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Stability of the Solar Cells with the Porous Silicon Doped with Phosphorus

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Abstract **- In this paper the experimental processes of thermal diffusion regimes in porous silicon, determining the depth of penetration of phosphorus in silicon and to build concentration depth profile p-n- transition as phosphorus diffusion of impurities through the porous silicon oxide film.**

Also in this paper we consider the possibility of increasing short-circuit current of the solar cell by optimizing the doping level and the reduction of dark current saturation p-n- junction. In this connection, the behavior were investigated reverse dark saturation current Is of the applied voltage, depending dopant oxide removal without it.

Keywords **– silicon solar cells, porous silicon, thermal diffusion, p-n-junction, etching.**

I. Introduction

Among the materials promising for creating solar cells with high performance parameters takes significant place monocrystalline silicon. Of particular interest is the development of solar cells, in which the antireflection surface is a developed structure of the porous type [1].

In this paper we investigate the possibility of using porous structures as antireflection surfaces for solar cells. Were carried out to create a thermal diffusion p-n-junctions structure silicon solar cells and to investigate the behavior of the dark reverse saturation current I_0, on the applied voltage, depending on the dopant oxide removal without it.

Many authors note the advantages of the por-Si as the antireflection layer in comparison with other coatings [2]. In work notice that the effective reflection obtained using por-Si is considerably less than with the classical coating TiO_2. In another study [3] obtained lower values of the reflection coefficient in comparison with an antireflection layer of ZnS.

In this paper we consider the experimental processes of thermal diffusion modes in porous silicon, determine the depth of penetration of phosphorus in silicon and constructing concentration depth profile p-n- junction, also phosphorus diffusion of impurities through the oxide layer of porous silicon.

II. METHODS OF MEASUREMENT

For the initial silicon were used monocrystalline silicon p-type conductivity and a resistivity of 1-3 ohm·cm, a thickness of 300 microns. The rear contact is formed by spraying alumina in a high vacuum, hereafter on the front surface of the chemical solution in anodizing HNO_3/HF for 30 seconds and thoroughly rinsed with deionized water.

After drying on the surface of porous silicon «spin-on" methods was formed by diffusant, containing phosphoric anhydride, tetraetoxisilan and ethyl alcohol. Then, plates were placed in a solid diffusant working zone fast pulsed annealing furnace and the temperature was adjusted from 900 ° C to 925 ° C for 30 to 60 seconds.

The overall design of a solar cell with porous silicon manufactured in this paper is shown in Figure 1.

For research and analysis of photovoltaic structures used a set of interrelated measuring techniques. Evaluation of the functioning of such structures is primarily based on the measurement of current-voltage characteristics under natural light or simulated solar radiation, resulting in key parameters are defined solar cells.

III RESULTS AND DISCUSSION

Diffusion of limited resources can be made for obtained of least series resistance depending on the porous silicon layers and demonstrated excellent fill factor.

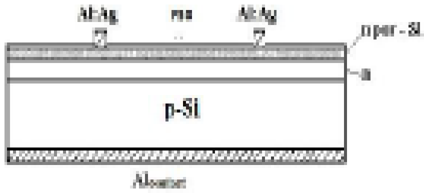

Figure 1 - The design of a solar cell with a porous silicon oxide (where, PSG-phosphosilicate glass)

Acid etching of silicon leads to the formation of a uniform layer of porous silicon surface with a reflectivity lower than 5%.

The diffusion coefficient of reflection (Figure 2) textured samples of porous silicon shows a minimum at 600 nm, which reflects its color after etching [4]. This experiment has been carried out by us in the electrolyte HF ethoxyethanol.

The figure shows that increasing the porosity of the nanostructure decreases the reflectance spectrum in the spectral wavelength range of 400 to 1000 nm.

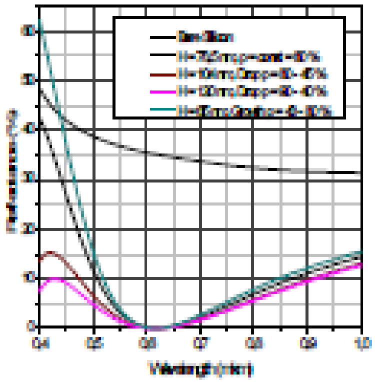

Figure - 2 light reflection spectrum of porous silicon

In the short-wave region reflection intensity with decreasing porosity increases. The upper curve corresponds to the dark reflectance of the original silicon.

Stability of nanostructures tracked followed by a photoluminescence spectrum before and long-term storage for 2 months in air show Figure 3.

Of the PL spectrum can be seen that the peak of the spectrum in the wavelength region remains unchanged for a long time, although the intensity of the PL peak decreased slightly and remained at a wavelength of 500 nm.

