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RESEARCH OF PHYSICAL PROCESSES AND DEVELOPMENT OF METHODS FOR RADIATION MODIFICATION PARAMETERS OF SEMICONDUCTOR OPTOELECTRONICS DEVICES

Operation of solid-state electronics products in the field of ionizing radiation can significantly change their properties, contributing to their premature destruction or loss of technical characteristics necessary for normal operation of the equipment. The changes observed in this case are caused by a number of specific processes discussed above. Distinguish between reversible and irreversible changes.

Irreversible (residual) include radiation changes that remain partially or completely after the termination of exposure. The magnitude of radiation changes is determined by the amount of energy absorbed by materials when interacting with radiation, as well as the rate at which this energy is transferred to them. It depends on the type of radiation and its parameters (energy spectrum, flux density, intensity, etc.), as well as on the nuclear-physical characteristics of materials.

Criteria for the radiation resistance of photodetectors. The criterion for the parametric reliability of photodetectors is formulated on the basis that the object under consideration degrades its parameters gradually, both with an increase in the duration of exposure and the dose of radiation. The purpose of the photodetectors, the imposed restrictions on the criterion of their performance, as well as the physics of the effect of radiation, allow us to consider photodetectors as an object functioning under noise conditions. This allows statistical analysis methods to be applied. With this approach, we can use a well-studied mathematical apparatus for testing statistical hypotheses. Three criteria of radiation resistance of photodetectors are proposed. The first is the signal-to-noise ratio in the interpretation of sufficient statistics, the second is the criterion for the average detection error (Kotelnikov's criterion), and the third is the Bayesian risk criterion. This article examines the physical processes and the development of methods for radiation modification of the parameters of semiconductor optoelectronic devices.

Keywords: solid-state electronics, radiation changes, statistical methods of analysis, photodetectors

Introduction. At present, practically all branches of industry, many branches of science use sources of ionizing radiation (IR). Nuclear power plants, gamma plants of various capacities, flaw detectors, counters and many other equipment are widely used in the defense complex, medicine, agriculture. However, the most important sector of the use of IR in Ukraine after the elimination of nuclear combat potential is nuclear power [1]. The country has five nuclear power plants (NPP) with reactors of two types, which generate about 40% of the country's total electricity [2].

In this regard, the problems of dosimetry, which today have become an independent scientific and technical area of nuclear physics, are acquiring ever increasing importance. Dosimetry, in its essence, solves the problem of linking physical quantities with the expected radiation effects of use IR. The main task of dosimetry - the identification sources of radiation, posing a threat to the environment and humans - today is solved using a variety of technical registration tools with varying degrees of efficiency. A comparative analysis of such means and methods of their application for registration and dosimetry is presented in this section [3]. In addition, the existing variety of terms and values in this industry requires some clarification in order to ensure the reliability of presented research results.

Analysis of previous studies. The level of development and application of radiation technologies is largely determined by the state of nuclear instrumentation. In a relatively short period of time, this industry went through several stages of development, and each of them was marked by the emergence of various devices that register and measure the parameters of ionizing radiation: gas-discharge counters, scintillators, semiconductor detectors, and others. Their appearance and further widespread use was provided in the past by works from Crookes, Rutherford, Geiger and Müller to the works which are closer to us in time Dmitriev A.B., Perelman S.N., Tchaikovsky V.G. and Baranov V.G., Golbek G.R., Nemirovsky B.V., Yakubovich A.L. and many others. The basis for the progress of nuclear instrumentation was the simultaneous development of two areas - nuclear physics research and electronics. However, both directions at that time developed independently, without proper mutual connection.

