PERSPECTIVE PHOTORECEIVERS FOR VISIBLE AND NEAR INFRA-RED REGION OF A SPECTRUM

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The paper is devoted to development and investigation of radiation resistance of photodiodes on the basis of layered compounds GaSe, InSe, GaTe intended for visible and near IR-region of a spectrum. It is shown, that the change of photosensitivity of photodiodes under the influence of ionizing radiation is due to change of majority charge carriers lifetime. The radiation resistance of the investigated photodiodes is checked and an opportunity of their use under the condition of high radiation level is revealed.

At present stage of science progress one of the major problems is the creation photoreceivers, operating in 0,6-1,1 μm spectral range, efficient under the conditions high radiation.

Nowadays photoreceivers available for 0,6-1,1 μm spectral range do not fulfill the requirements for photoelectronic devices on radiation resistance. On the other hand the creation of photoreceivers on the base of non-expensive layered semiconductors gives opportunity of increasing efficiency, quality of devices and reducing manufacturing expenditures.

This work is devoted to creation and research of radiation resistance of photodiodes on the base of single crystals of gallium selenide, indium selenide and gallium telluride.

For fabrication of electron-hole junctons the methods of alloying and diffusion of compensating elements of tin and gold were used. The source characteristics of used single-crystalline samples of gallium, gallium telluride and indium selenide are given in Table 1.

Table 1. Characteristics of GaSe, GaTe and InSe single crystals

Parametrs	**Semiconductor materials**		
	GaSe	GaTe	InSe
Type of electrical conductivity at 300 K	P	p	n
Thickness of a sample, μm	100-500	100-500	100-500
Concentration of charge carriers at 300 K, cm^{-3}	10^{15}-10^{16}	10^{15}-10^{16}	10^{14}-10^{15}
Mobility of majority charge carriers at 300 K, $cm^2/V \cdot s$	30-450	40-600	200-1200
Specific resistance, Ω·cm	10-10^3	10-10^3	10-10^2
Width of the forbidden zone	1,95	1,45	1,24
Surface	No polishing is required		

Elsewhere [1] a development of physical basics of a design and technology of manufacturing of photodiodes on the base of gallium selenide, indium selenide and gallium telluride are described in detail. The investigated photodiodes had photo-sensitivity in the 0,45-1,1μm range of of a spectrum with maxima λ_{GaSe} = 0,63 μm , λ_{InSe} = 0,95 μm and λ_{GaTe} = 0,85 μm at room temperature and also had comparatively high photoelectric parameters.

The basic characteristic parameters of such photodiodes are given in Table 2.

Table 2 Characteristics of photodiodes on the base of GaSe, GaTe and InSe single crystals

Photo-diodes	Operation conditions for photodiodes			I, μA	S_{abs}, A/Wt	I, V/Wt	I_{int}, μA/lm	R, Ω
	U_{bias}, V	λ_{max}, μm	T,K					
Sn-p-GaSe	3	0,63	300	0,3	0,5-1,84	(2,1-4,1) 10^4	10,20	10^7
	5	0,55	300	0,04	0,3-080	(1,4-3,0) 10^4	3-15	
Au-n-InSe	3	0,95	300	0,04	0,1-4,0	(1,3-7,1) 10^4	10-20	10^5-10^6
	3	0,95	263	0,04	0,3-9,2	(2,9-9,1) 10^4	15-25	
Sn-p-GeTe	3	0,85	300	0,05	0,3-1,5	(1,0-3,3) 10^4	3-10	10^5-10^7
	5	0.85	300	0,05	0,5-2,2	(1,5-4,5) 10^4	5,12	