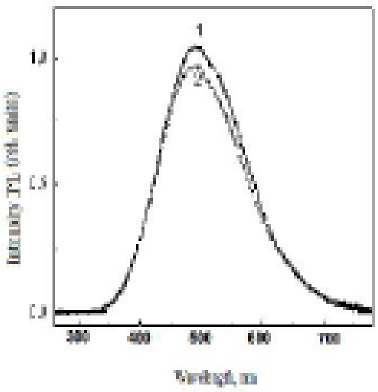

Figure 4 - The photoluminescence spectrum of oxidized porous silicon. 1 - PL after diffusion, 2 - PL after 2 months of storage in air

This means that for the doping of the nanostructure porous oxide solid solution remains stable.

The diffusion depth of the p-n junction defined by the formula, $X_j = \pi/\ln 2 \cdot \sqrt{D\tau}$ [5], considering the diffusion coefficient of phosphorus at 920 ° C of $5 \cdot 10^{-14}$ cm^2/s, the diffusion regimes specified supplying the formula, $X_j = 5{,}4\sqrt{D\tau}$; $\tau = 20$ min, we find the depth of the p-n junction of the diffusion layer. Thus, the experiment conducted on the treatment depth is equal to $X_j \sim 0{,}42$ microns.

Figure 4 shows the microstructure of porous silicon with a dopant oxide deposited on the surface of the solar cell with a p-n-junction.

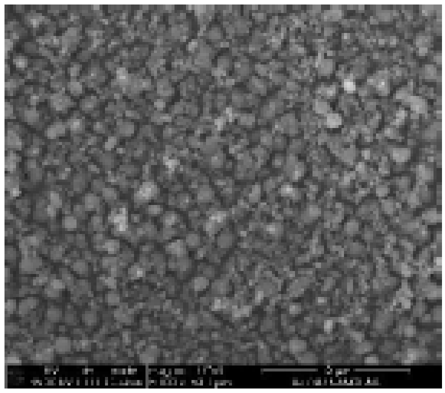

Figure 4 - The morphology of the porous structure at the surface with a dopant oxide

In the lower figure 5 shows the structure of porous silicon cross-section. The top layer represents a doped oxide film, the average - the porous film, reduce the bulk silicon. Here, the thickness of n - layer is about 450-500 nm, more than we expected for a given mode of thermal diffusion.

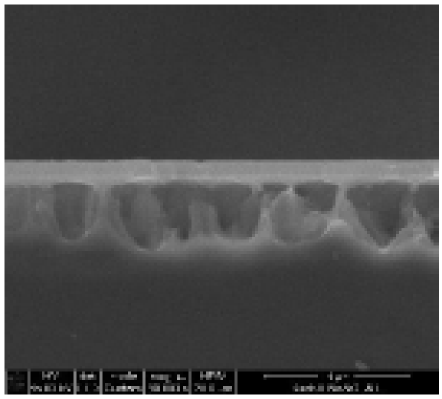

Figure 5 Structure of porous silicon cross-section

To determine the layer resistance and distribution of carrier concentration with depth p-n- transition, surface diffusion layers were etched in the etchant containing ethylene glycol and potassium nitrate in ratios of 100: 1, by electrochemical etching [6].

Then, by a 4-probe measurement was determined resistivity of each etched film. Figure 6 shows a density profile of the depth of the p-n-junction is a table of parameters and resistivity, etch depth and concentration.

Sheet resistance of the diffusion layer depends on the density of the dark reverse saturation current I_0. Minimum emitter reverse saturation current determines the quality of the p-n junction.

Typically, reduced reverse saturation current increases U_{oc}- circuit voltage of the solar cell, this dependency is expressed.

$$U_{oc} = \frac{kT}{q} \cdot ln \frac{I_s}{I_0}; \qquad (1)$$

Where, I_s - short-circuit current, I_0 - reverse saturation current and kT/q = 0,026 eV.

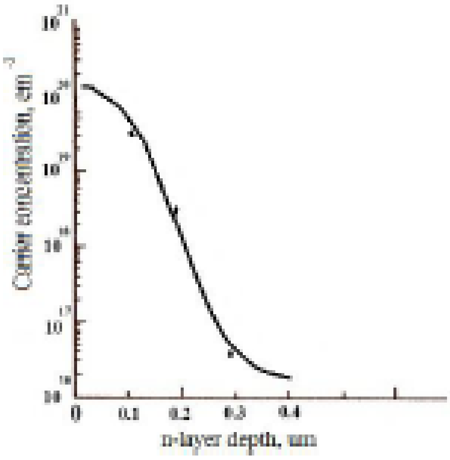

Figure 6 - Distribution of impurities in the depth of pn-junction

Figure 7 shows the curves of the current-voltage characteristics of the reverse saturation current at room temperature. The figure pattern - N1 is a curve where the diffusion porous silicon with phosphosilicate glass, you can see that the reverse saturation current at a voltage of 8 V is about 20 mA/cm^2 with a linear current density distribution.