The advent of modern semiconductor sensors for the first time linked nuclear instrumentation and electronics into a single complex - semiconductor detector. It combines semiconductor primary converter of ionizing radiation (sensor), secondary converter of information from the sensor (electronics) and software for processing this information, interconnected in terms of the problem being solved and parameters. The possibility of appearance such a complex is provided in materials science by the works of Vavilov V.S., Baransky P.I., in applied nuclear physics research - Maksimov M.V., Maslov O.V. and others. In these works, a technique was shown for the selection of semiconductor materials and a design of sensors was proposed, directions for the creation of electronics and computer programs for detectors were determined. This ensured the creation and effective use of semiconductor detectors in dosimetry, radiation control of materials and technological processes of nuclear power plants.

However, the development of nuclear energy, spread nuclear technologies have put forward new requirements for the control and metrology of ionizing radiation. The modern level of nuclear instrumentation cannot fully satisfy them. The solution to this problem can be provided by the development of: methods for choosing the optimal type of semiconductor materials and controlling their properties to create uncooled detectors; sensors with higher resolution; electronics with less noise; computer methods and information processing programs with lower estimated costs; control systems for nuclear materials and the state of NPP protective barriers that meet the requirements of the existing automatic control of radiation safety (ACR).

Main part. The problem of detecting a signal in noise is reduced to a particular algorithm for testing the hypothesis H_I of the presence of a signal in the noise $U_ш^{\Sigma}$ against a simple alternative H_0 - only noise $U_ш^0$ is present.

Under conditions of ionizing radiation, the total output noise $U_ш$ is an additive mixture of all noise sources arising in the circuits of photodetectors, which leads to a difference in dispersions $U_ш^{\Sigma}$ and $U_ш^0$. This is due to the influence of radiation, which changes not only the noise level, but also the characteristics of semiconductor devices, which in turn leads to additional noise.

Photodetectors based on $Cd_{1-x}Hg_xTe$ solid solutions (CHT). Photodetectors based on solid solutions have found wide application for the spectrum range of 8-14 μm, which, in contrast to photodetectors based on impurity germanium or silicon, can provide high sensitivity at T = 80 K.

The main parameter of photodetectors is the detectivity at maximum spectral sensitivity $\lambda_{\max}$:

$$D^*_{\lambda_{\max}} = S_i\left(\lambda_{\max}\right) \cdot A^{\frac{1}{2}} \cdot i_ш^{-1} \quad , \tag{1}$$

where $S_i\left(\lambda_{\max}\right)$ – is current sensitivity at $\lambda_{\max}$; $i_ш$ - noise current in a single frequency band; A - is sensitive surface area.

The maximum achievable value of detectivity is determined by the dominant noise of the photodetector. In ideal photodetectors, the detectivity is limited by radiation fluctuations (LM mode). To ensure LM mode, it is necessary to reduce the level of excess noise to a minimum by improving the technology and generation-recombination noise caused by thermal radiation. The LM mode will be achieved in the case of predominance the generation-recombination noise caused by optical excitation (from the background) over all other noises.

For an *n*-type CHT material with x=0.2 and with an electron density close to its own, the lifetime of charge carriers at T=77 K, and limiting background illumination, it is possible to achieve detectability values

$$D^* = 2.2\cdot 10^{12}\cdot \eta,\ \mathrm{sm\cdot Hz^{1/2}\cdot Wt^{-1}}\ , \qquad (2)$$

where η - is the quantum efficiency at $\lambda = 10$ mkm.

The implementation of photodetectors (PD) based on CHT is associated with the development of three areas: the creation of photoresistors, photodiodes, and MDP-structures. Photodiode radiation receivers are used mainly for receiving short pulses $\tau_{imp} \prec 10^{-9} \div 10^{-8}\ s$, and MDP-structures are used for receiving IR-images in the time delay and accumulation mode (CCD-receivers). The most widespread are photoresistor receivers based on CHT of the electronic type of conductivity (table 1).

