Effect Of Nanoparticle Agglomeration In Solar Cell Formation

Azimov J.T.

Associate Professor of the Department of Natural Sciences of the Academy of the Armed Forces of the Republic of Uzbekistan

ABSTRACT

This work allows us to discuss situations as the shape and radius of the ion particles affect the magnitude of surface charges. Also, this work considers the effect of nanoparticle agglomeration on the mechanical properties and durability of solar cells. The technique of ultrasonic dispersion is studied as a means for improving the uniformity of the distribution of nanoparticles in the resulting layer.

Keywords: solar cell, perovskite, nanoparticle agglomeration, surface, ionic bond agglomeration, ultrasonic dispersion.

The development of third-generation solar cells (SC) based on perovskites is currently one of the most rapidly developing areas of alternative energy [1]. Important advantages of perovskite SCs include high photoconversion efficiency (over 20%) and the fact that they can be made from fairly affordable materials and industrial chemicals. In addition, applying perovskite-based photosensitive elements directly to glass (or other materials) is much cheaper than methods for producing other thin-film elements [2]. This makes it possible to establish large-scale serial production that does not require huge expenditures of resources. Perovskites can also be applied to flexible structures such as plastic and fabric, which opens up great opportunities for their application.

To increase the photoconversion efficiency of perovskite SCs, work is currently actively underway to study inorganic hole-conducting materials (HTM (Hole Transport Material)). One of the most promising materials of this type is the p-type semiconductor - NiO. It has good optical transparency, due to the position of its energy levels, eliminates the possibility of electron leakage, and also maintains high quality and sufficient thickness of the perovskite film [3].

When synthesizing NiO films, special attention should be paid to observations during chemical experiments (synthesis). A feature of scientific observation is its focus on collecting the most complete information about the object under study.

Nickel oxide is a crystalline homogeneous powder insoluble in water, depending on the method of production and heat treatment, having a color from light to dark green or black. Nickel oxide is an inorganic binary compound of divalent nickel with oxygen, has weakly basic properties, dissolves in acids, is reduced by hydrogen when heated, and is very thermally stable. NiO occurs in nature as a rare mineral bunsenite, has two crystalline modifications: α-NiO (trigonal syngony) and β-NiO (cubic syngony), density: α-NiO - 6.67 g / cm^3, β-NiO - 7.45 g / cm^3. Melting point 1682° C, decomposition temperature 1230° C. Chemical formula: NiO.

Experimental part.

Synthesis of NiOx nanoparticles:

Ni(NO3)2 6H2O (0.5 mol) was dispersed in 100 ml of deionized water to obtain a dark green solution. The pH of the solution was adjusted to 10 by slowly adding NaOH solution (10 mol L-1). After stirring for 5 min, the colloidal precipitate was washed twice thoroughly with deionized water and dried at 80 °C for 6 h. The resulting green powder was then calcined at 270 °C for 2 h to obtain a dark black powder. The nanoparticles were dispersed in deionized water to the desired concentrations. The obtained nanoparticles had nanometer-scale sizes, and the average sizes of nanoparticles depend on the residence time in the solution - with time, the size of the nanoparticles increases, which is apparently due to agglomeration phenomena. The essence of the technique is to use ultrasonic treatment to disperse the nanoparticles. Ultrasonic waves lead to the destruction of agglomerates and promote the dispersion of nanoparticles.
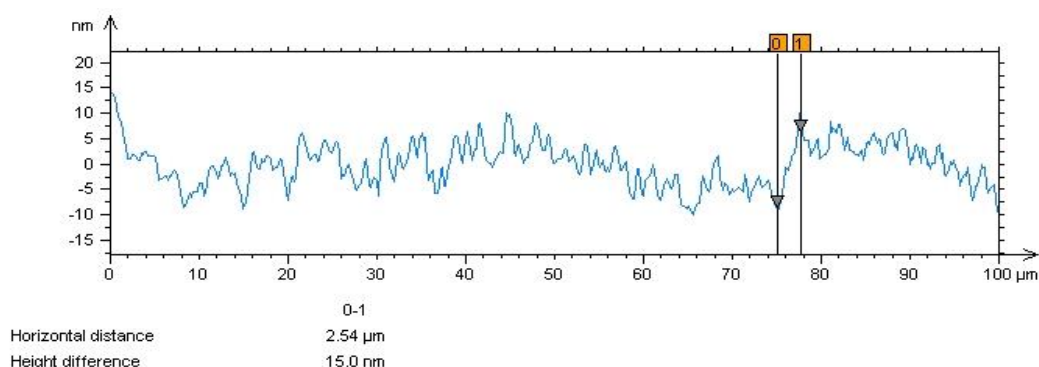
Results obtained.

