Influence of the Composition of Anti-Reflective Coatings on Short-Circuit Current and Efficiency of A Solar Cell Based

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ABSTRACT
The dependence of solar cell (SC) efficiency on the composition of antireflective layers was studied. It is s hown that the results are very similar to the evolution of the current dependence. This is because the diffe rence in open circuit voltage is almost independent of the composition of the antireflection layers. The hig hest short-circuit, and best efficiency, is achieved with the 4
layer Si/TiO2/SiNx/SiO2/MgF2/ antireflective surface (ARP). Obviously, due to this structure of the AOP i n the proposed compositions for the images of the spectrum and wavelength like this, a kind of negative i nterference is achieved, which leads to an effective decrease in the intensity of reflected waves.

Keywords: Nanoparticles, Solar cells, Titanium dioxide, Lanthanum titan ate, Efficiency of solar cells, Anti-reflective coatings, Short circuit current of SE.

INTRODUCTION

The simplest and most effective way to modify the properties of solar cells is to use functional coatings. T hey can increase the efficiency of solar cells without changing their design or changing their production te chnology. Of particular interest is the use of multicoatings that combine the properties of antireflective co atings and allow for extended visibility and increased efficiency of the solar cells. Such coatings can be made from polymer films containing metal nanoparticles. Metallic silver nanoparticles show promi se for use in functional coatings of silicon solar cells because they can generate surface plasmons, which c an produce surface charge density oscillations at the interface and dielectric polymer films. In other word s, it is a functional coating, a polymer film in the distribution of silver nanoparticles, which can combine th e protection function, the antireflective effectof the polyvinyl butyral polymer film and the plasmonic effe ct of silver nanoparticles, which finally improve the properties of the solar cell. In this work, polyvinyl but yral films containing silver nanoparticles were obtained on the surface of solar cells, and the effect of this functional coating on the electrical properties of the solar cell was studied. . The aim of the work [1] is to s tudy the effect of functional coatings based on polyvinyl butyral and silver nanoparticles on the mechanic al properties of silicon solar cells. The work shows the dependences of the external volume of the silicon s olar cell on different concentrations of silver nanoparticles in the polyvinyl butyral film. It has been deter mined that the maximum values of the energy of the external volume of the solar cell (22. 3% more than t hat of a solar cell without a functional coating) in the spectral range 5401040 nm recorded at a concentrat ion of silver nanoparticles in the film-forming solutionof 7 mmol/l

Titanium dioxide (TiO2) is one of the most promising materials among transparent oxides. TiO2 thin films are widely used in various photovoltaic devices due to their high sensitivity in the visible wavelength regi on and their electrical properties that vary depending on the process conditions. There is great interest in studying the electrical and optical properties of pure and doped titanium dioxide thin films due totheir p otential use in highly efficient thin
film solar cells andinformation measurement devices. To produce TiO2 thin films, several technical metho ds are used, including reactive magnetron sputtering, electron beam evaporation, vapor deposition, sputt ering followed by pyrolysis and thermal annealing [1]. In this work, the technical parameters of magnetro n sputtering were studied for the optical properties of TiO2 thin films produced by magnetron sputtering [2]. In order to determine the parameters of the optical properties of the studied thin films, the envelope method was used.

The envelope method was developed to analyze the cross section and critical signals, due to the interfere nce properties in the films thin, to determine the thickness of the film, the refractive index, the coefficient d absorption and loss [3].