Table 1

Parameters of photoresistive receivers based on CHT (T = 77 K)

Spectral range, Δλ, mkm	Photoresistor resistance, R_T, Om	Detectivity, D^*, $\mathrm{sm\cdot Hz^{1/2}\cdot Wt^{-1}}$	Threshold sensitivity in heterodyne mode, P_{thr}, $\mathrm{Wt\cdot Hz^{-1}}$	Inertia, t, c
9,5 ÷ 12	22 – 110	$(3,9\div 9)\cdot 10^{10}$	-	$1,6\cdot 10^{-6}$
10,5	-	$3\cdot 10^{10}$	-	-
3 ÷ 15	До 10^3	$(0,1\div 6)\cdot 10^{10}$	-	$4\cdot 10^{-6}$
8 ÷ 14	-	$5\cdot 10^{10}$	-	$1\cdot 10^{-8}$
10,6	200 ÷ 400	-	$7\cdot 10^{-20}$	$(0,5\div 2,5)\cdot 10^{-7}$

Model of the mechanism radiation modification photoresistors.

The results of radiation action on photosensitive elements based on this solid solution can be estimated from changes in the photoresponse signal [4-6]. For a photoresistor in idle mode, when the load resistance is much greater than the resistance of photoresistor, and small signals in a semiconductor with an electronic type of conductivity, photoresponse is determined by the formula:

$$\frac{\Delta U}{U} = \frac{\Delta\sigma}{\sigma_T} = \frac{G\left(\tau_n\mu_n + \tau_p\mu_p\right)}{n_T\,\mu_n}\ , \qquad (3)$$

where U - is offset on the photodetector; ΔU - voltage change at the photodetector when it is illuminated; σ_T - dark electrical conductivity of the semiconductor; $\Delta\sigma$ - photoconductivity; G - the rate of generation charge carriers; n_T - is dark concentration of electrons; τ_n, τ_p, μ_n, μ_p - are the lifetime and mobility of electrons and holes, respectively.

For CHT $\mu_n \succ\succ \mu_p$, therefore (3) will take the form:

$$\Delta U = \frac{G\tau U}{n_T} \cdot \qquad (4)$$

As follows from (4), the signal taken from the photoresistor is proportional to the bias. This is true for the value $U_n \approx \frac{\ell^2}{\tau\mu_p}$ (ℓ - distance between the contacts), at which the conditions for the passage of minor charge carriers through the photoresistor are realized. At $U \succ\succ U_n$, the signal voltage saturates and does not depend on the offset value:

$$\Delta U = \frac{G\ell^2}{n_T \mu_p} \cdot \qquad (5)$$

The lifetime of charge carriers is determined by the recombination mechanism and in narrow-gap semiconductors, which include CHT, depends on the carrier concentration. In this material, the Auger recombination mechanism dominates, and the lifetime is [7, 8]:

$$\tau_{A_0} = 4\tau_i \left(\frac{n_i}{n}\right)^2, \qquad (6)$$

where τ_i, n_i - are the lifetime and concentration of charge carriers in the intrinsic material ($Cd_{0,2}Hg_{0,8}Te$ $\tau_i = 3{,}3 \cdot 10^{-4}$ s, $n_i = 3 \cdot 10^{13}$ sm^{-3} at 80 K); $\tau_{ШР}$ - the actual value of concentration.

In an irradiated material, the lifetime changes:

$$\tau_A = 4\tau_i n_i^2 \left(n_0 + \frac{dn}{dF}F\right)^{-2},$$

where n_0 - is the initial value of carrier concentration in sample; $\frac{dn}{dF}$ - average rate of introduction of carriers during irradiation; F - integral flux of ionizing radiation.

Comparison (4) - (6) shows that of the two operating modes of photoresistor, from the point of view of radiation resistance, the minority carrier transit mode is preferable.

