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Effect of Microstructure of Different Treatments on the Electrical Properties of Schottky Diodes Based on Silicon

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Abstract: *In the given work are studied restoration degradatsionnye properties αNiTi-nSi in diodes Shottki (DSH) with thermoannealing and ultrasonic processing broken by an irradiation γin-quanta of characteristics of solar elements (SE), the amorphous materials made with application. Restoration degradatsionnye properties αNiTi-nSi in diodes Shottki (DSH) are connected with change of structure amorphous $Ni_{35}Ti_{65}$ an alloy, time the basic stage of process annealing "cures" the damaged diodes. The experimental results proving possibility restoration and managements in parametres silicon SE by means of ultrasonic processing (UP) are considered. Restoration electrophysical and photo-electric properties SE with UP broken γ an irradiation are connected from a regrouping and athermic annealing the radiating defects formed γ in-quanta.*

The experimental results demonstrating the ability to influence and control ¬ leniya parameters of silicon solar cells by sonication (RCD). The possibility of partial recovery of photovoltaic properties of solar cells that disturbed -γ irradiation with ultrasonic treatment. C to investigate the impact of RCD on the change in the mechanism of charge transport, after each step of ultrasonic treatment, we measured the photovoltaic characteristics and temperature dependence of current-voltage characteristics of silicon solar cells [SC] in the forward and reverse current. The temperature was varied from 80K to 350K.

Keywords: *diodes Schottky, annealing, degradations, ultrasonic influence, silicon solar element, ultrasonic waves, photo-electric properties, solar cells, ultrasonic processing, amorphous metals.*

1. INTRODUCTION

It is known that the irradiation of semiconductor devices of high-energy charged particles accumulate in the bulk of radiation defects, which leads to significant deterioration of the electrophysical and photoelectric characteristics of devices [1,2,3]. Controlled impact on the defect structure of a semiconductor device in the p-n junction and the base region can specifically adjust its characteristics. Traditionally, to restore the damaged properties of irradiated materials used heat treatment, utilization, which leads to some negative consequences . Therefore, as an alternative, more and more attention is paid to thermal methods of processing, one of which is ultrasonic machining (RCD).

The increase in reliability and improvement of quality of electronic devices, including devices on the basis of a barrier of Shottki, remains a crying need of modern semiconductor engineering. A metal role in most cases neglected. The role of metals and its crystal structure in processes or is not considered or badly studied. To identify a metal role, recovery processes деградационных properties depending on structure and area of contact piece of metals have been studied. [2-10.17]

As it is known, at an irradiation of semiconductor devices accumulation in volume of the semiconductor of radiation defects that leads to essential deterioration of electro physical and photo-electric characteristics of devices [1, 6.8.15.16]] occurs the charged particles high энергий. Traditionally to recovery of the upset properties of the irradiated materials apply thermal processing, use to which leads to some negative consequences [11]. Therefore, alternatively, the attention атермическим to modes to the processing's, one of which kinds is even more often paid, UP is.

Therefore, as an alternative, more and more attention is paid to thermal methods of processing, one of which is ultrasonic machining (RCD). In this paper we investigate the possibility of recovery by means of ultrasonic treatment of the initial properties of the investigated silicon solar cells, whose properties are worsened by exposure to radiation

In the given activity recovery деградационных properties αNiTi-nSi in DSH by means of a thermoannealing and the ultrasonic processing, upset by an irradiation γ quanta of characteristics of the solar cells made with application of amorphous materials is studied. In the given activity it is studied to influence of various processing's: mechanical, термо and ultrasonic (Ouse) on properties of DSH and upset by an irradiation γ- quanta of the characteristics made on technology DSH with application (αNiTi-nSi) of the sample of SE

2. EXPERIMENTAL PROCESS

For manufacturing DSH used a silicon plate п - type with orientation (III) and specific resistance of 0,7 Om.sm. The matrix contained 14 diodes which areas changed in the range from 100 to 1400 ^{mkm2}. The contact piece area was equal In our case 500 ^{мкм2}. A metal alloy αNiTi put a method of electron beam evaporation from two sources. Alloy Ni-Ti has been chosen from those reasons that both components are widely applied in microelectronics, and the alloy is well technological. For manufacturing αNiTi-nSi sample SE, it is applied on technology of DSH [2.17] About a capability of obtaining of films of this alloy with amorphous structure it was informed in activity [13]. Speeds of evaporation of components got out so that the film structure corresponded to alloy $_{Ni35Ti65}$ as in activity [13.9] were informed that such alloy is inclined to amorfez.

