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Films CdS Grown on Porous Si Substrate

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In this work, CdS films were obtained on the technology of chemical surface deposition on porous semiconductor substrates. The morphology and chemical composition of the obtained structures were studied. The possibility of using CdS/porous-Si/*p*-Si heterostructures as photovoltaic solar energy converters is considered.

Key words: Films CdS, Porous substrate Si, Chemical surface deposition, Photoelectric converters.

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1. INTRODUCTION

Recently, new areas of application of porous semiconductors have been proposed. So in our works [1-2] qualitative films of GaN cubic modification were obtained on GaAs porous substrates by a radical-radial epitaxy method. These studies have shown that porous substrates capable of taking on the elastic deformation arising in the heterostructure GaN/porous-GaAs/GaAs. Also, we were shown the possibility of using porous silicon for solar cells with an efficiency of 17.5 % [3] - The structure of ZnO/porous-Si/Si and SnO_2/porous-Si/Si. In work [4] supercapacitors with porous electrodes are presented.

The most common material for manufacturing a solar cell window is CdS. Qualitative epitaxial layers of CdS were obtained on mica [5]. For modern microelectronics, CdS films are needed on silicon.

However, the big difference in the parameters grids wurtzite CdS and cubic Si not provide high-quality epitaxial layers also in obtaining heterostructures CdS/Si at the interface formed sulfide silica, which prevents the coherent combination of arrays Cd and Si, and the third cause of sulfur involved in the growth of CdS, itself reacts with Si [6].

The aim of this work is to develop technology for smooth CdS films by chemical deposition on the surface of porous nanocrystalline silicon substrates, and also considering the use of heterostructures CdS/porous-Si/*p*-Si as photovoltaic solar energy.

2. MATERIALS AND METHODS

2.1 Getting Porous Silicon

Nanoparticle silicon was obtained by electrochemical etching of monocrystalline Si plates with crystallographic orientation of the surface (100) of the *p*-type conductivity with a specific resistance of 6 mOm·sm.

2.2 Getting a CdS Film

The formation of CdS layers was carried out by the method of precipitation in a chemical bath from an aqueous solution.

Films CdS on Si substrate substrates were obtained by chemical surface deposition. For chemical surface deposition of CdS films, a freshly prepared 0,015 M aqueous solution of cadmium chloride $CdCl_2$, a 1,5 M solution of thiourea CH_4N_2S, and a 14,28 M solution of ammonium hydroxide NH_4OH were used. Because of the low solubility of $Na_2S_2O_3$, long heating and mixing is not required for several hours. The pH of the final electrolyte was adjusted to 12.

To create heterojunctions, thin films of CdS were applied to the surface of porous silicon plates (Si). Immediately before the CSD films, the CdS substrate was degreased. Subsequently, the substrate, coated with the solution, was heated to 80 °C for 5 minutes.

2.3 Production of Solar Photocells

As a result of precipitation of CdS films on porous silicon substrates, solar photocells were made. Such a solar cell is a heterostructure *n*-CdS/porous-Si/*p*-Si.

The formation of ohmic contacts to the manufactured heterostructure was carried out by soldering the indium with subsequent shaping by an electrical impulse.

In order to provide contact with the front and rear surfaces of the photocell, the resulting heterojunction was connected to the electrical circuit with the help of a silver conductive paste. As a result of the conducted studies, the characteristics of solar cells were studied and their efficiency determined.

2.4 Research Methods

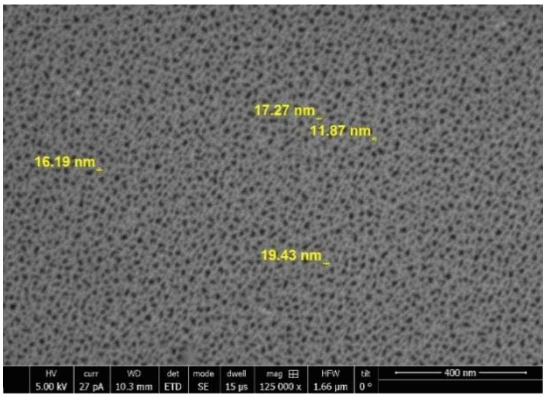
The morphology of the porous silicon surface was investigated using Quanta 3D scanning electron microscope with ultrahigh resolution (×125000). The cross-section of the obtained CdS/porous-Si/*p*-Si structures and the chemical composition of the films obtained was investigated using the scanning electron microscope JSM-6490 with a resolution of ×60000. Chemical composition was determined using X-ray spectral microanalysis.

3. RESULTS AND DISCUSSION

3.1 Morphology of Porous Si

In Fig. 1, a is represented by the morphology of the surface of porous Si with pore size of 17 nm with a thickness of a porous layer of 240 nm.