Both after and during an irradiation with low energy electrons with 6 MeV energy (fluence $10^{12} \div 10^{16}$ cm^2) and gamma-quanta (fluence $10^5 \div 10^8$ R), high-energy electrons with 25 MeV energy (influence $10^{12} \div 10^{14}$ cm^2), neutrons ($10^{11} \div 10^{14}$ cm^2) current-voltage and spectral characteristics of photodiodes on the base of gallium selenide, indium selenide and gallium telluride were measured. Thus the changes of monochromatic, integrated and volt-watt sensitivity of photodiodes were checked. Besides the times of loss of operating ability of photodiodes were determined during pulse irradiation using restored values of signal and noise voltage. Under the influence of penetrating radiation a wide range of changes of parameters of photodiodes create owing to change of the characteristics of semiconductor materials. The analysis of CVC of directly biased photodiodes irradiated with various particles shows that with increasing of irradiation fluence the direct and reverse current branches increase, in so doing factor of quality β sharply increases ($2 \leq \beta \leq 5$), which may be due to formation of surface conductivity channels. Increase of dark currents is connected with ionization effects in volume of the photodiodes.

On the basis of measurements of the spectral characteristics of photodiodes before and after different kinds of ionizing radiation it is established that the changes of photosensitivity of photodiodes on the a base GaSe, InSe and GeTe have identical character : at small fluences of irradiation the photosensitivity increases while large fluences result in reduction of photosensitivity.

With the purpose of study of the reason of photosensitivity changes of photo- diodes, majority charge carriers lifetime after irradiation by electrons with 25 MeV energy, pulse neutrons and gamma-quanta were measured. It is established, that with increase of integrated fluence of electrons with energy 25 MeV and pulse neutrons the dropping time of the photocurrent monotonously decreases, and low energy irradiation results in increasing of a dropping time of the photocurrent. Therefore it is possible to assume, that change in lifetime is one of the major factors, responsible for for variations in the photosensitivity of the irradiated photodiodes. During realization of investigations by pulse gamma-installation and pulse-reactor ossilloscope images of change of signal and noise voltage were detected simultaneously on two channels from two photodiodes for definition a time of loss of operating ability. As a result of measurements by pulse gamma-installation at effective pulse duration τ = 0,3-10,9 ns by the values of Uc with power $P\gamma=1,7.10^{10}$ R/s the time of loss operating ability of photodiodes on the basis of investigated compounds are $\tau_{TLS} \leq 0,05$ s. As a result of measurements on pulse reactor the following values have been found for τ_{TLM}:

$\tau_{TLM} \leq 1.8$ s for fluence of neutrons $\Phi_n = 3,08.10^{12}$ cm^2 by restoration Uc and $\tau_{TLM} \leq 0,01$ s by restoration U_{noise} for fluence of neutrons $\Phi_n = 3,35 . 10^{12}$ cm^2.

After 6-11 days of irradiation on the same photodiodes spectral distribution of sensitivity was measured. After an irradiation at small fluences their sensitivity increase and its maximum shifts longwave range of a spectrum. Accordingly, their monochromatic and volt-watt sensitivity increase, approximately in 2-3 times. On the other hand, it is not excluded the opportunity, that at small irradiation fluences mainly the redistribution of impurity of gold and tin may occur [2], owing to what the perfect and stable junction are obtained and the photosensitivity of photodiodes increases.

Low energy barriers existing in space between layers of layered materials promote migration of radiating defects with growth of radiation fluence. This, in its turn, facilitates process of formation of complexes of radiation and source defects in inter-layer space. In a consequence the formation of a new high-resistance layer take place, resulting in some degradation of photoelectric parameters with increasing of irradiation fluence. It must be noted, that under the influence of ionizing radiation in the above mentioned range of fluence on photoelectric properties of photodiodes on the base of GaSe, InSe, GaTe the change of values of the basic characteristic parameters does not exceed 30%. The results of the our investigations show, that the photoreceivers on the base of layered compounds GaSe, InSe, GaTe give a good opportunity for their use in systems, operating in visible and near infra-red region of a spectrum, in particular, in astronavigation.

REFERENCES

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