In [4]. One of the main problems is considered to be the effective use of the light flux on the front surface of silicon solar cells, determining the effective absorption conditions in the emitter and the base parts of t he structure by analyzing the return, rotation and transition of the moon. in the area of
two media using the phenomenon of polarization based on the theory of classical optics. Today, a lot of sci entific research is being conducted worldwide aiming to increase the photoelectric efficiency in silicon-based structures, in particular: increasing the surface efficiency of photoelectric processes to compensate for the reduction of light flux in pn junction structures made on silicon. The surface and its substrate, incl uding the surface level and concentration of photoreceptors, determine the conditions; front-
end and study techniques for efficient light absorption in silicon by fabricating single and multilayer optic alcoatings with textured layers on the back surface. One of the most important tasks is to study the metho ds and design solutions for increasing the photoelectric power by making the front layer of the p-
n junction [2-4];.
The work [5] shows the results obtained by magnetron sputtering followed by thermal and photon treat ment of synthesized films containing complex oxide components on titanium and lanthanum: lanthanum t itanate $La_2(TiO_3)_3$ of orthorhombic modification and complex oxide La_2TiO_5 of orthorhombic modificat ion. Comparing the results obtained from scanning electron microscopy and absorption spectroscopy, it w as determined that after the thermal treatment of the $La/TiO_2/Si$
heterostructure, a twolayer film structure was obtained. , which contains a layer of titanium dioxide and l anthanum oxide, which has high transmittances between 350 and 900 nm, which explains the high transp arency (~95%) of the double-
layer film studied. A different trend is observed for the film subjected to photon burst treatment; Its emiss ion in the cutoff range of 350 to 900 nm is lower than that of bilayer films after thermal annealing. As a re sult of processing
shots, a complex oxide film was created, the surface characteristics of which are different from those of th e original films of lanthanum and titanium oxides. According to Xray diffraction data, the main component of the film is lanthanum titanate $La_2(TiO_3)_3$. The analysis of side absorption showed that the energy val ues
of direct transitions for the sample after photon pulse treatment are E_{gd1} = 3.70 and E_{gd2} = 3.06 eV, whic h may be due to the contribution of La2 to the insert brackt. $TiO_3)_3$ and La_2TiO_5 phases, because these va lues differ from the direct transition energy for titanium dioxide E_{gd} = 3.47 eV [6]. The mechanism of for mation of complex oxide phases on titanium and lanthanum of the structure $La_2(TiO_3)_3$ and La_2TiO_5 is based on the high interaction of two oxides: TiO_2 and La_2O_3, i performed under the control of pulsed pho ton treatment.
In work [7]. As a result of the research, a solution was obtained to the inverse problem of spectral ellipso metry for a series of samples of inhomogeneous titania films deposited by RF magnetron sputtering on sil icon substrates; the evolution of the dispersion dependences of the refractive index $n(\lambda)$ of these films in t he visible region of the spectrum and the relationship between the $n(\lambda)$ spectrum and the film production methods; The structure of the studied films determined in
can be best described by a fivelayer model of two layers. The results of the study can be used to adjust the methods for the deposition of titanium oxide films on silicon devices by RF magnetron sputtering and the required parameters. Studies were carried out in the visible range of the optical properties of titanium ox ide films and their dependence on film formation methods by RF magnetron sputtering. A comparative an alysis of thecalculated index spectra revealed that the evolution of the scattering curves is influenced by t he substrate temperature. An increase in the temperature of the substrate increases the reflectivity of the film. Another factor influencing the optical properties of the titanium oxide films was found to be the com position of the air medium in which the target is blown. An increase in the percentage of argon in the gas mixture results in a decrease in the refractive index
of the film. The location of the neutral transition layer between the silicon substrate and the titanium oxid e film has been establishedTitanium dioxide (TiO_2) is one of the best among transparent oxides. TiO_2 thin films are widely used in various photovoltaic devices due to their high sensitivity in the visible wavelengt h region and their electrical properties that vary depending on the operating conditions. There is great int erest in studying the electrical and optical properties of pure and doped titanium dioxide thin films due to their potential use in highly efficient thin-
film solar cells andinformation measurement devices. To produce TiO_2 thin films, several technical metho ds are used, including reactive magnetron sputtering, electron beam evaporation, vapor deposition, sputt ering followed by pyrolysis and thermal annealing [8-
9]. In this work, the technical parameters of magnetron sputtering were studied for the optical properties of TiO_2 thin films produced by magnetron sputtering [10]. To determine the optical properties of the thin films studied in the envelope method was used. The envelope method was developed to analyze the cross

talk and critical signals, due to interference phenomena in thin films, to determine the thickness of the fil m, the refractive index, the coefficient d absorption and loss .

Experimental method

To obtain highly efficient solar cells (SCs) it is very
It is important to reduce the reflection of light images on the front screen and the participation of many i mages in the internal electronic photo effect. According to the laws of optics, reducing the reflection on th e front surface can be achieved mainly in two ways: by using flat antireflective coatings (ARC) from dielec tric films or by seeding the surface. AOPs can be single or multilayered. AOPs are several tens of nanomet ers thick. Because these thicknesses should be of the same order as the length of the incident wave. Under these conditions, the light entering the AOP is reflected from the interface, and after multiple reflections f rom the glass-
AOP interface and the AOPair, negative interference occurs. between reflected light beams. As a result, the intensity of light reflected by the material decreases.
However, negative interference can only occur if the correct AOPmaterial and its thickness are selected.

