HIGH-EFFECTIVE AND DURABLE SOLAR ELEMENTS ON THE BASIS OF a-Si:H

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In the paper authors have developed the technology for preparation of the thin films *a*-Si:H by means of the method of magnetron sputtering. Solar elements were made on glass and dielectric substrates on the basis of the obtained films. At the present moment the elements were made with the parameters on the level of the world analogues (within the intensity of illumination in 100 mW/cm^2, AM1), open-circuit voltage U_{oc}=0.88 mV, short-circuit current I_{sc}=15.3 mA/cm^2, the efficiency about 23%.

For recent years photogalvanic transformers of solar energy on the basis of hydrogenated amorphous silicon *a*-Si:H have been investigated widely and are of great scientific and practical interest. As a result of investigation, photoelectric properties of films are improved at the process of silane decomposition in plasma at superimposition of magnetic field.

Therefore thin films *a*–Si:H obtained by the method of magnetron sputtering at constant current have several advantages:

- good control for keeping of hydrogen in camera and in films;
- control of wide range of substrate temperature;
- allows to use for magnetron sputtering of compound composition;
- have high speed of precipitation;
- precipitation is obtained at the voltage less than 400 V that limits the negative influence of ion energy on heterostructure and hydrogen links in the films;
- easily applicated in mass production.

Silicon target of 99.99 purity was used for creation of films *a*–Si:H. Precipitation parameters of films were controlled: pressure of hydrogen P_H, pressure of P_{Ar}, temperature of substrate T_s, entrance power P and displacement on substrate V_B. Best films are created within the parameters shown in table 1.

Table 1

Technological conditions creation films α–Si:H

T(^{o}C)	P_H(%)	P_{Ar}(%)	P_{total}(mtorr)	V_B(V)
250	50	50	10	-100

The results of complex investigation of film characteristics are given in table 2, where 1 is the hydrogen content in silicon, 2 is the oxygen content in silicon, 3 is the optical width of band gap, 4 is the density of states, 5 is the dielectric constant, 6 is the ratio of conductivity to dark conductivity on glass substrate.

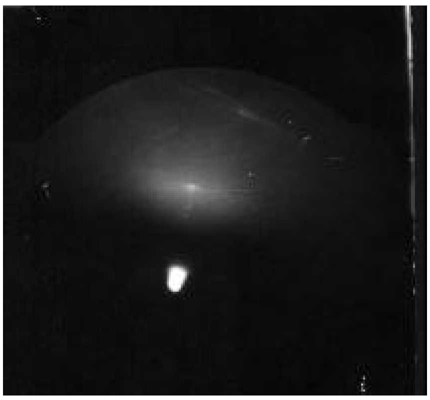
Table 2

Characteristics of the investigated solar cells

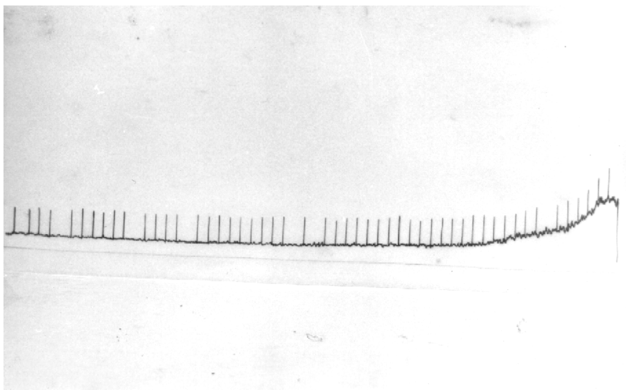
Hydrogen content H in Si (%)	Oxygen content O in Si (%)	Optical band gap (eV)	Density of states (cm^{-3}·eV^{-1})	Dielectr. Constant	Light to dark conductivity ratio
1	2	3	4	5	6
19	1	1.92	$8\cdot10^{16}$	8.5	10^5

Mono-, trio- and multicascade solar elements were created on the basis of p-n junction, heterojunction and structures with Shottky-barrier. Area of the created elements is 2×2 cm^2. Amorphous layers Al+Ni and Ti+Cu were used as metal electrodes, monocrystalline films of PtSi were used for creation of the Shottky-barrier. Thermo treatment of creation of monocrystalline PtSi and stabilization of α-Si:H parameters are combined and conducted in the vacuum and in the medium of forming-gas (N_2+H_2).

The structure of metal films are determined by X-ray diffractometry and electronography. The results are given in fig.1.*a* is the X-ray diffractometry figure of PtSi and *b* is the electronographic figure of amorphous films Al+Ni and Ti+Cu.