The relative change in voltage across the photoresistor in the latter case is [9]:

$$\frac{\Delta U}{\Delta U_0} = n_0^3 \left(n_0 + \frac{dn}{dF}F\right)^{-3} \cdot \qquad (7)$$

When irradiated $n-Cd_{0,2}Hg_{0,8}Te$ ($n_0 = 1 \cdot 10^{15}\ sm^{-3}$) by electrons with an energy of 5MeV with an integral flux $F = 1 \cdot 10^{14}\ sm^{-2}$, it was found that at 80 K $\frac{dn}{dF}$ =6,3 sm^{-1} [10]. Substituting these values into (7), we obtain that $\frac{\Delta U}{\Delta U_0} = 0{,}35$, and in the transit mode of minority carriers, signal change under the same conditions is half as much.

In samples $n - Cd_{0,2}Hg_{0,8}Te$ irradiated with fission neutrons at 80 K, lifetime of charge carriers is limited by the simultaneous action of Auger recombination and Shockley-Read recombination mechanisms. The dose dependence of the lifetime $\tau_{ШР}$ during Shockley-Read recombination is determined by a semi-empirical expression:

$$\tau^{-1} = \tau_0^{-1} + K_\tau \cdot F \ , \tag{8}$$

where "0" is an index referring to the value of parameter before irradiation; K_τ - coefficient of radiative change in the lifetime of minor charge carriers.

The relative change in the signal caused by ionizing radiation, taking into account (4), will take the form:

$$\frac{\Delta U}{\Delta U_0} = \tau \cdot n_0 \cdot \tau_0^{-1} \cdot n^{-1}. \tag{9}$$

For the mode of flight of minority carriers at $K_\tau = 3{,}5 \cdot 10^{-9}$ sm^2/neutron.·s, $F = 10^{14}$ sm^2/neutron and $\frac{dn}{dF} = 3$ sm^{-1} experimentally determined during irradiation with fission neutrons, we obtain $\frac{\Delta U}{\Delta U_0} = 0{,}83$ [11].

It should be borne in mind that for the above estimates of changes in the parameters photoresistor, data on changes in the bulk properties of an ideal semiconductor material are used. Any real semiconductor contains impurities and violations of the crystal structure. The general theory describing their influence on the concentration, mobility and lifetime of charge carriers, i.e. on the physical characteristics that determine the main parameters of photoresistors, with the simultaneous introduction of radiation defects, has not yet been created. Therefore, prediction of radiation resistance, taking into account impurities and defects, is possible only for materials in which the nature of impurities (defects), the energy levels created by them, their effect on the physical properties of a substance, and also change in these properties under the action of ionizing radiation have been experimentally established. The complexity of such a task makes it necessary to evaluate the radiation resistance of photodetectors on the basis of statistical methods of analysis.

Radiation control of photoresistors. Irradiation with fast electrons.

The irradiation of these devices with fast electrons $Cd_{0,2}Hg_{0,8}Te$ and the measurement of their parameters were carried out under the conditions described earlier. Photoresistors based on before and after irradiation were studied. In this case, the dark current I_{T_0} and resistance R_{T_0} were considered at the supply voltage U.

Analysis of the data obtained allows us to conclude:

- electron irradiation with doses of 10^{13}-10^{16} sm^{-2} leads to a decrease in dark resistance and an increase in dark current;
- relative change of these parameters is greater with decreasing temperature;
- for irradiation doses greater than 10^{15} sm^{-2}, the rate of relative change in parameters of photoresistors decreases.

The noted changes in the parameters can be explained by the formation of traditional donor-type defects in the material $Cd-Hg-Te$, as a result of which the concentration of free electrons[2,4].