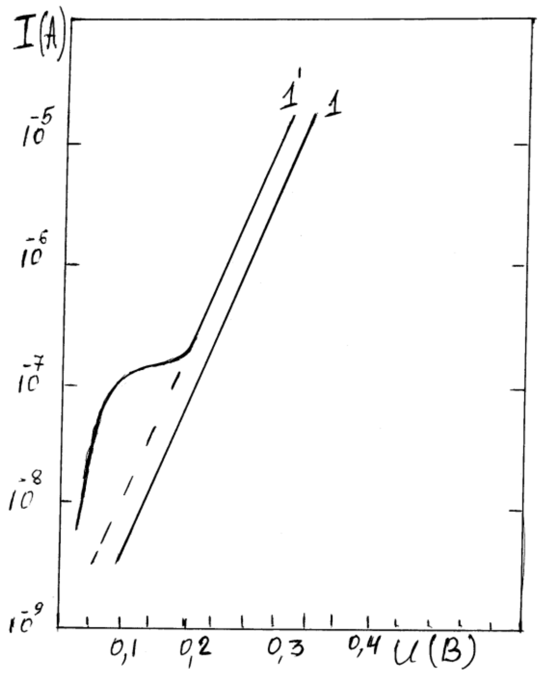

Fig. 1. Vakh for αNiTi-nSi DSH before and after an annealing at temperature 560Cº. S =500 $^{mkm2.}$

SE were irradiated γ- quanta 60Co with a dose $^{\sim 106}$ Rad at room temperature. Then these samples were consistently, in two stages, are subjected UP; the longitudinal wave was entered from the back party of the sample, is perpendicular to its work face. At the first stage UP -1 (frequency F $_{rcd}$ ≈95Mqs, intensity W $_{rcd}$ $^{\approx 0,55Vt/sm2}$, duration t ≈120s); on the second, UP -2, (F $_{rcd}$ ≈30Mqs, W $_{rcd}$ $^{\approx 15vt/sm2}$ and t ≈200s). After each stage UP electrophysical and photo-electric parametres SE were measured. It is shown that γ- the irradiation negatively affects both return and to direct Vakh, worsening the last in comparison with initial (increase in return current $_{Iобр}$).

Probe of degradation Vakh DSH consists that it in normal conditions meets infrequently, therefore for detailed studying of the indicated questions investigated Vakh DSH degraded by an artificial way, c the help микротвёрдомера PMT-3 created in the artificial image non-uniformity on border section **(BS)** contact piece metal - the semiconductor (a Fig. 2). The structure of a film of an alloy before and after an annealing was supervised by the radiographic analysis and elektronno-microscopic probes of a surface of a film [1.].

The standard diffusive technology of obtaining was applied to manufacturing of silicon *TiAu/Si-n* +-p-p + SC on the basis of an amorphous metal alloy *αTiAu* p-n transition p-n transition in a silicon plate [4.8] Capability of obtaining the films of this alloy with amorphous structure was informed in paper [7]. Speed of evaporation of components got out so that the film structure corresponded to alloy $_{Ti60Au40}$ as in paper [7] was informed that such alloy is inclined to amortization.

The investigated silicon solar cells were irradiated with γ- quanta 60Co with a dose of $^{\sim 106}$ Rad at room temperature. Then the samples were sequentially in two stages, subject to the RCD, the longitudinal wave was introduced into the back of the sample perpendicular to its surface. At the first stage RCD-1 (frequency F_{rcd} ≈9MGts,intensity W $_{rcd}$ $^{\approx 0,5Vt/sm\ 2}$, duration t ≈120min); on the second, RCD-2, (F $_{rcd}$≈27MGts,W $_{rcd}$ $^{\approx 1W/sm2}$ and t ≈200min). After each stage of the RCD was measured current-voltage characteristics of solar cells a wide temperature range (100 ÷ 350K).). It is shown that γ- the irradiation negatively affects both reverse and to direct current-voltage characteristics , worsening the last in comparison with initial (increase in reverse current $_{Irev}$ fig. 3, a curve 2 and current reduction in forward direction. The subsequent RCD-1 and, especially, RCD-2 restore dark current-voltage characteristics SE, approaching them to the initial.

