Journal of Advanced and Applied Physics
Received: Sep 07, 2016, Accepted: Oct 04, 2016, Published: Oct 09, 2016
J Adv Appl Phys, Volume 2, Issue 2
http://crescopublications.org/pdf/jaap/JAAP-2-010.pdf
Article Number: JAAP-2-010

Research Article **Open Access**

Study of Radiation Effects on Photoelectric and Luminescence Parameters of Two-Barrier Structures based on Silicon

AbasovFakhraddin Pasha*

Institute of Radiation Problems of NAS of Azerbaijan, AZ 1143, B. Vahabzadehst. 9, Baku, Azerbaijan

***Corresponding Author**: Abasov Fakhraddin Pasha, Institute of Radiation Problems of NAS of Azerbaijan, AZ 1143, B. Vahabzadehst. 9, Baku, Azerbaijan

Citation: Abasov Fakhraddin Pasha (2016) Study of Radiation Effects on Photoelectric and Luminescence Parameters of Two-Barrier Structures based on Silicon. J Adv Appl Phys 2: 010.

Abstract

Developed and analyzed two-barrier structures - silicon-based photo detectors with high sensitivity in the field of integrated short-range. We studied the effect of gamma radiation on the origin of the current mechanism in the structure as a whole, and in the Schottky barrier in thep - n - transitions separately. Also studied the effect of radiation on the photoelectric and photoluminescence parameters of the two barrier structure. Shown that two barrier structures can improve the photoelectric parameters of conventional detectors. The photodetector on the basis of silicon with the increased integrated sensitivity in short-wave area of a range is developed. Influence radiation scale on the mechanism of currentsofboth in structure like Schottky's barrier, and in p - π - transitions is investigated. It is shown that two-barrier structures allow improving photo-electric parameters of traditional detectors. Investigatedthe impact of radiation on the photoelectric and photoluminescence parameters of two-barrier structures.

Keywords: Siliconphoto detectors; Two barrier structure; p - π – transitions and Schottky barrier; Photo luminescence.

Introduction

Silicon photodetectors, still the most widespread type of photo converters. One of the main directions of increase of speed and increase in spectral sensitivity of modern receivers of radiation with one transition is creation of multibarrier structures. In which thanks to internal strengthening and growth of coefficient of collecting of the photo generated carriers - it is possible to improve significantly key parameters which meet the requirements and needs of optoelectronics. Reliability of work of the received structures under the raised conditions of radiation, as detectors of ionizing radiation is an actual task and makes a subject of our researches.

Recently for expansion of area of spectral sensitivity methods [1,2] bringing to photocurrent growth in short-wave area of a range are widely used. Example can is – varizon band structures; pulling fields, etc., based on reduction of speed of a superficial recombination. In our case such opportunity, but in planar execution it is possible to create at the expense of a field n-p-transition included in the opposite direction.

The forms of the spectra of these emissions, normalized to its maximum value each symmetrical with respect to the line:

$$\nu_s = \frac{\nu_{ex} + \nu_{\xi}}{2}$$

where, ν_{ex} - the frequency of the exciting radiation;
ν_l - frequency fluorescent light (usually Levshina).

When excited photoluminescence monochromatic radiation is most likely the appearance of a low-frequency fluorescent light, although it is possible and the emergence of a high-frequency (anti-Stokes) radiation (Figure 5).The spectra of the Stokes and anti-Stokes photoluminescence emissions. Spectral rules of photoluminescence due to the fact that the absorption of the exciting photon with energy.

$W_в = h\nu_в$,
where, h - Planck constant;
$\nu_в$ - the frequency of the exciting radiation,

$W_l = h\nu_l$,
where, ν_l- fluorescent light frequency.

The energy difference $W_b – W_l$ spent on various processes in the material, in addition to photoluminescence. In cases where a photon energy of the exciting radiation is added to some of the energy of the thermal motion of the phosphor particles

$H\nu_l = h\nu_b + akT$,
where, a - coefficient depending on the nature of the phosphor;
k - is Boltzmann constant;
T - absolute temperature of the phosphor, there is anti-Stokes photoluminescence.

