EFFECT OF THERMAL TREATMENT ON THE ELECTRICAL AND PHOTOVOLTAIC CHARACTERISTICS OF METHYLAMMONIUM LEAD TRIIODIDE PEROVSKITE FILMS

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I. INTRODUCTION

Recently, many new technologies for solar cells have appeared that make solar energy even cheaper. One promising direction is the use of photovoltaic converters based on organometallic perovskites, the use of which promises to solve the whole range of complex problems, combining, ultimately, low manufacturing cost and high conversion efficiency [1,2].

The perovskite semiconductor triiodide methylammonium lead ($CH_3NH_3PbI_3$) has a high carrier mobility and a long carrier lifetime. It allows light to generate electrons and holes that can move far enough to reach electrodes and generate current in an external circuit, rather than participate in recombination processes with energy loss in the form of heat. The energy zones of the perovskite photoconversion structure ensure the separation of charge carriers generated by absorption of photons (Figure 1).

In the process of creating solar cells based on organometallic perovskite, it is important to choose such modes of perovskite layer formation, which ensure obtaining the minimum electrical resistance and a high level of photocurrent. Analysis of the literature showed that the formation of the surface morphology of perovskite films with a uniform grain structure meets such requirements in the first place.

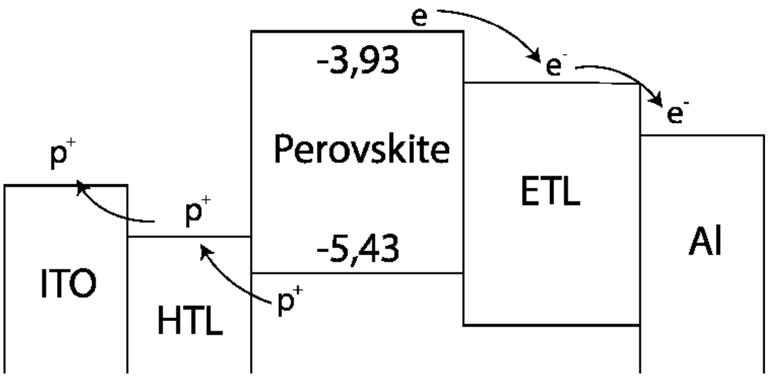

Figure 1. Zone diagram of a perovskite photoconverter structure

The effect of annealing temperature in the range from 80 to 150 °C on the surface morphology and photoelectrical characteristics of perovskite films, both after annealing and after solvent application to the perovskite film, was investigated. N-methylpyrrolidone was used as the solvent for application to the perovskite film.

II. RESULTS AND DISCUSSION

According to the results of optical investigations the crystal sizes after the application of the film of organometallic perovskites at 80, 90, 100 and 110 °C were determined and their values were 8.2x9.6, 9.3x11.0, 15.1x17.8 and 11.7x13.4 μm respectively. It was found that after treatment with solvent at temperature the film becomes more uniform and pronounced round-shaped germs can be seen on the surface. The dimensions of such germs were 10.3x12.3, 15.9x16.7 and 16.4x17.8 μm after solvent treatment at 80, 90 and 100 °C, respectively. The results of the measurements show that the germs sizes are larger than the crystals of organometallic perovskites. This indicates that the resistivity of such films will be lower than before the solvent treatment. This effect can be explained by a decrease in the number of interfaces that act as defects, which leads to a decrease in resistivity. It was found that the temperature treatment at 110 °C formed an almost completely uniform surface morphology of the perovskite film without germs formation. Organometallic perovskite film with such morphology makes it possible to create the most efficient solar cells with a maximum photocurrent of 270 μA and higher.

Samples with higher temperature treatment were also investigated: 120, 130, 140 and 150 °C. According to the results of the studies, the crystal sizes after applying the film of organometallic perovskites at 120, 130, 140 and 150 °C were determined, which were 32.9x50.7, 31.5x67.0, 29.3x34.3 and 6.9x8.2 μm, respectively. It was found that the size of crystals increased with increasing temperature and only at T = 150 °C crystals significantly decreased in size. This effect was explained by the fact that the thermal influence becomes so large that the atoms become very mobile and, as a result, they cannot form crystals of larger size. After this solvent treatment, even more germs are formed in the film compared to the lower treatment temperature. However, this can have an undesirable effect on the resistance of the films and the final quality of the solar cell. It is shown that solar cells based on such perovskite films are the least efficient and show a photocurrent of 5 to 20 μA.

III. CONCLUSIONS

As a result of studies it was found that the most optimal treatment temperature of perovskite films based on $CH_3NH_3PbI_3$ is 110 °C. Films obtained at this temperature have a uniform morphology and relatively low resistivity.

ACKNOWLEGMENTS

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