RADIATION RESISTANCE OF PHOTODIODES ON THE BASIS OF INDIUM SELENIDE

D.Sh. Abdinov, K.A. Askerov, M.G. Bektashi, V.I. Gadjieva

Institute of Physics of the National Academy of Sciences of Azerbaijan, Baku, Az-1143, H.Javid prospect, 33, Baku, Azerbaijan
E-mail: bbarhal@ mail.ru

ABSTRACT
Influence electron, proton and pulse gamma-neutron irradiaton on spectral characteristics of photodiodes on the basis of indium selenide have been considered. Before and after irradiation of photodiodes their monochromatic, integrated and volt-watt sensitivity at 300 K were investigated.

Keywords: radiation-proof, ionizing irradiation, gamma-quanta, indium selenide, photodiode, photoconverter,

I. INTRODUCTION

One of the important problems of photoelectronics is creation of the radiation-proof photoconverters operating in near infra-red region of a spectrum. Some works devoted to research of current-voltage characteristics and bulk characteristics of diodes on the basis of indium selenide [1] and influence of the ionized radiation on their photo-electric properties [2].

II. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this report influence of gamma-quanta by a doze 10^7 R and 10^8 R, an electronic irradiation with energy 6 MeV of fluences $1.2{\cdot}10^{12}$cm-^{2} and $1.31{\cdot}10^{14}$ cm-^{2}, a proton irradiation with fluences $1.0{\cdot}10^{12}$ cm-^{2} and $5.0{\cdot}10^{12}$ cm-^{2} and a pulse gamma-neutron irradiation with fluences $3.5{\cdot}10^{12}$ cm-^{2} and $1.2{\cdot}10^{14}$ cm-^{2} on spectral characteristics of photodiodes on the basis of indium selenide have been considered. Before and after irradiation of photodiodes their monochromatic, integrated and volt-watt sensitivity at 300 K were investigated.

For manufacturing photodiodes single crystalline samples of InSe with following initial parameters at 300K were used: concentration and mobility of the majority charge carriers $10^{14}\div10^{15}$ cm-^{3} and 800÷1200 cm^2 /V·s correspondingly; specific resistance 10-100 Ohm·cm.

Photodiode structures were obtained by the vacuum deposition of the gold on hot single crystalline InSe layers with the subsequent annealing during two hours at temperature 250 ^{0}C.

The design of the specified photodiodes and their key parameters are described elsewhere [3].

On Fig. 1 a spectral distribution of photosensitivity of the investigated photodiodes at room temperature before and after an electronic irradiation is presented. The photodiodes undergone to influence of ionizing irradiation possessed photosensitivity in the spectral region 0,45÷1,1 μm with a maximum λ_{max}= 0,95 μm.

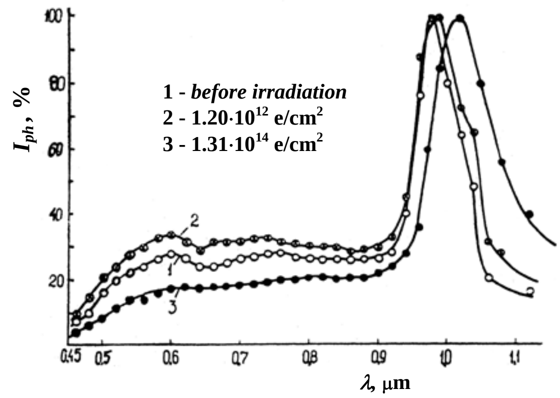

Fig. 1. Spectral distribution of photosensitivity of photodiodes on the basis of InSe before and after irradiation by electrons with energy 6 MeV at 300 K

From Fig. 1 also follows that photosensitivity at electron fluence $1{,}2{\cdot}10^{12}$ cm-^{2} in short-wave area of a spectrum increases a little, and the following fluence of electrons results in its reduction and shift of the basic maximum to longer waves. From spectral characteristics some characteristic parameters have been obtained: monochromatic sensitivity 0.95÷4.0 A/Wt, volt-watt sensitivity $(1.3\div7.1){\cdot}10^4$ V/Wt and integrated sensitivity to a source "A" - (10÷20) mA/lm. Practically changes were observed also at other used types of irradiations. In the case of a gamma -neutron irradiation at fluence $1.2{\cdot}10^{14}$ cm-^{2} reduction of sensitivity occurred over all spectral region (Fig. 2).