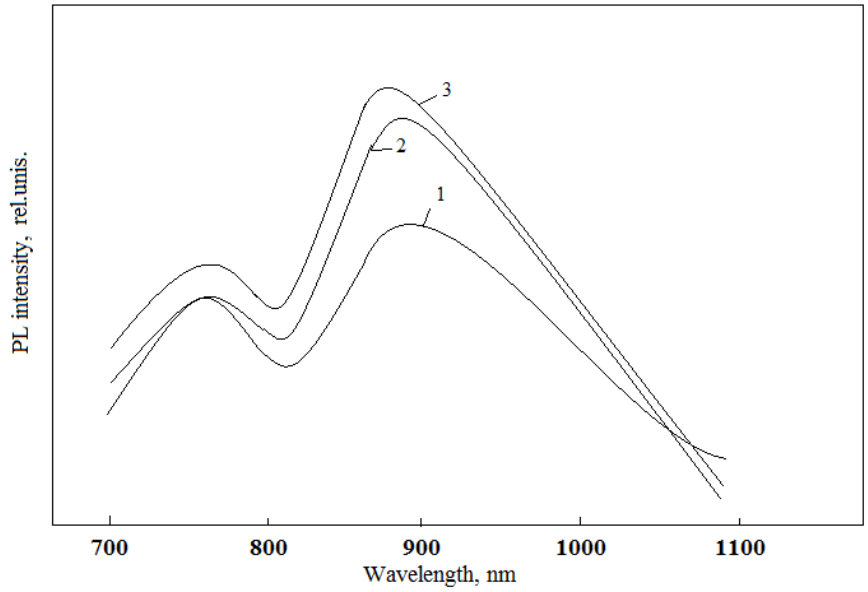

Figure 5: PL spectra of samples irradiated with gamma rays: 1- prior to irradiation, 2- D_γ– 150krad. 3) D_γ– 200krad.

Technique of Experiment and Discussion of Results

Features of two-barrier structures created on one plane are for the first time received and studied. It is shown advantages before traditional structures. For creation of photo detectors of planar execution with internal strengthening Au-Si Schottky barrier is created. As an initial material the structure p - n - type on a silicon substrate is used. The realization of management by current by means of light was enabled by selection of supply voltage of K-E in such a way that collector transition is closed, and emitter — is open, at free base. Under the influence of light in it electrons and holes are generated. At collector transition there is a division electronic hole couples which have reached owing diffusions of border transition. Holes are thrown by a field of transition to a collector,increasing own current, and electrons remain in base, lowering its potential. Thus on emitter transition there is additional direct tension that strengthens injection of holes from the emitter in base. The injected holes, reaching collector transition cause additional increase in current of a collector. As total collector current is proportional to coefficient of internal strengthening, increase of spectral sensitivity - reaching 0.65 takes place A/W. The purpose of work consists in studying of influence of a charging condition of nonequilibrium vacancies on processes occurring during radiation and silicon heat treatment with $Nn = 10^{16}$ sm^3, and also clarification of the mechanism of increase in integrated sensitivity of two-barrier structures of rather ordinary photo diodes.

In Figure 1 spectral characteristics of two-barrier structure before radiation are shown, at the room temperature at the return tension of U_{cont}. = 0B, and U_{cont}. = 0.5B. From drawing it is visible that with growth of the enclosed return shift on r-p-transition photocurrent increases what to lead to photosensitivity growth, at an optimum choice of the return tension on r-p-structure transition.

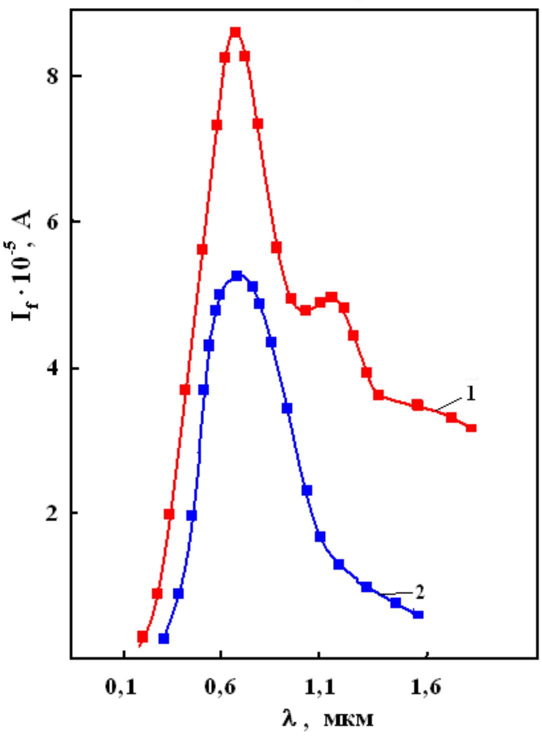

Figure 1: Spectral characteristic ofthe double-barrier structures at radiation 1.-$U_{rev.}$=0V; 2.-$U_{rev.}$=0.5 V. T = 300 K