Experimental results

In this work, we model the dependence of the main parameters of Si-based solar cells on the composition of anti-reflection coatings. When modeling, the following layers were considered: Si / TiO2 (1 layer), Si / TiO2 / SiNx (2 layers), Si / TiO2 / SiNx / SiO2 / (3 layers), Si / TiO2 / SiNx / SiO2 / MgF2 / (4 layers). To simulate the solar photon flux, the AM1.5d solar spectrum model was used. In this spectrum, the luminous flux power is 900 W/m2. 2D modeling is carried out using the commercial program TCAD Sentaurus. When calculating the AOP reflectance using the program, the transfer matrices method was used. The structure of the simulated SC is shown in Fig. 1, and the main parameters of the materials used are shown in Table 1. The results of modeling the current-voltage characteristics of the SC for various AOP compositions are shown in Fig. 2. The dependence of the short circuit current (Figure 2) and efficiency (Figure 3) of the SC on the thickness was determined layers of MgF2 and TiO2.

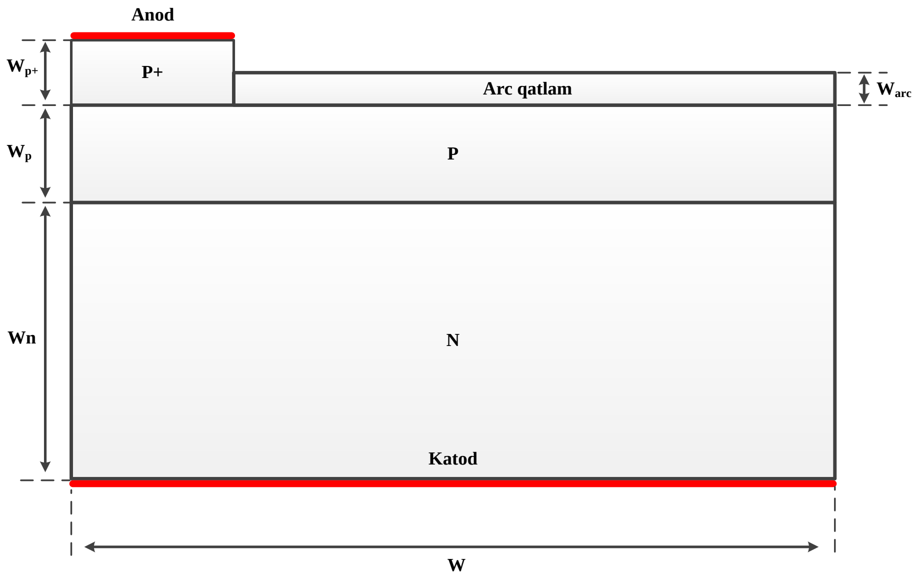

Fig.1 Structure of a simulated solar cell

Table 1. Parameters of materials used

Materialturi	c-Si	SiO_2	SiNx	TiO_2	MgF_2	ZnO	a-Si
Sindirish koʻrsatkichi (priλ=585 nm)	3,98	1,46	1,91	2,61	1,38	2,00	4,3
Yutishkoeffitsiyenti, 1/sm, (priλ = 585 nm)	6460	0	0	0	820,8	0	126690

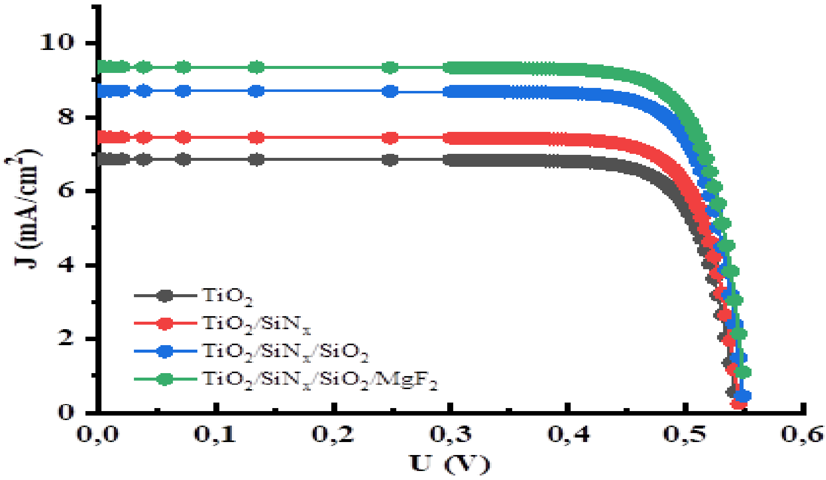

Fig.2. Current-voltage characteristics of a solar cell with different compositions of anti-reflection coating. From the current-voltage characteristics, the dependence of the short-circuit current and the efficiency of the solar cell was determined for various AOP compositions (Table 2). The table also shows the thicknesses of the various layers in the AOP.

