THE SOLAR CELLS BASED ON THE MONO-CRYSTALLINE SILICON AND SCREEN PRINTING PROCESS

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ABSTRACT: In this work is described the developed technology of solar cells (S.C.) based on Si- mono-crystalline (residues from manufactory Mezon). The contacts of the solar cells are formed on the base of the conductor paste Pd-Ag, metallized using the screen printing process. Drying and baking of the pastes were effectuated with the rapid treatment processing in atmosphere (RTP). The efficiency of the solar element is with anti reflex layer (ZnS) was of the level of 10%.

Keywords: Solar cells, conductor pastes, rapid photonic treatment.

1. INTRODUCTION

The cost-price of the solar cells strongly depends on the type of contacts and the deposition method. The requirements to the contacts of solar cells are:

1. The contacts must be ohmic;
2. The resistance of the contact metals - semiconductor must be minimal;
3. The contact grid's surface on the frontal part of the solar cells must be optimized in such way as the coefficient of shade of the surface and the grid resistance to be minim;
4. The adhesion of the contact on the surface of the solar cells to be enough high;
5. For solar batteries manufacturing the contacts must easy damp with tin;
6. The materials used for the contacts formation and the method of deposit must be cheap for the massively manufacturing assurance of the solar cells;

The best contacts for the solar cells based on Si- mono-crystalline are from Ti-Pd-Ag, deposited through vaporization's method with an electronic flux or the pulverization in plasma, but these contacts are very expensive due to big expenditure of electric energy for obtaining of the vacuum. In this work is described the technological part of the solar cells manufacturing with Pd-Ag contacts (produced by firm Heraeus, Germany) with the utilization of the rapid photonic treatment in nitrogen atmosphere.

2. EXPERIMENTAL PROCEDURES

For the solar cells manufacturing were used the substrate of Si- mono- crystalline, what were rebutted in the flux of the integrated circuits production (IC). The surface orientation of the p-type film (100) and the resistivity between 10 – 12Ω•cm. The maximal depth of the p-n junctions, which formed integrated circuits, is 10 μm.

The technological route of the solar cells manufacturing (Fig.1) contains the following technological operations:

1. The initial substrate, on the surface of that is the integrated circuit (IC)
2. The substrates etch in the solution of NHO3-HF-CH3COOH (10: 1: 1), that assures the glazed-frost surface of the mirror - type.
3. The substrates surface texture in KOH+ C_3H_7OH solution. As the result of this operation on the substrate surface are formed pyramids with the height of 1 μm
4. The formation of the n^+ - p junctions. The n+ layer with the depth of 0, 45 μm were formed through the method of diffusion with the utilization of PCl_3 in atmosphere of N_2, oxygen and water vapors. The diffusion was effectuated for 30 min to the films temperature of 850ºC. During diffusion the temperature of the source of diffusion (PCl_3) is maintained to the level of 42ºC, the concentration of impurities on the surface is of $2\text{-}5*10^{19}cm^{-3}$ and the resistivity is 35-45 Ω/□.
5. The removing of PSG layer in HF, the protection of the frontal surface with photoresist and the dismissing of n+ the layer from the opposite side of the solar cells.
6. Etching the photoresist film in dimethilformamid and the Pd-Ag pastes deposition. The pastes were deposited to the institute "ELIRI" (Chisinau) through the screen printing method. For the formation of p+ region on the opposite side of the solar cells, preventive were deposited an Al film by thermal vaporization in vacuum. After the pastes depositions is in progress their preventive drying at the temperature of 150ºC, 15 min in atmosphere in an electric furnace with conveyer and the rapid photonic treatment for the formation of the film structure [2, 3.]
7. The deposition of the anti reflex layer from ZnS through the thermal vaporization in vacuum. The thickness of the film during deposition was controlled by the method of the interference of the lasers rays, what is reflected from films surface and from the deposited film surface.