The similar picture also is observed at an irradiation photodiodes on the basis of InSe by protons with fluences $10{\cdot}10^{12}$ cm-^{2} and $5.0{\cdot}10^{13}$ cm-^{2} in comparison with the case of an irradiation by electrons with energy 6 MeV and pulse gamma-neutrons (Fig. 3, *a, b*).

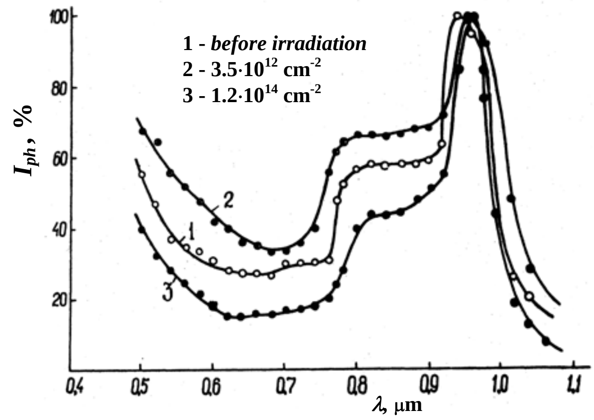

Fig. 2 Spectral distribution of photosensitivity of photodiode on the basis of InSe before and after irradiation by pulse gamma-neutrons at 300 K

In Fig. 3 (*a, b*) results of influence of the proton irradiation on spectral characteristics of photodiodes on the basis of InSe are shown. It is seen from figure that at fluence $1.0\cdot10^{12}$ cm^{-2} in all parts of the spectral characteristics photosensitivity of photodiodes increases.

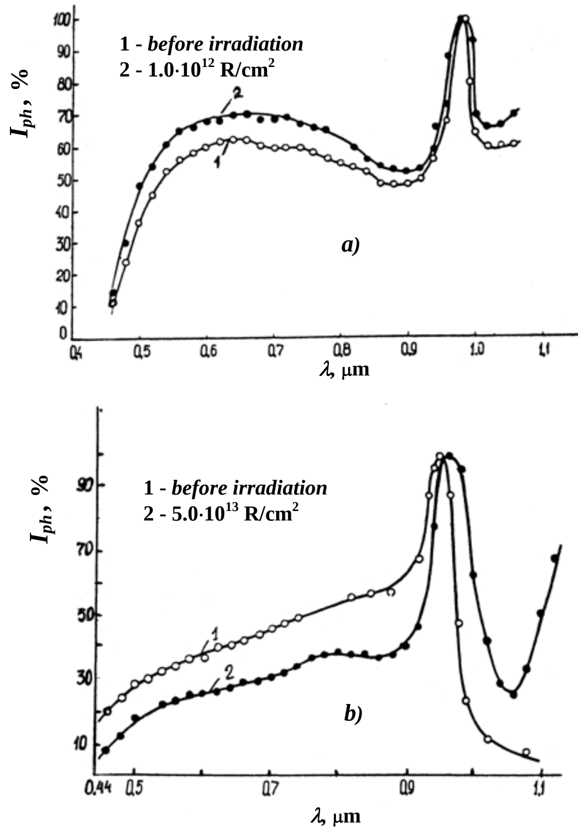

Fig. 3. Spectral distribution of photosensitivity of photodiodes on the basis of InSe before and after a proton irradiation at 300K

And the following fluence $5.0\cdot10^{12}$ cm^{-2} results in reduction of the photosensitivity in short-wave area of the spectrum and the additional maximum does not change. Thus the basic maximum is a little shifted to long-wave side of a spectrum.