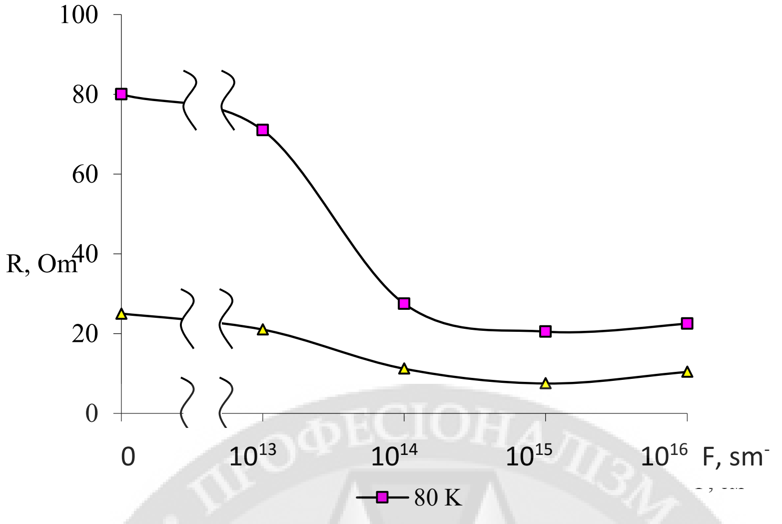

Figura 1 – Dependence of the dark resistance photoresistor on dose of electron irradiation

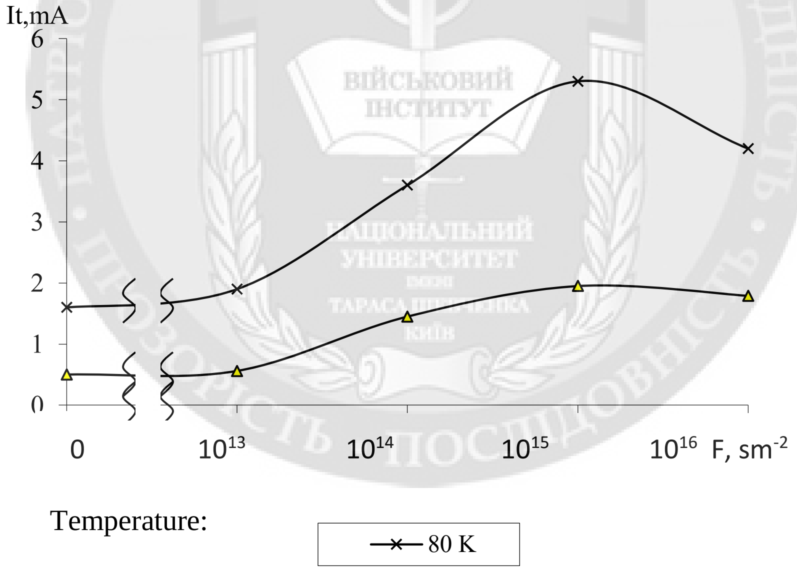

Figura 2 – Dependence of the dark current photoresistors on dose of electron irradiation

The number of such defects is predetermined by the number of mercury vacancies in the interstices of CHT-crystal lattice. Therefore, change in concentration of charge carriers introduced by irradiation, and hence the value of dark resistance, are limited by the concentration of mercury vacancies.

To clarify the mechanisms of degradation properties IR-photoresistors, the influence of ionizing radiation various types on parameters of a single-crystal compound $Cd_{0,2}Hg_{0,8}Te$, on the basis of which they are made, was studied.

Irradiation with gamma quanta.

Features of the photoresistor production technology do not allow achieving full compliance of the parameters of photosensitive elements (dark and light resistance, slope of the lux-ohmic characteristic, inertia) with the specified values. About 20-30% of the assembled devices do not meet the technical specifications. In this regard, the search for ways to adjust the parameters of devices to these standards is relevant. For this purpose, the effect of gamma irradiation Co^{60} on the main parameters of photoresistors based on CHT was studied. In this case, radiation doping is used as a method for the controlled introduction of defects responsible for the photosensitivity of the material.

