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Research Article

The resistance of leds to the effects of gamma radiation in various operating modes

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Abstract

The effect of active and passive power modes on the resistance of the LEDs (LEDs) made of multilayer AlGaAs heterostructures to gamma-quantum irradiation was studied. Three characteristic stages of emission power reduction during irradiation are distinguished for the studied LEDs irrespective of the power supply mode. When irradiating LEDs in the active power supply mode, two differently directed processes of changes in the emission power are observed. The assumption is made that the first process is caused by a decrease in the LED emission power due to the injection of appropriate radiation defects. The second process is caused by a partial recovery of the emission power due to radiation, radiation-thermal, and/or electrostimulated annealing of some of the defects created. The observed recovery of the emission power in the active power mode of the LED during irradiation significantly increases its resistance to gamma-ray irradiation.

Introduction

LEDs are widely used in almost all branches of science and technology, including fiber-optic communication lines, integrated optoelectronic devices, open-channel optical communication systems, medical instrumentation, etc. At the same time, various LED-based devices very often operate under harsh conditions [1-3]. In particular, LED-based devices are exposed to various types of ionizing radiation and operational factors in the conditions of space and nuclear power facilities. High responsibility and harsh operating conditions of LED-based devices are the main reasons for the study of relevant degradation processes.

During operation, the LEDs can be in different power modes. In this case, we can distinguish between passive (without passing operating current) and active power modes, in which a direct electric current flows through the LED and there is a separation of electron-hole pairs generated in the active layer of the LED under various external influences.

On the other hand, the rates of introduction of radiation defects into the neutral volume of the semiconductor structure and into the region where the separation of electron-hole pairs occurs and the induced current appears can differ significantly under the action of ionizing radiation [4,5].

The flow of direct current during the operation of the LED in

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continuous power mode leads to an increase in the temperature of its active layer, which may result in the thermal annealing of introduced defects [6].

The most currently studied LEDs are based on AlGaAs heterostructures [7,8].

The purpose of this work is to study the regularities in the change in the emission power of LEDs in the IR wavelength range, fabricated based on AlGaAs heterostructures when irradiated with gamma rays in passive and active power modes.

Objects and research methods

The objects of study in this work are industrial LEDs in the IR range, fabricated based on a multilayer AlGaAs heterostructure. The production technology is described in detail in the work [9].

The fabricated crystals were mounted in an optical compound, which additionally had a lens to form a directed beam of radiation. Since the results of preliminary studies showed that the used optical compound does not change its optical properties when exposed to gamma rays up to the absorbed dose $D\gamma = 5 \cdot 10^6$ Gy, all changes in the LED optical properties as a result of irradiation can be explained only by changes in the optical properties of the LED active element (crystal).

In this paper, we used the watt-ampere characteristic (P-I) as the main lighting characteristic of the LEDs, which determines the dependence of the LED emission power on the operating current. An automated measuring complex based on a photometric sphere was used to measure the P-I characteristic, which allows determining the direct voltage of the LED in the range from 0 V to 5 V for the range of direct currents 0 - 500 mA in increments of not less than 1 mA. This device is designed to measure the direct voltage drop across the LED and the dependence of the emission power of the LED on the value of the direct current through it. The structural scheme of the measuring complex is shown in Figure 1.

The LEDs were irradiated with gamma-quanta on a stationary isotopic unit (^{60}Co) under normal conditions in different power modes. The level of gamma-quantum exposure was characterized by the absorbed dose Dγ(Gy(Si)).

A special cassette was made to supply bias voltage during irradiation in order to perform irradiation with different LED power modes. Passive and active LED power modes were used during irradiation:

- Passive mode (LED1) - open circuit, LED electrical outputs are open. In this case, there is no space charge region and induced current (this mode is typical for LED storage);

- Active mode (LED2) - direct current transmission Iop = 50 mA.

A separate sample with at least 10 LEDs was used for each power mode. The results of the experiment were statistically processed using OriginPro 2015 (OriginLab Corporation, Northampton, MA, USA).