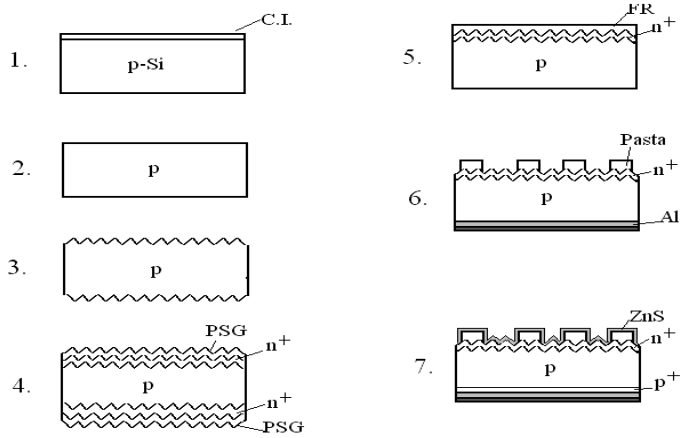

Fig.1. The technological route of the solar cells manufacturing.

3. REZULTS AND DISCUSION

3. 1 The rapid thermal treatment (Rapid Thermal Processing) RTP.

The first investigations of the thermal treatment of pastes were performed in electric furnace. But the results were not positive. Frequently the deposited pastes on the frontal surface (n+) of the solar cells had good adhesion, but n^+ -p was defeat due to of high diffusivity of Ag in Si from the constitutive paste. If the n^+ - p junction kept then the paste has no adhesion. So, the results were not reproductive. From these consideration were confectioned an installation with rapid thermal treatment (Fig. 2).

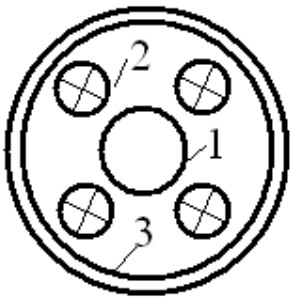

Fig. 2 The scheme of RTP installation: 1 - the quartz reactor; 2 - the halogen lamp with the power of 5 kW; 3 – the spotlight screen cooled with water

The scheme of power supply of the installation let the possibility to control the temperature in the range of 100 - 1000ºC on the programmable time up to 100 s. The precision of the temperature is ±2 ºC .The times' increase of the temperatures up to 1000ºC is equal with 10 s. The researches gave the possibility to optimize the temperature of drying and baking of the pastes (Fig. 3.)

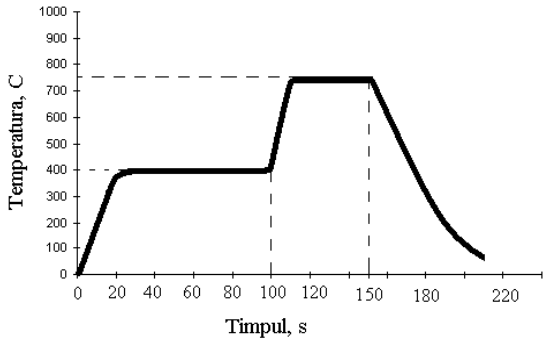

Fig.3 Scheme of RTP firing

The paste drying at the temperature of 400ºC is fated for the elimination of the organic substances from the constitutive paste [2].

3. 2. The resistivities and the parameters of the solar cells

In order to optimize the process of the rapid photonic treatment, have been researched the resistivities of the solar cells :

- $\rho(\Omega\bullet cm)$ – the average resistivity of the diffused - n^+ layer;
- ρ_s ($\Omega/\square$) – the surface resistivity;
- ρ_c ($\Omega\bullet cm^2$) – the resistivity of contact of the paste with the region – n^+;