To vary the parameters of the NiOx conductive layer, we studied the effect of the spinning speed on its thickness at different amounts of the applied solution, and also investigated the morphology of the obtained films. The film thicknesses were determined using the standard technique using atomic force microscopy (AFM). Data on the effect of spinning conditions on the NiOx layer parameters are presented in Table 1. Fig. 1 shows some corresponding measurements of the thicknesses of the obtained NiOx films.
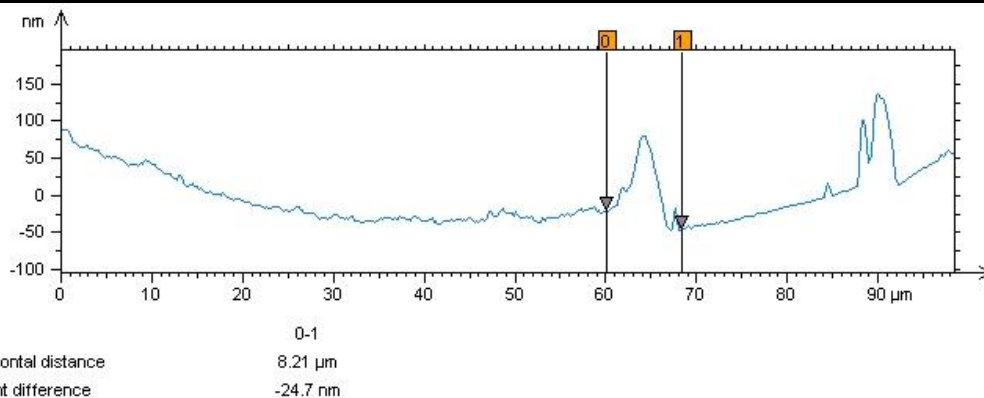
Table 1. Effect of spinning conditions on the parameters of NiOx films.

Volume of solution, µl	Spinning speed, rpm	NiOx layer thickness, nm
25	2000	170
20	2000	125
20	3000	70
20	4000	40
20	5000	37
20	6000	40
15	3500	35
15	4000	25
15	6000	15

a)

0-1	
Horizontal distance	2.54 µm
Height difference	15.0 nm

b)

0-1
Horizontal distance   8.21 μm
Height difference   -24.7 nm

c)

0-1
Horizontal distance   13.6 μm
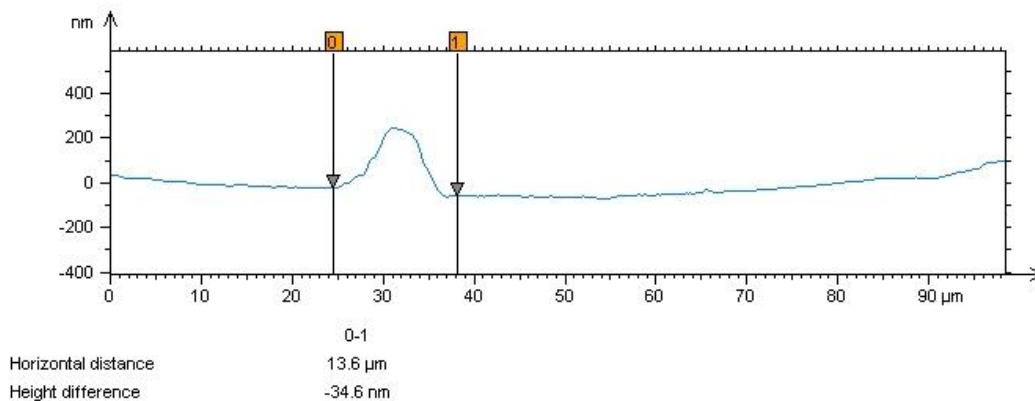Height difference   -34.6 nm

Fig. 1. Measurements of the thickness of NiOx films obtained under different conditions:
a) spinning 15 μl of solution at 6000 rpm; b) spinning 15 μl of solution at 4000 rpm; c) spinning 15 μl of solution at 3500 rpm;