3. Results and Their Discussion

On fig. 1. Are presented Vakh for αNiTi-nSi DSH before and after an annealing at temperature 560Cº. Apparently from the schedule direct and return pressure there is a superfluous current. It is known that amorphous films of metal at certain temperatures change structure and pass in a polycrystalline condition [13]. Hence, it is possible to assume that occurrence of a superfluous current to Vakh αNiTi-nSi DSH after an annealing at temperature 560ºC and is above connected with change of structure of a metal film of an alloy [13]. The thermoannealing of diodes was conducted at 100=600ºC temperatures during identical time on duration t =20 minutes

Table1. *Results of recovery degraded properties αNiTi-nSi DSH in normal, it is artificial degraded and annealing (200 Cº - 400Cº) conditions, loading {F = 100)} and quantities of violations (N=1) during time: (17s, 65s, 148s, 260s, 410s, and 580s.) (VoB=0,20V).*

t-sek	17	65	148	260	410	580
α_T (200ºC)	0,260	0,160	0,110	0,089	0,082	0,06
α_T (300ºC)	0,060	0,038	0,031	0,022	0,021	0,018
α_T (400ºC)	0,031	0,020	0,015	0,012	0,009	0,007

On fig. 2. Are presented recovery Vakh for αNiTi-nSi DSH it is degraded it is artificial by means of diamond идентера under loading F (100), quantities of violations (N=1) before and after an annealing 400ºC during time: (1-17s, 2-65s, 3-148s, 4-260s, 5-410s, 6-580s.) (Vов=0,20V). Recovery degradation properties αNiTi-nSi DSH was supervised by a method of removal Vakh both in forward direction, and in the return.

The formula was applied to the quantitative characteristic of recovery of a superfluous current under the influence of an annealing taking into account time:

$$\alpha_T = \frac{I_t - I_H}{I_o - I_H}$$

Where I_H normal (intact) diodes Shottki,

I_o Diodes directly after effect identer (t=0),

I_t Damaged diodes, annealing during *t* sec,

α_T Characterizes relative recovery of a superfluous current under the influence of a thermo annealing in time t .

As shown in table 1. With change of parameters of an annealing its value changes in an interval $0 \le \alpha_T \le 1$. From the received results it is visible that, first, the milestone of process of an annealing occurs for short initial periods, secondly, annealing process "cures", restores the damaged diodes Eventually, even at room temperature, level of a superfluous current decreases, recovery process occurs that faster, than above temperature flow of time of an annealing.

Table2. *Photo-electric parameters αNiTi/Si sample SE before and after γ - irradiations and after UP at R_{izl} =120mvt/sm2 and T=300K.*

Parameters / **Condition**	**A**	**U_{xx},V**	**$I_{кз}$,mA**	**P,mvt**	**ξ**
The sample	2,32	0,542	26,82	12,54	0,7232
To an irradiation After γ - irradiations	2,66	0,498	21,14	9,53	0,7214
After UP -1	2,56	0,528	22,61	10,52	0,7235
After UP-2	2,42	0,536	26,65	12,41	0,7263

Influence γ- an irradiation and UP is direct on fotoelektrik and electrophysical characteristics investigated SE it is visible from table 2 and table 3 to which are presented fotoelektrik (where Iк.з short circuits, Ux.x - open-circuit voltages, Ioб - a return current., A− factor, Pmax - the maximum output power, and γ- space factor) and electrophysical (τn - factor of diffusion and time of life of nonbasic carriers, Ln-diffuzionnaja length of nonbasic carriers, Io - a return current of saturation, Nэф - effective concentration of the ionized centers, Ea - energy of activation) parametres of sample SE that is shown in reduction of a current of short circuit Iкз and open-circuit voltage Uxx and as consequence, in drop of maximum output power Pmax the Subsequent UP -1 and, especially, UP -2 restore parameters SE, approaching them to the initial.

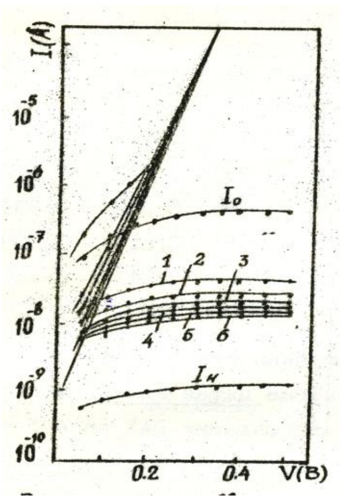

Fig.-2. *Recovery Vakh of properties αNiTi-nSi DSH. In normal, it is artificial degraded and annealin (400Cº) conditions loading F (100) and quantities of violations (N=1) during time: (1-17s, 2-65s, 3-148s, 4-260s, 5-410s, 6-580s), where I_H normal (intact) diodes Shottki, I_o diodes directly after effect identer ($t = 0$), (Voв=0,20V)*