Gamma irradiation was chosen by the authors as the most promising for these purposes due to its high penetrating power. This makes it possible to simultaneously irradiate a large number of photoresistors, does not induce residual radiation, and can change the concentration and energy spectrum of local centers. The dose rate of gamma radiation acting on the photoresistors was chosen to be 1000–6000 rad/s (E = 1.7 MeV), and the exponential dose varied from 10^4 to 10^{10} rad. The temperature of the photoresistors during irradiation did not exceed 30^0C, which was achieved by forced air blowing. It was found that the parameters R_T, $R_{св}$, $tg\alpha$, τ_H, τ_{sm} were the most sensitive to gamma radiation.

Lux-ohmic characteristics of photoresistors after gamma irradiation are shown in fig. 2. It can be seen from it that parameters of the photoresistor change even at a dose of Co^{60} rad. Simultaneously with the decrease R_T, there is a decrease $R_{св}$. However, the relative change $\frac{1}{R_{св}}$ in magnitude predominates. This indicates an increase in the photosensitivity of devices as the dose is accumulated [11, 12]. In this case, a non-linear decrease in the relative changes in and occurs R_T and $R_{св}$ a tendency to saturation is observed.

The initial rate of change is proportional to the intensity of gamma irradiation. Its influence on the slope of the lux-ohmic characteristic $tg\alpha$ is described by the formula:

$$tg\alpha = \frac{\ell gR_1 - \ell gR_2}{\ell gE_1 - \ell gE_2}, \tag{10}$$

where R_1 and R_2 - are the resistances at illumination E_1 and E_2, respectively.

The change in this parameter begins with a dose of $5\cdot10^4$ rad. Annealing at a temperature of 40-45 ^{0}C for 40-45 hours leads to (15-20)% restoration of parameters, as well as natural aging within 120-150 hours after the cessation of radiation.

Injection laser and light emitting diodes based on A_3B_5 compounds. The current-voltage characteristic of such devices is the most informative. Its form is determined by such important parameters of the diode as the contact potential difference and the resistance of high-resistance region, which is most sensitive to external influences. The slope of the current-voltage characteristic plotted in coordinates determines the mechanism of charge carrier scattering. By the nature of its change, one can judge the mechanism of effect irradiation on properties of source material and the device itself.

Laser diodes based on indium-gallium-arsenic-phosphorus solid solution are a new type of devices. There is no information in the literature about the effect of irradiation on their properties. In the work of the authors, irradiation with electrons with an energy of 2.4 MeV was carried out with doses from 1013 to 1015 cm-2. Studies have shown that as the dose increases at fixed voltages, the current through the diodes increases.

The following procedure was used to determine the threshold voltages of laser diodes.

On the graph of the dependence of the voltage of the photodiode - the laser radiation receiver - on the voltage of the rectangular pulse generator, we draw two straight lines: the first is tangent at the starting point, and the second coincides with the linear section.

The threshold voltages of the diodes obtained by this method lie in the range from 4.5 to 5.5 V and did not change during electron irradiation with doses from 10^{13} to 10^{15} sm^{-2}.

Thus, based on the results of studying the effect of irradiation with electrons with an energy of 2.4 MeV on the characteristics of laser diodes based on a quaternary solid solution of indium-gallium-arsenic-phosphorus and LED based on gallium phosphide, the following conclusions can be drawn [13, 14]:

1. Treatment with doses from 10^{13} to 10^{15} sm^{-2} reduces the resistance of the diodes and changes the slope of the current-voltage characteristic (in a semi-logarithmic scale) from 2.49 to 2.11.

2. The threshold voltage of laser radiation generation does not change under electron irradiation with doses from 10^{13} to 10^{15} sm^{-2}.

Conclusions. 1. Irradiation with low doses of electrons leads to the following effects in transistors based on epitaxial silicon layers: there is a tendency to increase the breakdown voltage, shape of breakdown region changes; the gain is reduced by approximately 5-15%.

2. Radiation processing by fast electrons of integrated temperature sensors leads to an increase in the modulus of the voltage temperature coefficient, and, consequently, to an increase in their sensitivity. The technology of radiation processing by fast electrons in order to increase TKU consists in irradiating temperature sensors on the linear electron accelerator ELU-4.