Fig. 2. shows the optical microscope images of the surface of NiOx films obtained under different conditions, and Fig. 3. shows a typical surface of the nickel oxide layer in AFM. As can be seen from Fig. 3, the surface of the nickel oxide film has a developed relief under the above formation conditions, which, according to [4], should lead to an increase in the conversion indicators of perovskite cells when using NiOx as the bottom layer with hole conductivity. In the future, it is planned to create cells with NiOx, as well as study and optimization of their performance characteristics.
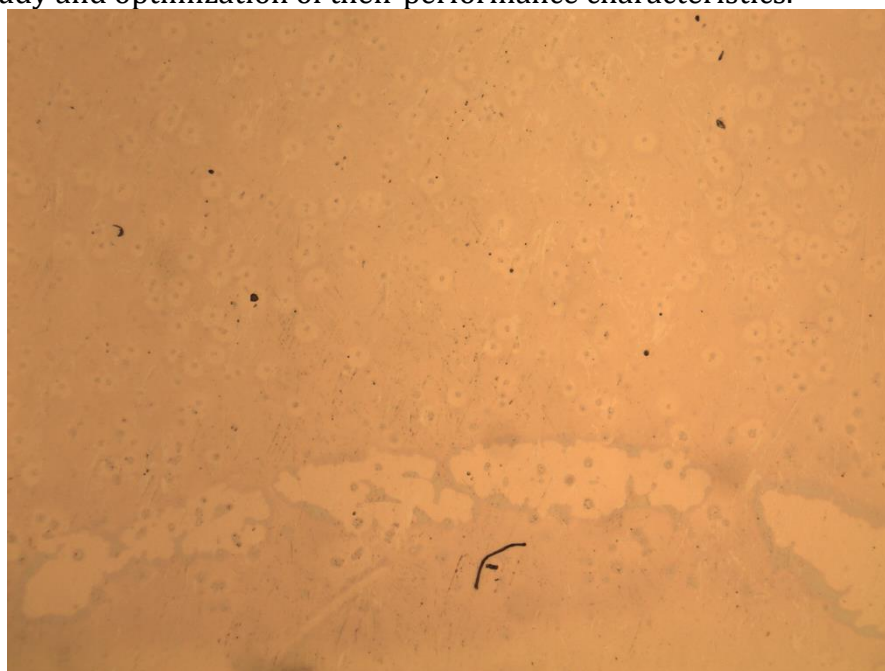
Fig. 2. Optical microscope images of the surface of NiOx films obtained at different spinning speeds: 7000 rpm.
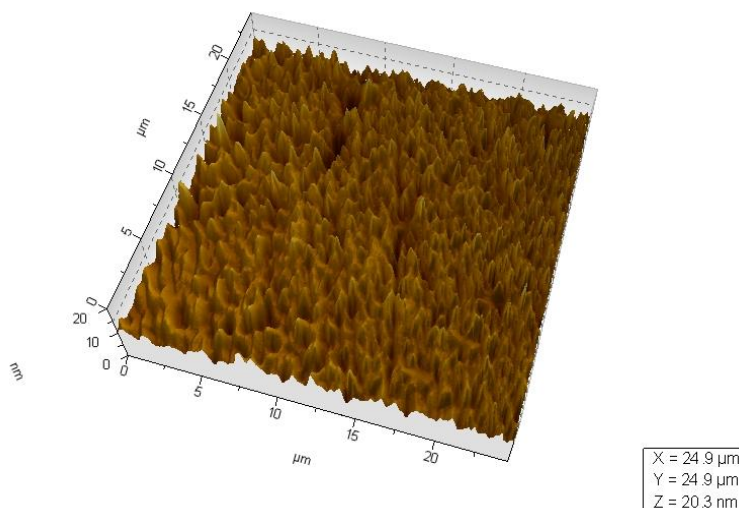

Fig.3. Typical three-dimensional AFM image of the surface of a nickel oxide layer.

Conclusion.

The experiment shows that under certain conditions, agglomeration of particles occurs. This is a harmful phenomenon for the technology of solar cell manufacturing and it must be dealt with. The question arises - how? To deal with agglomeration, it is necessary to understand the nature of this phenomenon. Of the most probable models, it can be assumed that the agglomeration of ionic crystallites is associated with the Coulomb attraction of charges located on the surface of nanoparticles in the form of localized states (Tamm levels). The theory of surface states for ionic crystals is well described by Davison and Lieven (Tamm Surfaces ... Ch. 3, paragraph 10) In the simplest version of the theory, the Modelung model is used, ... that the width of the forbidden zone is associated with the Modelung energy (Coulomb binding energy) in Kittel (Introduction to Solid State Physics). The main result of the Modelung theory as applied to the surface is the following: the band gap is related to the value of the Modelung energy (it is larger in the volume). In the bulk of the crystal, the Modulung energy is greater than on the surface, since the ions on the surface have non-closed bonds, as a result of which the electron gap and the Modulung energy on the surface are less than in the bulk of the crystal (approximately 2 times). Moreover, the Modelung energy on the surface depends on the shape of the surface: in the case of convex inhomogeneities, the Modelung energy is less (and the gap too); in the case of concave surfaces, the Modelung energy is greater (and the gap energy is greater). These ideas allow us to discuss situations in which the shape and radius of the ion particles affect the value of surface charges, as well as their sign. Undoubtedly, the phenomena of agglomeration of ionic crystallites should be associated with Tamm levels, but for a curved surface this phenomenon is more complex.

References

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