These parameters have been investigated by four-point probe method [4], placed sondes on the bands of the contact grid of the solar cells. Through the sonde from margin is applied a voltage U_1 and is measured the current I. The drop of voltage U_2 is measured on the middle sondes. Knowing the distance between bands - l_1, the length of the band - l_2, its width - l_3 and the thickness of the n^+ regions we can calculate the resistivities:

$$\rho = \frac{U_2}{I} * \frac{hl_2}{l_1}; \ (1) \qquad \rho_s = \frac{U_2}{I} * \frac{l_2}{l_1}; (2) \qquad \rho_c = \frac{U_1 - 3U_2}{2I} * l_2 l_3 \ ; (3)$$

For the n+ regions were obtained the following results:

ρ=12 – 14*10^{-4} Ω•cm; ρ_s =28 – 40 Ω/□; ρ_c =0,03 – 0,07Ω•cm^2 ;

The deposited pastes directly on the region *p* of the n^+ - p junction doesn't form ohmic contact. Therefore before deposition of pastes, on the region *p* is grown an Al film (Fig. 1).

During R.T.P, Al diffused in p-Si and formed the region p^+. For this region

ρ_c =0,109 – 0,13Ω•cm^2.

The load characteristic of the solar cells with the sizes of 2x2cm^2 was researched to an installation of laboratory. The light source is a halogen lamp with the power of 1000W. The beams pass through a condenser, what is transparent for ultraviolet rays. The incandescence power on the surface of the solar cells is equal with 100mW/cm^2; The load characteristic is presented on Fig. 4.

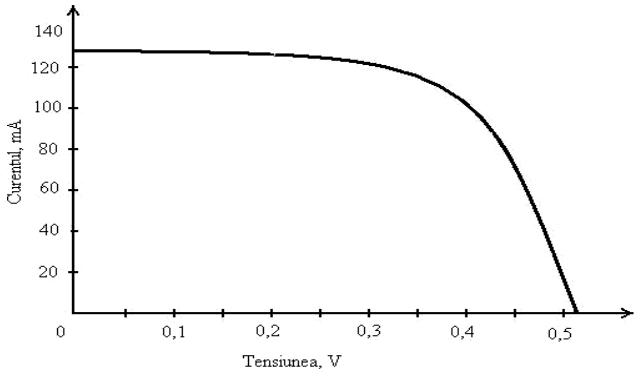

Fig. 4. The load characteristic of the solar cells.

From the characteristic were determined the parameters of the solar cells :η=10%, FF=0,6%

4. CONCLUSIONS

At this moment the deposition of the contacts on the solar cells through the screen printing method has more advantages from viewpoints of simplification of the technological process and of the minimization of the energy expenditures [5].

The rapid photonic treatment in air or in nitrogen don't influence to the parameters of the solar cells. The obtained efficaciousness is less than the one showed in [3] of 13%. But by decreasing ρ_c on the *p* region of the solar cells we can increase FF and then it shall obtained more efficiency.

5. REFERENCES:

[1] S.W.Glunz, J. Knobloch, C. Hebling, W. Wettling: 1997, "The Range of light– Efficiency Silicon Solar Cells Fabricated at Fraunhofer ISE", Proc.26th IEEE Spec. USA , 231-234.

[2] Д.Хамер, Дж. Биггерс ,1975, "Технология Толстопленочных гибридных интегральных схем", Москва, "Мир".

[3] I.E.Reis, P.Hahne, D.Hulguc, S.W.Glunz, W. Wettling (1998), "Screen – Printing Solar Cells With Mesh – Structured Emitters " 2nd World Confernce and Exhibition on Photovoltaic Solar Energy Conversion , Viena, 1495 – 1498.

[4] В. М. Андреев, В. А. Грилихис, В. Д. Румянцев, 1989, "Фотоэлектрическое преобразование концентрированного солнечного излучения", Leningrad, 310 p.

[5] V.Trofim,V.Dorogan,M.Manole,„Солнечные батареи на основе монокристаллического кремния", Conf. Int."Utilizarea surselor renovabile de energie " Chişinău, Moldova, 33 -34.