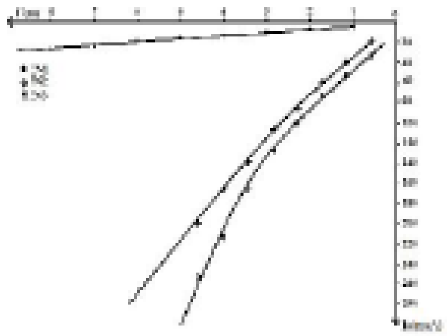

Figure 7 - The current-voltage characteristic dark reverse saturation current

It is seen that the sample - N2 and N3, remote oxide phosphosilicate glass, reverse saturation currents sharply increases to 250-280 mcA at 5V. Thus, the measurements confirm the conservation of the emitter junction in the structure of the phosphosilicate glass antireflective coating of the solar cell with the porous silicon.

Pre-voltage characteristics were measured with nanoporous silicon solar cells on the installation L2-56 under tungsten light source with a power of 87 mW / cm^2. (Figure 8).

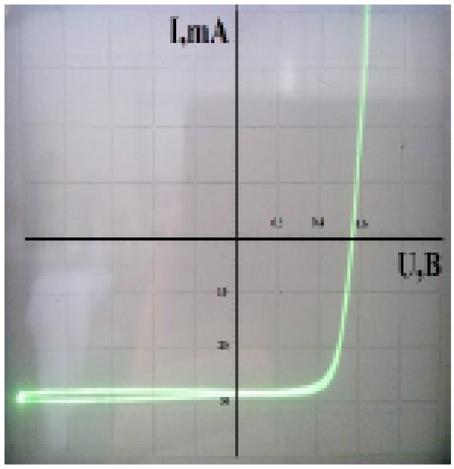

Figure 8 - Light-voltage characteristic

From the current-voltage characteristics can be seen that the fill factor is about 75% and good rectifying properties of a curve indicating a low series resistance of diffusion layer. Furthermore, the short circuit current reaches 30 mA/cm^2.

Thus, solid solution alloying retains a high level of concentration in the oxide, thus reducing the dark the reverse saturation currents and increase the short circuit current of the solar cell. Reduced effectiveness in some samples due to a decrease circuit voltage due to an increase in the reverse saturation current and increasing the resistivity of the base layer of silicon source.

CONCLUSION

Oxidized porous silicon is the best optical "window" and the anti-reflective coating with a reflectivity lower than 5% in the visible range from 300 to 1100 nm for a silicon solar cell. The reflection spectrum has a minimum in the visible region at a wavelength of 600 nm.

As a result, the depth of the diffusion experiment p-n-transition by two methods: the method of staining p-n-transition and on the instructions of the diffusion regime. Both methods proved to be close, with Xi ≈ 0,45 m.

Mastered the technique of measuring the resistivity of the layers and the diffusion n$^+$ - layer stratified etching to pn-transition. Built distribution profile of the impurity concentration.

Showed that phosphosilicate glass coating substantially reduce the diode reverse saturation current of the solar cell structure with a porous silicon as a result it is possible to increase the voltage and current of a short-circuit voltage; 30 mA/cm^2 and 0.6 V, respectively, and ~ 15-16% efficiency.

REFERENCES

[1] Strehlke S., Bastide S., Levy-Clement C. Optimization of porous silicon solar cells. //Solar Energy Materials & Solar Cells. – 1999. –Vol.58. - P. 399-409.

[2] Takagahara T., Takeda K. Theory of quantum confinement effect on excitons in quantum dots of indirect-gap materials //Phys. Rev. B. – 1992. –Vol.46, №23. -P.15578-15581.

[3] Adamian Z.N., Hakhoyan A.P., Aroutiounian V.M., Barseghian R.S., Touryan K. Solar cells with porous silicon as antireflection layer //Solar Energy Materials & Solar Cells. -2000. –Vol.64. - P. 347 - 351.

[4] Chakravarty B.C., Tripathi J., Sharma A.K. et al. The growth kinetics and optical confinement studies of porous Si for application in terrestrial Si solar cells as antireflection coating //Solar Energy Materials and Solar Cells. -2007. –Vol.91, № 8. –P.701–706.

[5] Dikhanbayev K.K, Taurbayev E.T, Bayganatova Sh.B., Kablanbekov B.M. New effective methods for obtaining and optoelectronic properties of nanoporous silicon // Proceedings of the VIII International Conference "Advanced technologies, equipment and analytical systems for materials and nanomaterials." - 2011. Almaty, - P. 283-290.

[6] Bilyalov R.R., Stalmans L., Schirone L. et al. Use of porous silicon antireflection coating in multicrystalline silicon solar cell processing //IEEE Trans. Electron Devises. -1999. –Vol.46. –P.2035-2040.