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ELECTROPHYSICAL PROPERTIES OF SCHOTTKY DIODES MADE ON THE BASIS OF SILICON WITH AMORPHOUS AND POLYCRYSTALLINE METAL ALLOY AT LOW DIRECT VOLTAGE

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Abstract- The summary of this paper is devoted to the obtaining of Ni_xTi_{100-x}-nSi Schottky diodes (DSH) and studying its electrophysical properties (where *x*=4, 19, 37, 74 and 96). The Schottky diodes made on the basis of amorphous and polycrystalline metal alloys at low direct pressure. It is declared that the $Ni_{35}Ti_{65}$ alloy has amorphous structure. The height of a potential barrier is found by two methods of *I-V* and *I-T*. The obtained results show that the barrier height is rather sensitive to structure of a metal alloy, in comparison with a polycrystalline film of metal. It is shown that an amorphous film of metal to silicon the border of separation is rather homogeneous.

Keywords: Amorphous Structure, Schottky Diodes, Richardson's Constant, Barrier Height, Border, Non-uniform, Film Thickness.

I. INTRODUCTION

Formation of amorphous structure of metals and alloys leads to fundamental changes of magnetic, electric, mechanical, superconducting and other properties. Some of them have appeared very interesting both for science, and practically. Value of other properties is not completely opened yet. Considering the studied literatures and technology of contact metals, it is obvious that the semiconductor has only a role to occurring in such processes as well as the role of metals in most cases is neglected. The role of metals and their crystal structure in the processes have not been also considered or studied [1-3].

To identify the role of metals, the properties of Schottky diodes, regardless of the structure and area of contact of metals have been studied. It is shown that the main parameters of Schottky diodes, such as the density of a flow of saturation and height of a barrier, breakdown potential, factor of in ideality depend on the area of contact and thickness of a metal film. Experimental results have been explained by heterogeneity of the contact. According to this model the contact is regarded as parallel of the elementary contacts are connected to various heights of a barrier and other parameters. To increase the quality of Schottky diodes it was suggested to use amorphous films of metals. It has been found that the Schottky diodes made with amorphous films of metals are more reliability for termostability of parameters that is important for electronics of high temperature.

Discovery of amorphous metals has made a big contribution metals science, essentially changed the idea about their behavior and application. It has been appeared that the amorphous metals strikingly differ on the characteristic and properties from metals crystals regarding to the ordered arrangement of atoms.

It is known that the amorphous films of metals carry out the functions of diffusion barriers properly in microelectronic structures [3-8] and allow to make DSH with a high potential barrier (to 1 eV), that is of interest for solar power [7, 8].

With changing the temperature and structure of a metal film, the metal alloys will be also changed and consequently the relation of DSH parameters will be changed as well [3, 5, 10, 13, 14].

II. EXPERIMENTAL PROCESS

The paper is devoted to reception of Ni_xTi_{100-x}-nSi DSH and studying its delectrophysical properties with amorphous and poly crystalline films metal alloys at low direct voltage. For manufacturing of DSH as the semiconductor silicon plate of *n* type with orientation of 111 and specific resistance of *n* layer with 0.7 Ohm, it is required to work on the metal used in Ni_xTi_{100-x} alloy (where *x* = 4, 19, 37, 74 and 96). The films of alloy Ni_xTi_{100-x} are obtained by a method of electron beam evaporation from two sources.

The structure of an alloy of a film was supervised by a method of the radiographic analysis on plant DRON-2 [1-3]. The roentgenogram is resulted in Figure 1. Apparently, from drawing a film of $Ni_{35}Ti_{65}$ alloy, it had amorphous structure, and other films polycrystalline [1, 2]. This conclusion made on the basis of that a series of maxima and minima is accurately expressed at crystals that denotes not only about a correct arrangement of the nearest atoms, but also about existence of a distant order. In the other words, it is possible to spend co-ordinates in crystals, which relative positioning of atoms same on the distance many times over exceeding size of an elementary cell. In amorphous film $Ni_{35}Ti_{65}$ also, as well as in Crystals the first maxima is completely resolved, i.e. the first minima concerns an axis properties. It means that on certain distance the density of disseminated electrons is practically equal to zero. Maxima and minima are expressed to presence of different internuclear distances, aspiring in a limit to a smooth curve.

In amorphous film $Ni_{35}Ti_{65}$ the near order within each elementary cell constructed also, as well as in a crystal is observed only. Outside of a cell the order is broken. It occurs, because each following cell is a little turned concerning previous, and the direction of turns often statistical. As a result, X-ray system NiTi analysis is established, that in dependence on quantity of atoms Ni before reception of structure $Ni_{35}Ti_{65}$ the periods crystal cell will change not submitted to the Vegard's law [1-5].