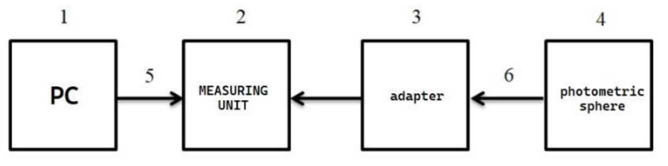

Figure 1: Structure scheme of measuring device: 1 - a computer with necessary software; 2 - measuring unit; 3 - adapter; 4 - photometric sphere; 5 - RS232 cable; 6 - cable.

Results and discussion

As a result of gamma-ray irradiation, both catastrophic and parametric LED failures due to various causes have been observed. The analysis of catastrophic failures is a subject of a separate study due to the need for special equipment and appropriate methods of analysis.

For more efficient analysis of changes in LED parameters during irradiation, we used the normalized change in LED emission power, which is defined as follows:

$$\frac{P_\gamma(I_{op})}{P_0(I_{op})} = F(D_\gamma) \quad (1)$$

Where P_0 (I_{op}) and $P\gamma$ (I_{op}) are the emission powers of the LEDs, measured at a given operating current before and after irradiation with gamma rays *Dγ.*

The use of such normalization of LED emission power makes it possible to compare the results of LED studies with different initial individual characteristics.

Figure 2 shows the change in the normalized emission power of LED1 when they are irradiated with gamma rays in the passive mode. The presented results of LED1 studies allow us to distinguish three characteristic stages of power change:

Stage I: $D\gamma < 3 \cdot 10^5$ Gy;

Stage II: $3 \cdot 10^5$ Gy < $D\gamma$ < $2 \cdot 10^6$ Gy, characterized by a sharp drop in the emission power at the beginning and a partial recovery of the power at the end;

Stage III: $D\gamma > 2 \cdot 10^6$ Gy, characterized by partial recovery of emission power with subsequent recession and appearance of catastrophic failures.

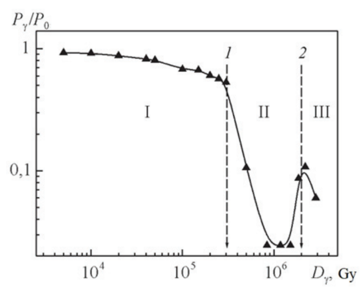

Figure 2: Normalized change in the emission power of the LED1 measured at Iop = 50 mA at gamma-quantum irradiation in the passive mode; symbols are experimental data; lines are established regularities; I, II, and III have selected stages of the emission power changes; vertical arrows are boundaries between selected stages.

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Consider the change in the normalized emission power of LED2 during irradiation in the active power supply mode, which is shown in Figure 3.

Figures 2,3 show that in the active mode of LED, there is a significant increase in the resistance when irradiated with gamma rays as compared to irradiation in the passive mode of power supply. Figure 3 also highlights the three stages of emission power reduction.

Let us consider in more detail the change in the emission power for LED2 at stage I. The following relation can describe the observed pattern of change in power for stage I:

$$\frac{P_\gamma}{P_0}(I) = 1 - k_I \cdot D_\gamma \text{ at } D_\gamma \le 3.4 \cdot 10^5 \text{ Gy} \quad (2)$$

Where P_γ/P_0 (I) is the change in normalized emission power of LED2 at stage I of power decrease; $k_I = 7 \cdot 10^{-7}$ Gy^{-1} is the damage coefficient of LED2 at stage I of power decrease.

$$\frac{P_\gamma}{P_0}(II) = B - k_{II} \cdot D_\gamma \text{ at } 3.4 \cdot 10^5 \text{ Gy} \le D_\gamma \le 3 \cdot 10^6 \text{ Gy} \quad (3)$$

Where B = 0.82 - proportional coefficient, whose value is determined by the stage II contribution to the total emission power decrease; $k_{II} = 2.2 \cdot 10^{-7}$ Gy^{-1} - II stage damage factor of LED2.

At $D\gamma > 3 \cdot 10^6$ Gy, stage III appears, which is characterized by unstable LED performance and the appearance of catastrophic failures.

Two simultaneous multidirectional processes can describe the observed increase in the resistance of LED2 compared to LED1. The first one is related to the reduction of the emission power because of irradiation due to the introduction of radiation defects. The second is a partial recovery of the emission power due to radiation, thermal, and/or electrostimulated annealing of the introduced radiation defects. As the irradiation dose increases, the process of generating radiation defects becomes predominant, which leads to a decrease in the power of the LEDs. Similar phenomena have been observed in other works [10-12].