The irradiation γ- quanta 60Co with energy of an order ~1,35Mev, is equivalent to internal irradiation SE the fast electrons resulting dispersion and photoabsorption, leads basically to formation of defects of dot type. Thus as a result of interaction of radiation defects with defects already available in a crystal

Conducted in two stages, UP -1 and especially UP 2 investigated silicon SE, have led to kickdown $N_{эф}$ (table 3) that testifies about atermik an annealing of radiation defects. As it is known, to an annealing of radiation defects there can correspond some gears: migration of defects on drains [15], formation of more difficult defect, dissociation of a complex, etc.

Thus, effect UP is an effective mode of increase of internal energy of solids. Unlike thermal energy absorbed in regular intervals in all volume of the semiconductor, attenuation UP of waves occurs, basically, on defects of a crystal lattice, promoting their redistribution to an equilibrium condition [1.6,10].

Tables 3. *Electro physical parameters αNiTi/Si sample SE*

Before and after γ- irradiations and after UP at =120mvt $^{/ sm2}$ and T=300K.

Parametres / Condition	$N_{эф}$,sm^{-3}	E_a	I_o, mkA	L_n,mkm	τ_n, mks
The sample	$2{,}34\cdot10^{16}$	0,83	90,235	72,0	0,883
To an irradiation **After - irradiations**	$3{,}25\cdot10^{16}$	0,67	306,4	65,4	0,752
After UP -1	$3{,}916\cdot10^{16}$	0,73	286,9	69,7	0,801
After UP-2	$2{,}6210^{16}$	0,83	128,6	70,4	0,838

The structure of a film of an alloy was supervised by the radiographic analysis, as shown in drawings-1. Alloy $Ti_{60}Au_{40}$ has amorphous structure. In amorphous film $_{Ti60Au40}$ also, as well as in crystals the first maximum is completely resolved, i.e. the first minimum concerns a shaft of abscissas. It means that on certain distance firmness of absent-minded electrons is almost equal to zero [3]. Effect of γ irradiations and RCD directly on the photoelectric characteristics of the investigated solar cells can be seen from Figure 3, which shows the load current-voltage characteristics of investigated solar cell. As might be expected, γ- irradiations leads to a deterioration of the load VAC SC, resulting in a decrease in short-circuit current I_{sc} and open-circuit voltage U_{hv} and as consequence, in drop of maximum output power P_{max}, and γ- space factor. Follow the RCD-1, and particularly the RCD-2 reduced load VAC SC, bringing them closer to the original figure 4 (curves 3 and 4).

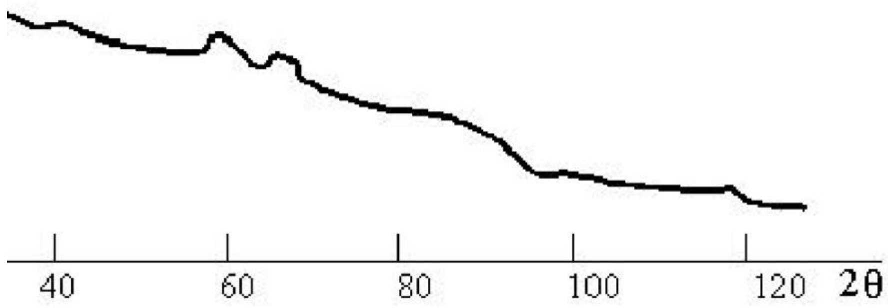

Fig. 3. *The X-ray analysis of amorphous metal films $_{Ti60Au40}$*

Let us analyze the possible mechanisms for the observed changes. It is known that the magnitude of the photocurrent is determined from the expression [5]:

$$I_f = qSN\Phi Q, \tag{1}$$

Here, q - electron charge, and SNf - total number of photogenerated electron-hole pairs at the site S, Q - collection coefficient of charge carriers. Since the value of SNf remains practically constant in this experiment, it is happening as a result of γ-irradiation drop in photocurrent SE is obviously due to a decrease in Q. When the diffusion length of minority carriers in the base Ln <<dp, the value of Q is defined in [12]:

$$Q = \frac{\alpha L_n}{\alpha L_n + 1}, \tag{2}$$

Here α - light absorption coefficient.