Table 2. Efficiency, short circuit current of SCs for different AOP compositions

№	Number of Struktura	anti-reflective coatings	Efficiency (%)	Efficiency (%)	Jsc (mA/cm^2)
1	1 слой АОП	"Si/TiO_2 / havo"	200 mkm / 100 nm	3.021	6.86
2	2 слой АОП	"Si/TiO_2/SiNx/ havo"	200/75/25	3.3	7.456
3	3 слой АОП	"Si/TiO_2/SiNx/ SiO2/havo"	200/50/25/25	3.888	8.712
4	4 слой АОП	"Si/TiO_2/ SiNx / SiO2/MgF_2 / havo"	200/25/ 25 / 25 / 25	4.191	9.355

CONCLUSION

It is clear from the results that the dependence of the strength of the SC on the formation of antireflection layers is almost always dependent on the short-term. This is because the variation of the open circuit voltage is almost independent of the composition of the antireflection layers (Fig. 2). The highest short-term, and best efficiency, is found with 4-layer Si/TiO2/SiNx/SiO2/MgF2/AOP. Obviously, with this structure of the AOP in the proposed compositions for images of such spectrum and wavelength, a negative interference is achieved, which leads to an effective decrease in energy of reflected waves.

REFERENCES

[1] Devitsky, A.A. Kravtsov, I.A. Sysoev News of the Southern Federal University. The influence of the concentration of silver nanoparticles in polyvinyl buteral films on the characteristics of silicon solar cells. Engineering Science Section IV. Nanotechnology and materials science UDC 539.232 DOI 10.23683/2311-3103-2019-5-214-223 O.V.

[2] Surface roughness. https://www.booksite.ru/fulltext/1/001/008/123/723.htm;

[3] S. Zainabidinov, R. Aliyev, M. Muydinova Features of radiation absorption in silicon with surface texture and radiation on the properties of photoelectric converters. // International scientific journal "Alternative energy and ecology" 2019, No. 28-33. pp. 264-266.

[4] S. Zainabidinov, R. Aliev, M. Muydinova, B. Urmanov On the optical efficiency of silicon photoelectric solar energy converters. // Solar technology (Applied solar energy), vol. 50, No. 5, 2018, pp. 3-9;

[5] Yu. V. Gerasimenko, V. A. Logacheva, E. V. Babushkina, A. M. Hoviv Structure and optical properties of titanium dioxide films doped with lanthanum condensed media and interphase boundaries, volume 12, no. 4, p. 348 —354

[6] Gerasimenko Yu. V., Logacheva V. A., Khoviv A. M. // Condensed media and interphase boundaries. 2010. T. 12. No. 2. P. 113-118.] and lanthanum oxide Egd = 5.70 eV [14 Logacheva V.A., Lukin A.N., Tikhonova Yu.A. et al. // Inorganic materials. 2008. T. 44. No. 10. P. 1254—1259

[7] Ivashkevich, I. V. Structural and optical properties of thin films of titanium oxide on semiconductor substrates EB BSU: Natural and Exact Sciences:: Physics No. 010503112021, Dep. at BSU 03.11.2021138-141].

[8] Belyanin A.F. Borisov V.V. The influence of heat treatment on the structure and characteristics of field emission cathodes on layered structures of titanium nitride and carbon nanowalls/

[9] N.I. Sushentsov, S.A. Stepanov, D.E. Shashin //Nanotechnologies: development, application of the 21st century. – 2017. – No. 1(9), – P. 4-11. 2.

[10] N.I. Sushentsov, S.A. Stepanov, D.E. Shashin Development of a technique for the formation of functional coatings based on complex titanium and aluminum nitride and study of their properties // Strengthening technologies and coatings. – 2017. – No. 3(147). – pp. 105-107.

[11] N.I. Sushentsov, S.A. Stepanov, D.E. Shashin. Formation and study of thin-film structures based on copper oxide and zinc oxide, obtained by reactive magnetron sputtering, for use in solar energy // Bulletin of the Volga State Technological University. Radio engineering and infocommunication systems. – 2017. – No. 3(35). – pp. 69-77.