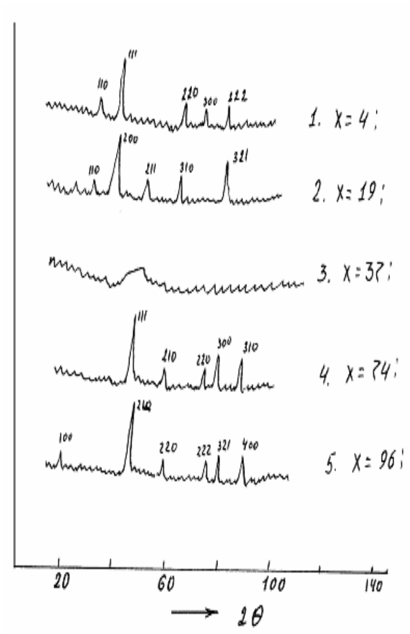

Figure 1. The roentgenogram of films of an Ni_xTi_{100-x} alloy (where x = 4, 19, 37, 74 and 96)

III. RESULTS AND DISCUSSIONS

In the field of direct voltage $V > 3kt/e$ the parameters of Schottky diodes are defined from current-voltage characteristic which is expressed by the formula [12]:

$$I = SAT^2 \exp\left(\frac{\varphi_b}{kt}\right)\left[\exp\left(\frac{\varphi_b}{nkt}\right) - 1\right] \quad (1)$$

where A is Richardson's effective constant, n is factor of inideality and φ_b is barrier height. All other designations have usual sense.

For the same purpose an initial site of voltage $V < kt/e$ where current-voltage characteristic of DSH is described by the following equation in [3-5].

$$I = SAT\frac{l}{k}\exp\left(\frac{\varphi_b}{kt}\right)V \quad (2)$$

From Equation (2) it is shown that the resistance of transition is described by the following relation.

$$R = k / lASA_0T \exp\left(\frac{\varphi_b}{kt}\right) \quad (3)$$

From comparison of the Equations (2) and (3), it is obvious that the current-voltage characteristic is a straight line with the angular factor equal to $1/R$.

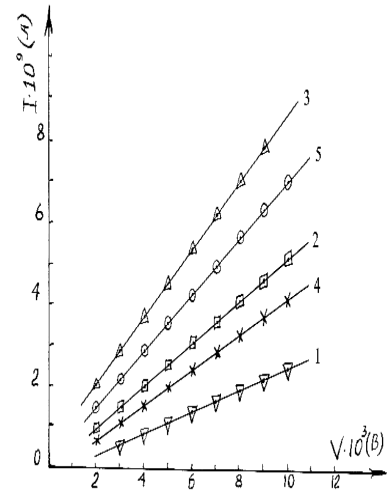

Figure 2. Current-voltage characteristic of Ni_xTi_{100-x}-nSi for DSH at low direct voltage 1-4; 2-19; 3-37; 4-74; 5-96

Figure 2 presents the experimental current-voltage characteristic of Ni_xTi_{100-x}-nSi for DSH, where parameter of straight lines is percentage of components of an alloy [5-8]. The specified relation has been obtained at a room temperature for diodes with the area $S = 1200\ \text{mm}^2$.

Figure 3 presents the V_{akh} of αNiTi-nSi for DSH before and after an annealing at temperature 673K. Apparently from the schedule at small direct pressure after a thermo annealing there is a superfluous current.

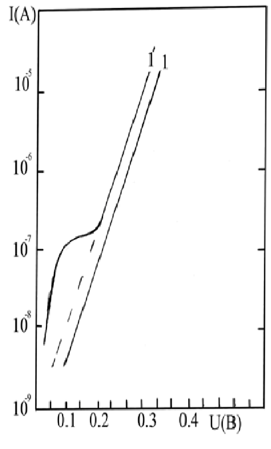

Figure 3. V_{akh} of αNiTi-nSi for Shottky diodes for before (1) and after (1') a thermo annealing at 673K

It is known that amorphous films of metal at certain temperatures change structure and pass in a polycrystalline condition. Hence, it is possible to assume that the occurrence of a superfluous current in DSH after an annealing at temperature 673K based on above connected with change of structure of a metal film of an alloy. Really, probes of structure of metal $Ni_{35}Ti_{65}$ film on installation of DRON-2 before and after an annealing process at temperature 673K which Figure 4 shows that the film of metal from an amorphous or quasi amorphous condition passes is in polycrystalline.

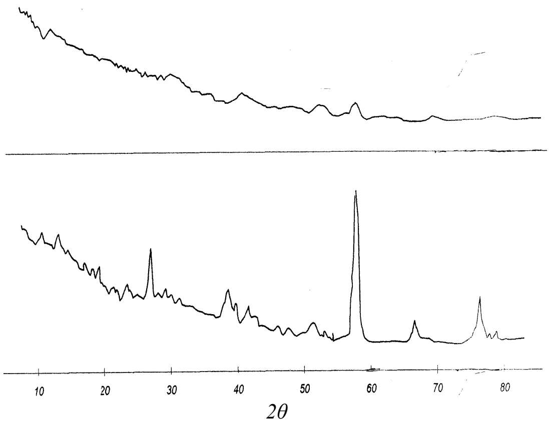

Figure 4. The roentgen diagram analysis of amorphous metal films of NiTi; before (1) and after (1') a thermo annealing at 673K

Value of height barriers was defined by two methods. According to the first way (*I-V* method), the barrier resistance has been defined from experimental current-voltage characteristic. Then using Equation (3), the φ_b is calculated with the assumption that the contact area *S* is obtained from the geometrical area, and $A = 110$ acm^{2}k^2.