The observed changes as a result of the influence of the ionizing radiation can be connected to formation of radiating defects formed in layered structure of the indium selenide.

The results obtained are presented in Table1.

It is possible to make the assumption from experiment carried out that a number of changes of photoelectric parameters of photodiodes upon an irradiation by high energy particles apparently is connected to specific features of crystal structure of layered materials, i.e. interaction of the radiating defects arising in crystal layers and interlayer spaces. Low in comparison with a layer the energy barriers existing in interlayer spaces favor to migration of radiation defects. It in turn facilitates process of formation of complexes of radiation and initial defects in the interlayer space that results in the change of the photocurrent relaxation time and, hence, change of the photosensitivity [4]. At small irradiation fluences, most likely, mainly occurs a redistribution of impurity of the gold being the compensating element at reception of the *p-n*-junction, as a result more perfect and stable *p-n* junction and photosensitivity of photo diodes increases [5].

For finding-out of the reason of degradation of key parameters of photodiodes as a result of influence of the ionizing irradiation, in experiment simultaneously were irradiated photosensitive elements as well as the photodiodes created on their basis. Changes of key parameters in them practically did not differ that specifies insignificant influence of the irradiation on elements of a design of the photodiode.

Before and after an irradiation also influence of isochrone annealing by duration of 30 minutes on photo-electric properties of the irradiated photo diodes were examined. It was found out that after the isochrone annealing in an interval 70-130 ^{0}C (with step in 20 degrees) photoelectric parameters of researched photodiodes almost completely are restored. It is established, that the defects entered by an irradiation are non-stable, they disappear for one stage isochrone annealing, i.e. gradual recombination of the radiation defects occurs.

The defects created in photodiodes as a result of an electronic and proton irradiation are practically restored after single annealing at temperature ~100÷300 ^{0}C. After an irradiation with the subsequent annealing at the specified temperature defects are restored by pulse gamma-neutrons not completely, and only for 80 %.

III. CONCLUSION

The received results allow to state that photodiodes on the basis of InSe are radiation-proof, and hence, can be used upon high radiation conditions.

Researched photodetectors on the basis InSe on a level of radiation resistance to pulse-neutron, electron, proton and gamma irradiation fully comply with the modern requirements made to photoelectronic devices.

Table 1. Effect of irradiation on photoelectric parameters of the photodiodes on the basis of indium selenide

Photoelectric parameters	Electron irradiation with energy 6 MeV				Proton irradiation			
	Before irradiation	After irradiation			Before irradiation	After irradiation		
		5,0·10^{11} e/cm^2	1,2·10^{12} e/cm^2	1,31·10^{14} e/cm^2		1·10^{12} p/см^2	5·10^{13} p/см^2	1,0·10^{14} R/cm^2
Monochromatic sensitivity, S, A/Wt	1.6	1,8	2,1	1,20	2,1	2,85	1,95	1,3
Volt-Watt sensitivity, J, V/Wt	2,5·10^4	2,8·10^4	3,1-10^4	2,2·10^4	4,5-10^4	5,2-10^4	4,0·10^4	2,5·10^4
Integral sensitivity, J_1, mA/lm	11,0	12,5	16,2	1,0	15,3	18,2	14,5	12,5

Photoelectric parameters	Pulse gamma-neutron irradiation				Gamma-neutron irradiation			
	Before irradiation	After irradiation			Before irradiation	After irradiation		
		5,0·10^{11} n/cm^2	3,5·10^{12} n/cm^2	1,2·10^{14} R/cm^2		10^6 R	10^7 R	10^8 R
Monochromatic sensitivity, S, A/Wt	1,35	1,25	1,45	0,95	1,5	1,6	1,8	1,15
Volt-Watt sensitivity, J, V/Wt	3,2-10^4	3,1·10^4	3,8·10^4	2,9·10^4	1,9·10^4	1,95·10^4	2·10^4	1,7-10^4
Integral sensitivity, J_1, mA/lm	8,5	8,7	9,3	6,2	7,5	7,3	6,5	7,5

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