechanism of SnO2 sol-gel formation during the synthesis process can be expressed as follows [9,12]:

$$SnCl_2*2H_2O + 2C_2H_5OH \rightarrow Sn(OH)_2 + 2C_2H_5Cl \quad (1)$$

$$Sn(OH)_2 \rightarrow SnO + H_2O \quad (2)$$

$$2SnO + O_2 \rightarrow 2SnO_2 \quad (3)$$

The films obtained by spinning were first thermally annealed by heating at 180°C for 60 min. Next, the SnO_2 films were treated with UV radiation from a mercury lamp for 15 minutes at a radiation density of the order of 0.5 W/cm^2. The lamp used for UV/ozone treatment can produce UV radiation at two wavelengths of 253.7 nm and 184.9 nm with corresponding photon energies of 472 and 647 kJ/mol. Both of these photon energies are higher than the Sn-Cl and O-H binding energies of 350 and 459 kJ/mol, respectively [13]. They are also larger than the binding energies of C-C (346 kJ/mol), C-H (411 kJ/mol) and C-O (358 kJ/mol) [13]. Therefore, ultraviolet radiation can easily break these chemical bonds so that the reaction continues. The 184.9nm wavelength of light can convert oxygen molecules O_2 into active ozone molecules O_3, which promotes the formation of SnO_2 and the decomposition and oxidation of organic components. The final by-product will be released as carbon dioxide CO_2 and water vapor H_2O. In addition, the UV lamp itself causes heating of the samples, and the temperature of the samples during UV treatment is approximately 70°C.

Manufacturing of cells.

The formation of cells, with the exception of coating the substrates with SnO_2, was carried out in a glove box filled with N2, containing no more than a few ppm of water vapor and oxygen.

A $CH_3NH_3PbI_3$ perovskite tape was formed on the prepared n-type SnO_2 layer. The perovskite absorber was synthesized by a one-step method with a PbI_2:MAI=1:1 ratio of 1:1. As in p-i-n cells with PEDOT:PSS, the pre-prepared solution was heated at 60-700C for 8 hours. The solution was applied by spinning for 40 s at 3000 rpm with 100 μl of toluene added dropwise at the 7th second. Next, the resulting perovskite layer was annealed for 10 minutes at 1000C.

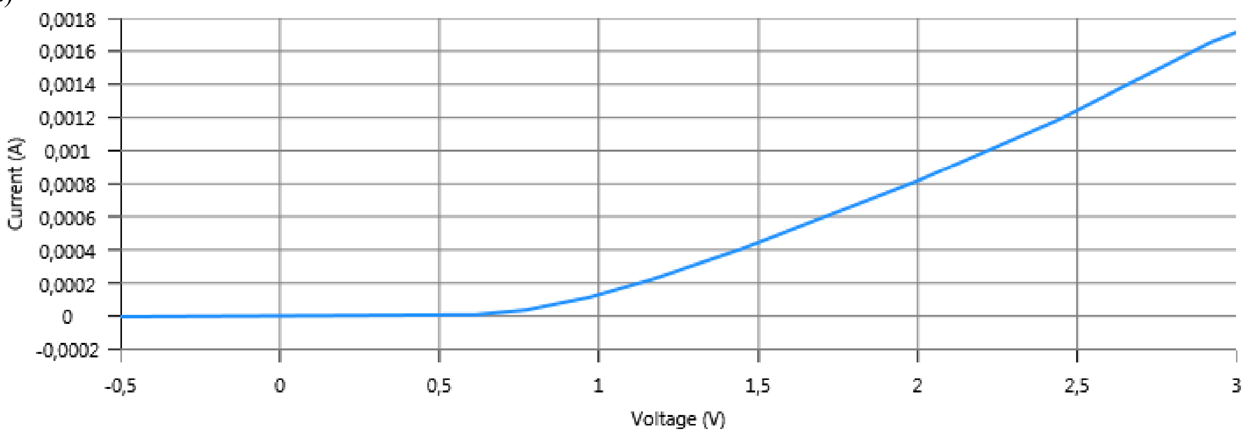
We used polythiophene polymer (P3HT) as a material with hole conductivity. The P3HT layer was formed by spinning for 12 s at a speed of 600 rpm and then for 40 s at a speed of 2000 rpm. The resulting layer was then annealed at 1000C for 10 minutes.

The top conductive layer was formed by depositing nanotube material onto P3HT, manufactured at the Institute of Nanotechnology at the University of Texas at Dallas (USA).

CVC study of solar cells.

A study of the current-voltage characteristics of the obtained solar cells based on iodide perovskite with an n-i-p structure on SnO_2 shows that the CVC data have a form characteristic of semiconductor structures with a p-n junction (Fig. 1a). When illuminated with a standard power of 1 Sun, effective generation of photocarriers and photo-emf is observed (Fig. 1b). Under these conditions, in the indicated cells, the short-circuit current density has a value of up to Jsc = 0.5 mA*cm^{-2}, and the open-circuit voltage is V_{oc}=0,5-0,7 V. These values of the cell parameters are close to those described in the literature (see, for example, [9]) and indicate the promise of further research on the creation of solar converters based on iodide perovskite with an n-i-p structure with SnO_2 as a layer with electronic conductivity, including by varying the conditions of thermal annealing and introducing an antisolvent into the forming absorber.

a)



б)

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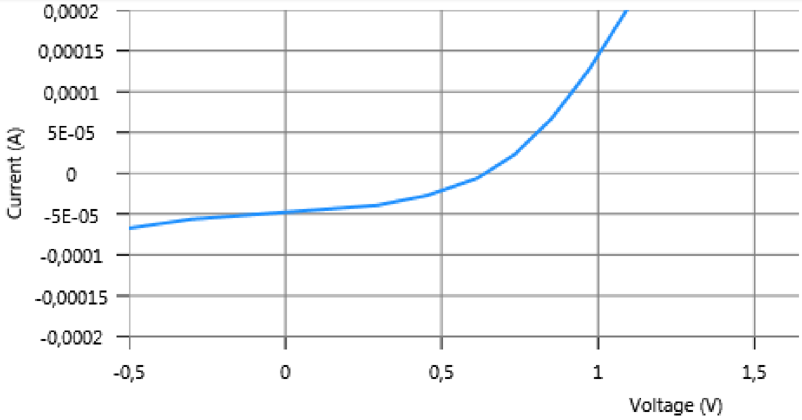

Fig. 1. Typical current-voltage characteristic (CVC) of a solar cell with an n-i-p structure based on iodide perovskite $CH_3NH_3PbI_3$ with SnO_2 as an electronically conducting layer: a) dark CVC; b) CVC under lighting (fragment).

Conclusion

As a result of systematic theoretical and experimental studies of energy conversion processes and transfer phenomena in solar cell materials based on organic-inorganic perovskites, new experimental facts were established and the basic physical laws characterizing these processes were formulated [14].

It is shown that the cell parameters are close to those described in the literature and indicate the promise of further research on the creation of solar converters based on iodide perovskite with an n-i-p structure with SnO2 as a layer with electronic conductivity, including by varying the conditions of thermal annealing and introducing an antisolvent into the emerging absorber.

The totality of the results obtained allows us to draw a conclusion about the feasibility, importance and prospects of continuing experimental and theoretical work in this area.

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