It is known that $L_n = \sqrt{D_n \tau_n}$, where D_n and $t_{\tau n}$ - factor of diffusion and time of life of non-basic carriers in base accordingly.

Considering (2) for a photocurrent the following expression is obtained:

$$I_\Phi = qSN_\Phi \frac{\alpha\sqrt{D_n \tau_n}}{\alpha\sqrt{D_n \tau_n} + 1} \tag{3}$$

Open-circuit voltage U_{xx} is determined as (5)

$$U_{xx} \approx \frac{AkT}{q} \ln \frac{I_{кз}}{I_o} \tag{4}$$

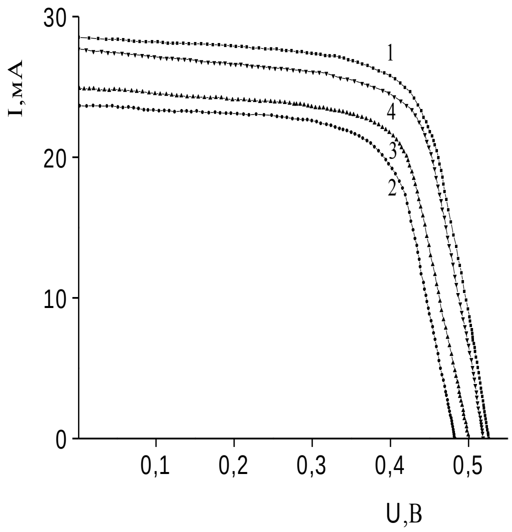

Fig. 4. *Loading VAC TiAu/Si-n +-p-p + the sample subjected to an irradiation γ - quanta both RCD at $=100mW/cm2$ and T=300K.*

Curves: 1 - initial;

2 - after γ - irradiations at a dose of

10^6 Rad;

3 - After RCD-1 (W_{rcd} $\approx$0,5W/sm2, t ≈120 minutes, F_{uz} ≈9 MHz);

4 - after RCD-2 (W_{rcd} $^{\approx 1W/sm2}$, t ≈200min. F_{rcd}≈27 MHz).

where k - Boltzmann constant, T - temperature, k - dimensionless coefficient characterizing the rate of recombination in the space-charge layer, Io - the reverse saturation current flowing through the p-n junction, Isc - short-circuit current

Tables 4. *Photo-electric parameters of TiAu/Si-n +-p-p + sample SE before and after γ - irradiations and after RCD at* $_{Rizl}$ $^{=120mVt/sm2}$ *and T=300K.*

Parameteres Condition of the sample	A	U_{xx},V	$I_{кз}$,mA	P,mW	ξ
Before irradiation	2,32	0,542	26,82	12,54	0,7232
after γ-irradiation	2,66	0,498	21,14	9,53	0,7214
After RCD-1	2,56	0,528	22,61	10,52	0,7235
after RCD-2	2,42	0,536	26,65	12,41	0,7263

According to our estimates, the irradiation of γ-rays does not lead to significant change and the effect of γ-irradiation and RCD directly on the photoelectric characteristics of the investigated solar cells can be seen from Table 4, which represent the photovoltaic (where Isc-short-circuit current, Uh.h - voltage idling, a dimensionless ratio, Pmax - the maximum output power, and -ξ fill factor), the parameters of the sample SE, resulting in a decrease in short-circuit current Isc and open-circuit voltage Uhh, and as a consequence, to reduce the maximum power Pmax Follow the RCD-1, and particularly the RCD-2 restore options SE, bringing them closer to the source. It is known that exposure to γ-rays with energies of 60Co ~ 1.2 MeV, which is equivalent to the external irradiation by fast electrons SE resulting from Compton scattering and photoabsorption, which leads mainly to the formation of defects of the point type. In this case the interaction of radiation defects with those already in the crystal defects in the p-n junction and the base are more electrically and optically active centers, which play the role of recombination centers, resulting in a decrease in the lifetime of minority carriers tn and parameters Q and IF-dependent tn. In the initial state (Fig. 3, curve 1) the slope of the temperature dependence of Irev amounts 0,71~ eV, which indicates the presence of a diffusion mechanism of charge transport and generation. As the irradiation γ - quanta creates radiation defects in SE which are more mobile at the subsequent UP the acoustic wave co-operates mainly with the last, promoting their redistribution and atermik to an annealing [11.1.15.14].