Surface and sectional images are obtained on a



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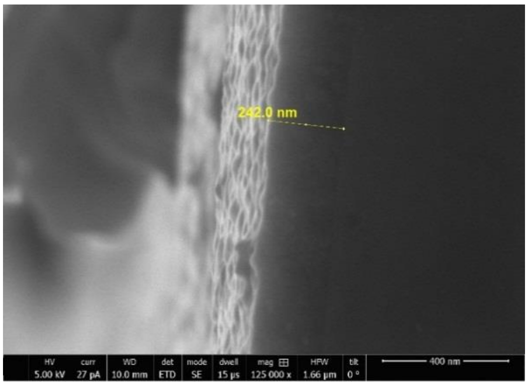

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Fig. 1 – Surface and cross-section of porous Si

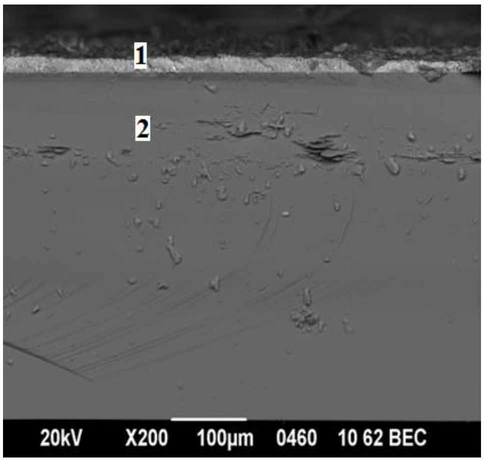
scanning electron microscope with resolution (×12500). It is on a microscope with this resolution that you can observe the nanosized silicon structure. Pores are perpendicular to the surface.

3.2 Morphology and Chemical Composition of Films CdS

The semiconductor substrate Si after the CSD process on a certain working surface was coated with a continuous film characterized by cadmium sulphide in a yellow-green color. The film was well bonded to the porous substrate.

The cross sectional micrograph (Fig. 2, a) shows that CdS (1) was grown on a porous surface of the Si p-type (2), has a thickness of about 20 μm (the JSM-6490 microscope resolution was not sufficient to observe pores with a diameter of 16 nm).

From the microphotography of the CdS layer of SEM cross section formed on the porous substrate Si (Fig. 3), it is possible to see the porous Si-intermediate layer between the CdS film and the Si substrate. This image shows that the CdS layer and the porous Si were composed of nanosized and nanocrystals of the two bonded materials. And the CdS particles are closely connected with the wall of porous Si. The colonic structure of CdS in the initial growth stage was transformed into a continuous layer during growth and the CdS layer penetrated the pores. In fact, the growth of the CdS layer on the substrate of porous Si starts in pores and, consequently, creates a bulky contact and ends with growth in spatial mode. The CEM cross-sectional microfilm shows that the thickness of this CdS layer is homogeneous and varies from 10 to 30 μm (Fig. 3). CdS films had a conductivity of n-type, the thickness was 25 microns.



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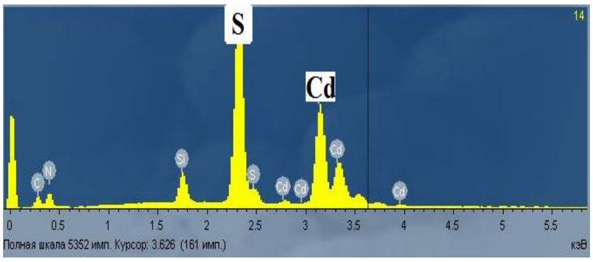

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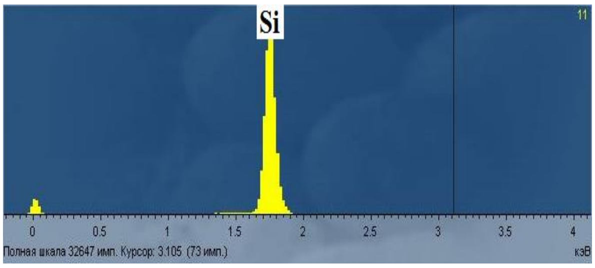

c

Fig. 2 – SEM-microphotography of the cross-section of the obtained structures (a); the study of the obtained films using the method of energy-dispersive X-ray spectroscopy (b, c)

In addition to the main substances of the film Cd and S (Fig. 2) on the surface are present in small quantities and other chemical elements (carbon, oxygen). The carbon source may be intermediates that arise from dissociation of thiourea N_2H4CS during the reaction. The most likely source of oxygen can be the CdO compound, which occurs due to the oxidation of cadmium by oxygen contained in the reaction volume. The study of the distribution of the concentration of impurities in depth showed that in the volume of films CdS the carbon and oxygen content is reduced by half, the concentrations of other impurities do not significantly change. It follows that the other source of carbon and oxygen is the surface adsorption that occurs after the production of