3. The radiation resistance of microassemblies treated with fast neutrons is higher (10^{16} sm^{-2}) compared to their resistance when treated with fast electrons (10^{15} sm^{-2}). The radiation resistance of microassemblies is determined by: a small change in the main parameters (with the exception of U_{cm}) ; changing the on and off currents of the output transistor; a decrease in transfer coefficient of the base current; high radiation resistance of operational amplifiers (op-amps) included in the assembly.

The difference in the radiation resistance of microassemblies when irradiated with fast electrons and fast neutrons is explained by the fact that action of electrons is accompanied by heating of the product, due to their deceleration in the structural elements.

4. Irradiation of photodetectors based on MCT changes their characteristics: threshold sensitivity (to increase it, it is necessary to decrease the concentration of the main charge carriers and increase the quantum efficiency), inertia (to reduce it, it is necessary to reduce the lifetime of charge carriers) and the region of spectral sensitivity of photodetector.

5. Electron irradiation with an energy of 2.4 MeV laser diodes based on a quaternary solid solution of indium-gallium-arsenic-phosphorus and LEDs based on gallium phosphide showed that treatment with doses from 10^{13} at 10^{15} sm^{-2} reduces the resistance of the diodes and changes the slope of current-voltage characteristic (on a semi-log scale) from 2.49 to 2.11. The threshold voltage of laser radiation generation does not change under electron irradiation with doses from 10^{13} до 10^{15}sm^{2}.

These physical results were unexpected, since it was known that the irradiation of gallium arsenide diode lasers with high-energy electrons leads to a deterioration in their properties, the restoration of which was observed only after prolonged heating to 400-450^{0}C.

REFERENCTS:

1. Vavilov V.S. Effect of radiation on semiconductors / V.S. Vavilov, N.P. Kekelidze, L.S. Smirnov. - Moscow: Nauka, 1988 .-- 192 p.

2. Lenkov S.V. Physical and technical foundations of radiation technology of semiconductors / S.V. Lenkov, V.A. Mokritsky, D.A. Peregudov, G.T. Tarielashvili. - Monograph. - Odessa: Astroprint, 2002,297 p.

3. Garkavenko A.S. Radiation modification of the physical properties of wide-gap semiconductors and the creation of high-power lasers on their basis / Lvov: ZUKTs, 2012. - 258 p.

4. Banzak OV New generation semiconductor detectors for radiation monitoring and dosimetry of ionizing radiation / O.V. Banzak, O.V. Maslov, V.A. Mokritsky. - Monograph. - Odessa, 2013. - Publishing house "VMV". - 220 p.

5. Bouchet J.M. PWR primary flow masurements by correlation analysis of nitrogen-16 fluctuations / J.M. Bouchet, et al. – Progress in Nuclear Energy. – 1982. – Vol. 9.

6. Awadalla S.A. Characterization of detector-grade CdZnTe crystals grown by traveling heater method (THM) / S.A. Awadalla, J. Mackenzie, H. Chen, eds. // Journal of Crystal Growth. – Vol. 312, issue 4. – 2010. – 507-513c.

7. Grybos P. Front-end Electronics for Multichannel Semiconductor Detector Systems; EuCARD Editorial Series on Accelerator Science and Technology, Vol.08 / Institute of Electronic Systems Warsaw University of Technology . – Warsaw: 2010. – 201 p.

8. Dumitrescu A. Comparison of a digital and an analogical gamma spectrometer at low count rates / A. Dumitrescu // U.P.B. Sci. Bull., Series A. – Vol. 73. – Iss. 4, 2011. – P. 127-138.

9. Maslov O. Passive Computer Gamma- Tomography of Nuclear Fuel / O. Maslov, V. Mokritsky, O. Banzak, // ANIMMA. Third International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications – Marseille, June 23-27, 2013. – Book of Abstracts – P. 51.