Thus the value of φ_b for DSH at Ni_xTi_{100-x}-nSi (where x = 4, 19, 37, 74 and 96) are found. The essence of the second way is as follows from the Equation (3). The relations between ln*RT* and l/*T* is described by a straight line, which inclination defines height of potential barrier φ_b (method *I-T*) [5, 11]. The corresponding results are shown in Table 1.

Table 1. Altitude of the potential barrier based on the methods of (*I-V*) and (*I-T*)

x%	4	19	37	74	96
φ_b (*I-V*)	0.61	0.65	0.69	0.64	0.63
φ_b (*I-T*)	0.54	0.58	0.60	0.53	0.51

As seen from Table 1 the height of the potential barrier, based on the methods of (*I-V*) and (*I-T*), the greatest height corresponds to Ni_xTi_{100-x}-nSi of DSH where the alloy has amorphous structure.

From [11], it is known that Ti has body lattice of *J* with the period of an elementary cell of 3.33 Å, and Ni has face centered lattice *F* with the period of 3.52Å. Also there are data on existence hexagonal versions of these components. However, the diffractograms by the author with pure elements Ni and Ti have shown that reflexes of diffractograms are displayed on the basis of cubic primitive lattices (Table 2). Therefore, having assumed as a basis a cubic lattice, indexed the roentgenograms corresponding to various structure Ni_xTi_{100-x}-nSi. It is determined that the increase in quantity Ni in the field of 4, 19, 37 leads to crystallisation of the sample. However there are no natural changes of the periods of a lattice.

Table 2. Interplane distances *d* (Å), indexes (hkl), the periods (a) and types of lattices on roentgenograms of alloys Ni_xTi_{100-x}

No	1		2		3		4		5	
X_a> %	4		19		37		74		96	
	d(Å)	hkl	*d*(Å)	hkl			*d*(Å)		hkl	hkl
1	2.356	110	2.797	110			3.083	110	2.058	111
2	1.690	200	2.254	111			2.311	200	1.564	210
3	1.364	211	1.408	220			1.824	211	1.266	220
4	1.175	220	1.275	300			1.435	311	1.199	300
5	1.054	310	1.163	222			1.175	321	1.100	310
	3.33 Å *J*		3.92 Å *P*				4.45 Å *F*		3,52 Å *P*	

Change of the periods and types of lattices is connected with statistical distribution of separate atoms in unequal crystalographic positions ($J \to P : F \to P$).

As it was marked above, depending on quantity of atoms Ni before obtaining of structure $Ni_{35}Ti_{65}$ the periods of a crystal lattice linearly change. With increase in quantity of atoms Ni the barrier altitude is increased. At structure $Ni_{35}Ti_{65}$ the received sample is amorphous. From the table it is visible that to this structure DSH there corresponds the greatest altitude of a barrier. With the further increase in quantity Ni (in the field of 37, 74, 96) the barrier altitude decreases DSH. This results from the fact that system Ni-Ti forms firm solutions.

IV. CONCLUSIONS

Comparing results of X-ray in the analysis and value of DSH parameters, it is possible to conclude that changing the Ni_xTi_{100-x}-nSi DSH parameters. Considering the results for $V < kt/e$ allow to conclude that in comparison connected with change of structure and structure of a film of metals with a polycrystalline film of metal, in case of contact of an amorphous film of metal with silicon, the border of separation is rather homogeneous and barrier heights are rather sensitive to structure of a metal alloy. With the further increase in quantity Ni (in the field of 37, 74, 96) the height of a barrier decreases and the factor of not idealities of DSH increases. This results from the fact that Ni-Ti system forms firm solutions. Results of X-ray analysis and dependence of parameters of DSH on a percentage condition show that change of Ni_xTi_{100-x}-nSi of DSH parameters are connected with change of structure and structure of a film of metals.

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BIOGRAPHY

Islam Geray Pashaev was born in Qubadli, Azerbaijan on March 1, 1957. He is a candidate of science in physics and mathematics and Associate Professor of the chair of Physical Electronics. He has conducted subjects in the chair of physical electronics in Baku State University, Baku, Azerbaijan since 2007 including technology of microcircuits, semiconductor electronics, solid-state physics, solid-state electronics, radiophysics and optoelectronics. He is also the author of 75 scientific articles and 1 published book. He is currently conducting scientific research in the field of metal semiconductor contact physical properties.