(a)



(b)

Fig.1. The structure of metal films determined by the X-ray (a) and electron diffraction (b) methods.

Application of amorphous and monocrystalline films provides durability and reliability of the elements.

Construction of created solar elements on the basis of monocascade *p-n* junction is represented in fig.2, where: 1 is the glass substrate, $1^{/}$ is the SiO_x thin film, 2 and 5 are electrodes, 3 is the *p*-type *α*-Si:H, 4 is the *n*-type *α*-Si:H, 6 is the enlightening covering.

Diboran (Â$_2$ Í$_4$) and phosphine PH_3 were used in the sputtering process with the purpose of obtaining the films conductivity of p - and *n*-types.

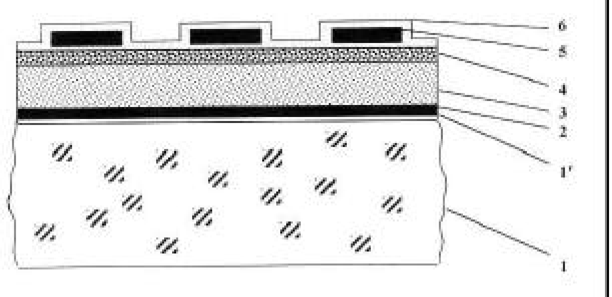


Fig.2. Construction of created solar elements.

The thin layer of SiO_x with the thickness of 0.01 mkm is plated on the glass substrate for improving the adhesion of metal electrodes.

Parameters of produced elements were determined on the special test-bench with the regulated illumination. The current voltage characteristic of the *α*-Si:H monocascade solar elements are given in fig.3.

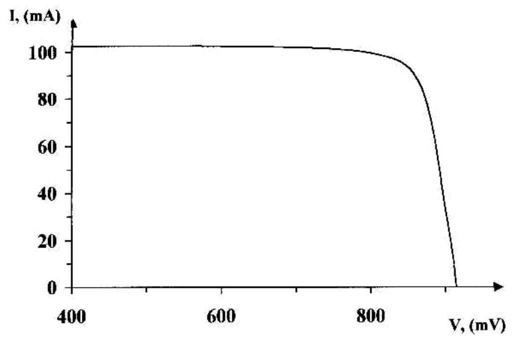


Fig.3. Current voltage characteristic of the α-Si:H monocascade solar elements.

Maximization of effectiveness is important for solar elements i.e. obtaining the highest coefficient of photogalvanic transformers of energy is the basic factor. It is determined as:

$$\eta = \frac{P_m}{P_i} ,$$

where P_m is the maximal entrance power of the instrument, P_i is the power of incident optical radiation. Maximum importance can be determined from the following: $P_m = I_m \times V_m$

$$V_m = V_{O_c} - \frac{nkT}{q} ln\left(1 - \frac{qV_m}{nkT}\right),$$

$$V_{O_c} = \frac{nkT}{q} ln\left(\frac{I_L}{I_S} + 1\right),$$

$$I_m = \frac{qI_s V_m}{nkT} exp\left(-\frac{qV_m}{nkT}\right).$$

Measuring of the tension value of idling and short-circuit current,

$$I_{SC} = I_S\left[exp\left(\frac{qV}{nkT}\right) - 1\right]$$

at the constant illumination are considered from the equation given above. Here I_s is the saturation current of diode, I_L is the current formed by the superfluous carriers within the optical excitation. If consecutive resistance can be neglected then I_L can be presented as a short-circuit current I_{SC}, that is $I_L=I_{SC}$.

The higher coefficient of effectiveness of the solar elements, the closer the coefficient of ideality (*n*) of the junction to the unit. In this case *n*=1.02. After application of hydrogenated amorphous nitric of silicon as enlightening covering the effectiveness reached up to 23% (within the intensity of illumination in 100 mW/cm^2, AM1, open circuits voltage U_{oc}=0.88 mV, short-circuit current I_{sc}=15.3 mA/cm^2) due to decrease of rate of the surface recombination.

The repeated measurement of the element parameters after five years showed that their parameters didn't significantly change. So, it can be concluded that high effective elements can be created on the basis of hydrogenated amorphous silicon with the application of amorphous and monocrystalline films as the metal electrodes.

[1] Koladzie, S. Nowak. Characteristics of hydrogenated amorphous silicon thin film transistors fabricated by D.C. Magnetron sputtering.- *Thin Solid Films*, 1989, v. 175, N8, pp.37-42.

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