Generation of defects in p-n-junctions that are made from GaAs and GaAlAs after the X-ray irradiation

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Abstract - **The process of generation and reproduction of dark-patch defects in GaAs and GaAlAs p-n-junctions after the X-ray irradiation are considered.**

Keywords - **p-n-junction, impurity centre, dark-patch defects, X-ray irradiation.**

I. INTRODUCTION

Wide spreading of A_3B_5 type of semiconducting materials in microelectronics provokes interest to investigations of irradiation-induced effects in their compounds and alloys. During an exposure by a hard radiation in semiconductive materials appear irradiation-induced defects, which change the basic electrical materials properties, such as a lifetime, mobility and carrier density. Such modifications lead to degradation of parameters of electronic devices that are made of these materials and more often are a root cause of decrease of their working life. The question about the nature of formation of irradiation-induced defects, which lead to degradation of A_3B_5 semiconductors, remains open.

Processes of formation of defects in such materials are earlier investigated during the bombardment by high-energy particles [1]. For investigation of irradiation-induced defects the greatest interest represents a subthreshold impact defect formation, during which damages in semiconductors are generated by the low-energy flying particles when impulses of electrons or quanta are insufficient for collision displacement of atoms. In this case the dislocations pile-ups are being localised in the same way, as during an exposure by X-rays. This dislocations pile-ups term dark-patch defects. The given report is devoted to studying of properties of such pile-ups of defects in GaAs and GaAlAs p-n-junctions.

II. DISCUSSION OF OUTCOMES OF EXPERIMENT

The dark-patch defect concentration increases during such external actions, as electronic and laser exposure, and also during a passage of high currents through p-n-junction. Simultaneously reproduction of dark-patch defects is promoted by such interior processes, as high intensity of generation and charge carrier recombination, a recharge of an impurity site, the strong nonuniform warming up of chips, inhomogeneity of an electric field and a current density and a modification of altitude of potential barrier in p-n-junctions at a forward-bias potential. Which of these pointed factors plays the basic role in degradation processes of semiconducting electronic devices, is not clear.

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For clarify up of a role of exciting of an electronic subsystem of impurity centres during of degradation GaAs and GaAlAs we investigated modifications of performances of p-n-junctions during a X-ray exposure from tube БСВ-4 with the copper anode (voltage 40 *kV*, a cathode current – 10 *mA*). Intensity of electron-hole pair generation in p-n-junctions during the X-ray exposure we estimated by value of a short-circuit current.

At comparison of the obtained outcomes with data of work [2] we obtained, that intensity of generation of electron-hole pairs in p-n-junctions during a X-ray exposure is being approximately $5 \cdot 10^{18}$ $cm^3 s^{-1}$, that in 10^5 times is less, than in [2] during a long-term flowing of a big forward current.

Like the long-term flowing of a high current through p-n-junction [2], an exposure of light emitting diodes by X-rays leads to a modification of their current-voltage characteristic.

After the influence of a X-ray irradiation, a value of a forward current most strongly increases at small biases when the basic contribution to a current gives a phenomenon of tunnelling of electrons in local inhomogeneities of p-n-junction. Modifications of a forward current after a X-ray exposure are maximum only for bias voltage defined values, that testifies to magnification of intensity of tunnelling of electrons through certain fixed deep energy levels in dark-patch defects, which situated in space-charge region of p-n-junction. Ionisation energy of the impurity energy levels, which participate in a process of tunnelling of electrons, we estimated up by values of voltage of the forward-bias potential, which corresponded to maximum relative changes of a current.

After the irradiation we have discovered a increasing of concentration of centres of tunnelling of electrons with ionisation energies 0.16 and 0.45 *eV* in GaAs-p-n-junctions, or 0.56, 0.78 and 0.98 *eV* in GaAlAs-p-n-junctions. Concentration of the same centres increased as well at the long-term flowing of a big forward current through p-n-junction [2]. Coincidence of ionisation energies of some impurity centres allows to conclude that both a long-term flowing of a high current, and a X-ray exposure, despite difference of these degradation mechanisms, are accompanied by the same phenomena in p-n-junction, which lead to a modification of concentration of the same local levels of energy. However during a X-ray exposure the electron-hole pair generation appears more homogeneous thanks to weak absorption of X-rays. Thus, the current density is being obtained small, owing to the fact that decreasing of altitude of potential barrier in p-p-transitions related to inhomogeneity of a warming up of chips is negligible.