4. Conclusions

Thus, it is possible to conclude that recovery of a superfluous current is connected with change of parametres of an annealing, in given to activity its value changes in an interval $0 \le \alpha_T \le 1$. From the received results it is visible that, first, the milestone of process of an annealing occurs for short initial periods, secondly, the milestone of process of an annealing "cures" the damaged diodes.

On the basis of electro physical and photo-electric measurements of parameters it is proved that recovery of electro physical and photo-electric properties silicon NiTi/Si sample SE by means of the ultrasonic processing, upset γ - an irradiation, occurs at the expense of a regrouping and atermiaт an annealing of radiation defects formed gamma in quanta. The results resulted in activity testify that UP partially restores perfection of crystal structure γ NiTi/Si sample SE, upset in the course of an irradiation γ - quanta. The received results allow to make a conclusion that, at structure $Ti_{60}Au_{40}$ the sample is amorphous**.** Laws of influence of ultrasonic processing on photo-electric properties investigated silicon SE are revealed and it is established that interaction of ultrasonic waves with heterogeneous semiconductor structure of silicon SE affects the generation-recombination mechanism of conducting the current. The photo-electric measurement has proved that recovery of photo-electric properties of silicon SE by means of the ultrasonic processing, upset by γ - an irradiation, occurs at the expense of a regrouping and athermal annealing of radiation defects formed by gamma in quanta.

REFERENCES

[1] D.K. Wickenden, M.J. Sisson, “Amorphous Metal-Semiconductor Contacts for HighTemperature Electronics”, Solid State Electron, Vol. 27, No. 6. pp. 515-518, 1984.
[2] S.M. Zi, “Physics of Semiconductor Devices”, R.A.Surusa Publication, Moscow, Russia, Vol. 1, p. 456,1984
[3] I.G. Pashaev //ElektronysikalL Properties of SCHOTTKYdiodes made on the basis of silikon wtth amorphous and polycrystaline metel alloy atlow direct International Journal on //“Technical and Physical Problems of Engineering” (IJTPE), Iss. 10, Vol. 4, No. 1. 2012 pp. 41-44
[4] Sh. G.Askerov I.G. Conference Proceeding Second International Conference on Technical and Physical Problems in Power Engineering. Tabriz –Iran 6-8 september 2004. pp/ 367 – 368.
[5] K.T.Y Kung, I.,Suni M.A Nikolet.//" Elektrikal charakterics of amorphorus molyubdenum-nickel contacts to Si"// J.Appl.Phus., 1984. Vol.55 No 10. pp3882-3884
[6] I.B.Yermolovich, V.V.Milenin, R.V.Konakova, etc., Letters in JTF, 1996, Vol. 22 No 6, pp.33-36.
[7] N.S.hare, V.G.Bojko, P.A.Gentsar, O.S.Litvin, V.P.Papusha, N.V.Sopinsky, FTP, 2008, Vol. 42 No 2, pp.207 - 211.
[8] I. G. Pashayev the Influence of Ultrasonic Treatment on the Properties of Schottky Diodes // Open Journal of Acoustics, 2013, 3, 9-12.
[9] Ш.Г Askerov., SH.G.Aslan, I.G.Pashaev, the Electronic engineering., Microelectronic devices, 1989, Vol.6, №78, pp.46-48.
[10] P.N.Krylov, the Bulletin of the Udmurt University. Physics. 2006, №4,p p. 125-136.
[11] I.V.Ostrovsky, L.P.Steblenko, A.B.Nadtochy, FTP , 2000, Vol..34 № 3, pp. 257-260.
[12] P.B.Parchinsky, S.I.Vlasov, R.A.Muminov,etc.,Letters in JTF,2000.Vol., 26 № 10, pp.40-45.
[13] K.Sudzuki, F.Hasimota, «Amorphous metals». M. 1987.
[14] P.B.Parchinsky, S.I.Vlasov, L.G.Ligaj, etc., letters in JTF, 2003, Vol.., 26 №10, pp.40-45.
[15] I.G Pashaev.The study of the electrical properties of Schottky diodes based on silicon with amorphous and polycrystalline material// Universal Journal of Electrical and Electronic Engineering 2013, Vol. 1(4), pp. 118 - 121
[16] A.I.Vlasenko, J.M.Olih, R.K.Savkin.//ФТП, 1999, Vol 33, №4, pp.410-414.
[17] Ю.К Kovneristyj, E.K.Osipov, E.A.Trofimova, the Physical and chemical bases of creation of amorphous metal alloys. M.Nauka, 1983, pp.23-29.

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