10. Maslov O.V. The Improved CdZnTe Dose Rate Probe / O.V. Maslov, M.V. Maksimov, L.L. Kalnev // 2008 IEEE Nuclear Science Symposium, Medical Imaging Conference and 16th Room Temperature Semiconductor Detector Workshop – Dresden: 19–25 Oct. 2008. – P. 12-87.

11. Maslov O. Multiple energies passive computer tomography of nuclear fuel / O. Maslov // Proceedings of the International Ukrainian-Japanese Conference on Scientific and Industrial Cooperation – Odesa 24 – 25 October 2013. – P. 114-116.

12. Masuruk K. Dopant incorporation during liquid phase epitaxy / K. Masuruk, T.Bryskewicz // J. Appl. Phys., 1981. – V. 52. – N3. – part 1. – P. 1347–1350.

13. Mokritsky V.A., Maslov O.V., Bansak O.V. Methods and means controls of nuclear materials and state of protective barriers at nuclear power plants // Collection of scientific works of the Military Institute of the Taras Shevchenko National University of Kyiv. - К .: MIKNU, 2019. - № 63. – С. 66 – 72.

14. Mokritskij V.A., Maslov O.V., Banzak O.V. The detector on basis of CdZnTe-gauge for systems radiating-technological control // Collection of scientific works of the Military Institute of the Taras Shevchenko National University of Kyiv. - К .: MIKNU, 2018. - № 58. - С. 68-73.

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ДОСЛІДЖЕННЯ ФІЗИЧНИХ ПРОЦЕСІВ І РОЗРОБКА МЕТОДІВ РАДІАЦІЙНОЇ МОДИФІКАЦІЇ ПАРАМЕТРІВ НАПІВПРОВІДНИКОВИХ ПРИЛАДІВ ОПТОЕЛЕКТРОНІКИ

Експлуатація виробів твердотільної електроніки в полі іонізуючих випромінювань може істотно змінювати їх властивості, сприяючи передчасному руйнуванню або втраті необхідних для нормальної роботи апаратури технічних характеристик. Спостерігаються у своїй зміни або зумовлюються низкою специфічних процесів, розглянутих вище. Розрізняють оборотні та незворотні зміни. До необоротних (залишкових) відносять радіаційні зміни, що зберігаються частково або повністю після припинення опромінення. Величина радіаційних змін визначається кількістю енергії, що поглинається матеріалами при взаємодії з випромінюванням, а також швидкістю, з якою ця енергія передається. Вона залежить від виду випромінювання та його параметрів (енергетичного спектра, щільності потоку, інтенсивності та ін.), а також від ядерно-фізичних характеристик матеріалів. Критерії радіаційної стійкості пристроїв, що фотоприймають. Критерій параметричної надійності пристроїв, що фотоприймають сформульований, виходячи з того, що об'єкт, що розглядається, погіршує свої параметри поступово як при збільшенні тривалості впливу, так і дози випромінювання. Призначення пристроїв, що фотоприймають, обмеження, що накладаються на критерій їх працездатності, а також фізика впливу радіації дозволяють розглядати пристрої, що фотоприймають як об'єкт, що функціонує в умовах шуму. Це дозволяє застосувати статистичні методи аналізу. За такого підходу ми можемо використовувати добре вивчений математичний апарат перевірки статистичних гіпотез.

Пропонуються три критерії радіаційної стійкості фотоприймальних пристроїв. Перший – відношення сигнал/шум у трактуванні достатніх статистик, другий – критерій середньої помилки виявлення (критерій Котельникова) та третій – критерій Байєсовського ризику.

У цій статті розглянуто фізичні процеси та розробку методів радіаційної модифікації параметрів приладів напівпровідникових приладів оптоелектроніки.

Ключові слова: твердотільна електроніка, радіаційні зміни, статистичні методи аналізу, фотоприймальні пристрої.