Probable reason of a modification of an energy spectrum of local levels in space-charge region is the modification of a charge state of centres through which electrons tunnel through p-n-junction.

Efficiency such quasi-chemical reaction of point defects intensifies during an exposure of p-n-junction with following feeding of a reverse voltage. We obtain, that after the X-ray irradiation with following feeding of avalanche-breakdown voltage remaining thickness of space-charge region appears essentially more, than after the X-ray irradiation without following feeding of a reverse voltage. The absorption of X-ray quanta leads to a modification of a charge state of atoms, which is accompanied by disintegration of complexes, or a splitting of the charged point defects from major clusters. During the following feeding of a reverse voltage the strong field in space-charge region carries away more mobile charged component of the complex which has disintegrated during the X-ray exposure. It promotes of stabilization of an ionisation state of centres and hinders of a reverse reaction of restoration of an initial charge state of clusters.

We have measured electroluminescent characteristics of the LEDs before and after of X-ray exposure. After of irradiation of p-n-junctions we observed the quenching of luminescence at a long wavelength component of a spectrum and some decreasing of intensity of a short-wave component. But, even for various parameters of exposure we have detected no shifting of maximums of a emitting intensity and no modification of a halfwidth of spectrum bands.

As it was possible to expect, after the X-ray exposing which speeds up formation of defects in a semiconductor, and probable appearance of additional levels in semiconductor forbidden band, a new emission bands in spectrum of the samples should be observed. Absence of additional emission bands is an argument in favour of the fact, that irradiation-induced disturbances are the nonradiative recombination centres, which are decreasing a total efficiency of process of light emitting.

An exposure of light emitting diodes by X-rays leads also to an essential modification of their reverse branch of current-voltage characteristic. Increasing of a reverse current of tested p-n-junctions after X-ray exposure can be a consequence of homogeneous magnification of concentration of dislocations in the whole depletion-mode region, as well as the increasing of their density in localised defect clusters. For clearing up of reasons of the modifications of reverse current after X-ray exposure, the volt-ampere characteristic of p-n-junction in the photodiode mode has been investigated during illumination by light from an incandescent lamp. We have obtained minor alteration of a diffusion length of minority carriers of a charge after an exposure. Measuring of an electric capacitance of junction has shown, that an average thickness of space-charge region after an exposure practically remains invariable. Thus, it is possible conclude, that after an exposure we obtained the considerable localisation of a reverse current on inhomogeneities of type of dark-patch defects, which surface area is much less than p-n-junction cross-section area.

Appearance of excess of forward and reverse currents after an X-ray irradiation is related to an intensification of localisation of the same inhomogeneities of dark-patch defects.

We obtained, that an average thickness of space-charge region of a dark-patch defects makes up 124 *Å* before a X-ray exposure, and – 98 *Å* after an exposure. Average effective diameter of tunneling regions makes up 0. 15 *mcm* before a X-ray irradiation, and – 0.058 *mcm* after an irradiation.

This allows to draw a conclusion, that after an exposure we obtained the maximum increasing of density of point defects near to the cluster's core of dark-patch defect, that was observed also in work [3].

III. Conclussion

1. After the X-radiation exposure we observed an increasing of concentration of impurity centres responsible for tunnelling of electrons at a forward-bias potential. At the same time, the thickness of a depletion layer in inhomogeneity decreases.
2. We obtained, that the intensity of a boundary injection component of electroluminescence as a result of the X-ray exposure of samples is being decreased. Thus, the recombination of electrons and holes in inhomogeneities has nonradiative character.
3 Imperfections that are being generated by the X-radiation, are mobile at a room temperature.
4. Decreasing of effective area of surface of tunnelling after the X-ray exposure will agree with representation about dark-patch defects as about dislocations that environed by clouds of pile-up of the impurities atoms and their complexes.

References

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