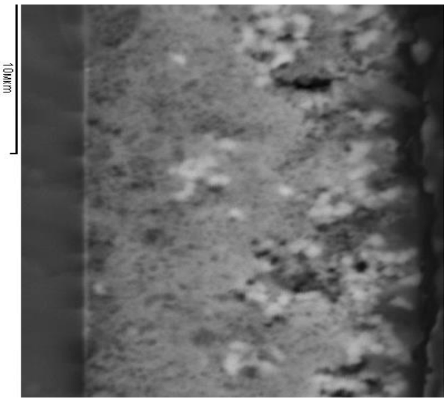

Fig. 3 – SEM-microphotography of the cross-section of the CdS film obtained on the porous surface Si

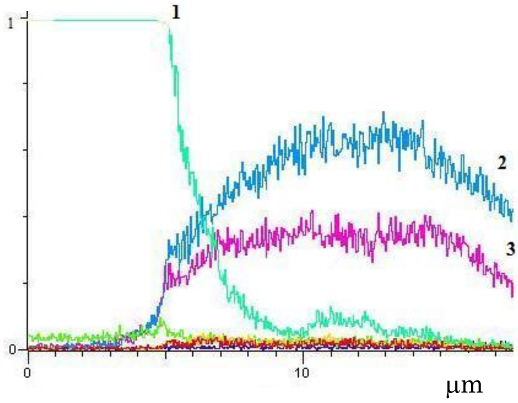

Fig. 4 – Distribution of elements in the structure of CdS/porous-Si in depth: 1 – silicon, 2 – sulfur, 3 – cadmium.

samples when they are dried at elevated temperature (80 °C), as well as for long storage in the air.

In Fig. 4 presented data show the distribution of elements (Cd, S, and Si) in the resulting structures in depth.

3.3 Diffractometric Studies

The phase analysis of the obtained heterostructures CdS/porous-Si/*p*-Si was determined using the DRON-3 X-ray unit (Cu-Kα-radiation). The results of the studies made it possible to identify the crystalline phases.

X-ray diffractograms of the sample exhibit pronounced peaks at $2\theta \approx 26.5$ and at $2\theta \approx 43.3°$, which correspond to the hexagonal modification of CdS. There are also intense peaks from the silicon substrate.

3.4 Volt-ampere Characteristic of the Heterostructure CdS/porous-Si/*p*-Si

Measurement of the light-voltage characteristics of the received heterostructures CdS/porous-Si/*p*-Si was carried out in AM lighting mode 1.5. The voltage of the idle speed U_{xx}, the current density of the short circuit $J_{кз}$ and the coefficient of filling the volt-ampere characteristic of the FET *FF* were measured. The results of the conducted studies are presented in the table. Research direct current-voltage characteristics of heterostructures CdS/porous-Si/*p*-Si, measured at room temperature showed that they obey dependence [7]:

Table 1 – Results of experimental tests of heterostructures CdS/porous-Si/*p*-Si

№	Parameter	Sample
1	Deposition time, min	5
2	Thickness of the layer CdS, μm	25
3	Initial temperature, K	300
4	Final temperature, K	380
5	Voltage of idling, U_{xx}, mB	370
6	Current density of short circuit, $J_{кз}$, mA/cm^2	8,4
7	Factor FF	0,37
8	Efficiency, %	26

$$I = I_0 exp\left(\frac{qV}{nkT}\right),$$

where I_0 is the saturation current, A; q – charge of the electron, Cl; V – voltage, V; k – Boltzmann constant, J/K; T - absolute temperature, K; n – is an indicator of ideality.

The value of the ideal index was $n = 2.0$. These calculations show the subordination of the current flowing through the heterojunction, the processes of generation and recombination of carriers in the spatial charge region.

The efficiency of the solar cells produced is determined by the ratio of the photovoltaically generating output power to the power of the incident light stream on it. However, the total power falling on a photocell is equal to 100. Therefore, the efficiency can be calculated by the formula:

$$\eta = V_{xx} I_{кз} FF.$$

The value of the efficiency of solar cells obtained for heterostructures CdS/porous-Si/*p*-Si exceeds 5.4 % efficiency values for similar structures CdS/*p*-Si under the same conditions obtain transparent conductive film of *n*-type CdS.

The production of a FET based on the heterojunction between a wide-band semiconductor (CdS), which plays the role of an optical window, and a narrow-band semiconductor (Si), used as an absorbing layer, minimizes charge losses due to surface recombination.

Thus, in solar cells based on heterostructures CdS/*p*-porous-Si light absorption and carrier generation and recombination occur in the space charge region or quasi-neutral region of silicon.

4. CONCLUSION

Developed in the technology of chemical surface deposition of thin films of CdS surface crystal *p*-porous-Si enabled first get fotoconductive heterojunctions CdS/porous-Si/*p*-Si, demonstrating the possibility to realize high conversion efficiency of solar radiation on the substrate *p*-porous-Si large Squares.

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Thus, heterostructures CdS/porous-Si/*p*-Si, manufactured by deposition CdS layer in the chemical bath of aqueous solution can be used as the basis of photovoltaic cells for solar energy.

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