The results of these studies do not allow us to make assumptions about the nature (structure) of the defects that are involved in the processes described above. The study of the structure of these defects is the subject of separate investigations.

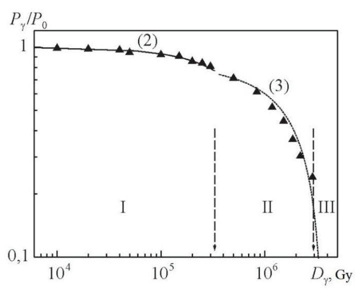

Figure 3: Normalized change in the emission power of the LED2 measured at Iop = 50 mA at gamma-quantum irradiation in the active mode; symbols are experimental data, lines are established regularities; I, II, and III are selected stages of the emission power changes; vertical arrows are boundaries between selected stages.

Conclusion

The influence of active and passive power modes on the resistance of the LEDs fabricated based on a multilayer AlGaAs heterostructure, to gamma-quantum irradiation.

For the investigated LEDs, regardless of the irradiation supply mode, three characteristic stages of emission power reduction are distinguished. The second stage is characterized by a higher damage coefficient and the third stage is characterized by the appearance of catastrophic failures.

Two simultaneous differently directed processes describe the increase in the resistance of LEDs in the active power mode compared to LEDs in the passive power mode under gamma-quantum irradiation. The first process is due to a decrease in the emission power because of the introduction of radiation defects during irradiation. The second process is a partial recovery of the emission power due to radiation and/or electrostimulated annealing of part of the created defects.

The relations that describe the reduction of LED power in the active power supply mode during gamma-ray irradiation were established, three characteristic stages were identified and their boundaries were determined.

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References

1. Weide-Zaage K, Chrzanowska-Jeske M. Semiconductor devices in harsh conditions, CRC Press. 2016; 256.
2. Schubert EF. Light-Emitting Diodes (3rd edition), Rensselaer Polytechnic Institute, New York. 2018; 672.
3. Wilcoxon R. LEDs in Harsh Environments. Solid State Lighting Technology and Application Series. 2013; 499-518. DOI: 10.1007/978-1-4614-5091-7_15
4. Brudny VN, Peshev VV, Surjikov AP. Radiation-induced defects formation in electric fields: gallium arsenide, indium phosphide, Novosibirsk, Nauka, 2001;136.
5. Olantera L, Bottom F, Kraxner A. Radiation effects on high-speed InGaAs photodiodes. IEEE Transactions on Nuclear Science. 2019; 66: 1663–1670.
6. Pearton SJ, Polyakov AY. Effects of radiation damage in GaN and related materials. International Journal of Materials and Structural Integrity. Damage Mechanics of Electronic Materials. 2008; 2: 93-105.
7. Bergh AA, Dean PJ. Light-emitting diodes. Oxford, Clarendon Press. 1976; 591.
8. Kogan LM. Semiconductor light-emitting diodes. M. Energoatomizdat. 1983; 210.
9. Gradoboev AV, Orlova KN, Asanov IA, Simonova AV. The fast neutron irradiation influence on the AlGaAs IR-LEDs reliability. Microelectronics Reliability. 2016; 65: 55-59.
10. Gradoboev AV, Simonova AV, Orlova KN. Influence of irradiation by ^{60}Co gamma-quanta on the reliability of IR-LEDs based upon AlGaAs heterostructures. Physica Status Solidi. 2016; 13(10-12): 895–902. doi:10.1002/pssc.20160003
11. Pons D, Bourgoin JC. Irradiation-induced defects in GaAs. Journal of Physics C: Solid State Physics. 1985; 18(20): 3839–3871. doi:10.1088/0022-3719/18/20/012
12. Belyaev AE, Boltovets NS, Konakova RV, Milenin VV, Sveshnikov YuN, Sheremet VN. Radiation damages of contact structures with diffusion barriers exposed to ^{60}Co γ-irradiation. Physics and Technology of Semiconductors. 2010; 44.

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