At further increase in U_{cont}.spectral sensitivity falls. Such behavior of S_{λ}connectedwith growth of area of a volume charge and improvement of coefficient of collecting of photo carriers. With a further growth of U_{cont}, because of overlapping of zones, photoinjectionof BSh is blocked and the structure works in a mode of one photo diode (Figure 2).

The structure was irradiated at T=300 K in gamma quanta of Co^{60}. Isochronous (30 min) annealing of radiation defects was carried out in the range of temperatures of Ta = 200-450 K.

Method of photo MF of Voc = ln + ln =Vj+VB

I showed that primary radiation defects (RD) in p-Si crystals at 300 K are loaded positively.

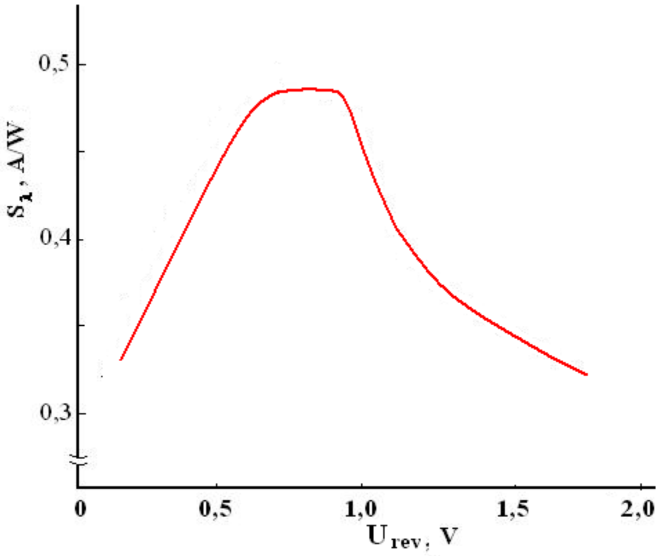

Figure 2: Dependence of the spectral sensitivity of the structure the applied reverse bias the p-njunction

The analysis VAC (Figure 3) and spectral characteristics showed that recombinational currents increase in process of increase in a dose of radiation. Annealing of diodes leads to decrease in recombinational currents. At Ta temperature ≈ 300°C there is an annealing and reorganization of divakansiya to formation of the V2 complexes + O, and at Ta = 350°C the A-centers (V + O) and complexes (V2 + O) are actively annealed. The analysis of change of a current of through BSh and n-p- transition showed distinction of influence of annealing near a surface and in the depth of a crystal. It can be explained with growth of a photo response of BSh connected with accumulation of a charge and improvement of coefficient of collecting.

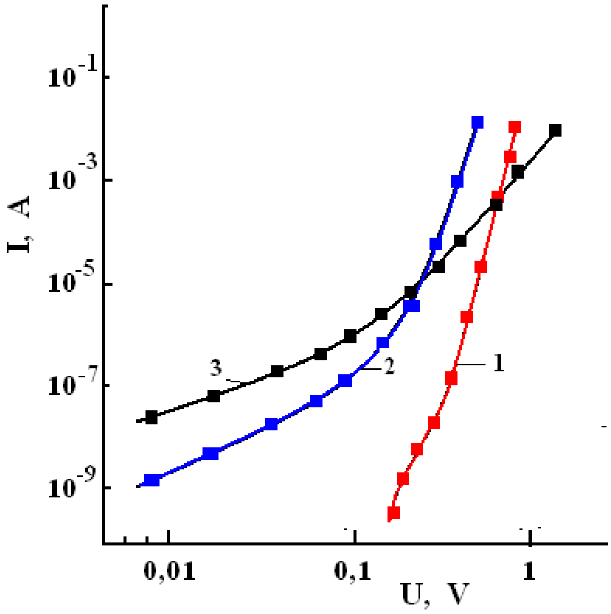

Figure 3: Volt-ampere characteristics of p-n-junction1.Original. 2. Dγ = 100krad.3. Dγ = 200krad. Annealing results are insignificant.

In Figure 4 curves of spectral dependence of photocurrent before and after radiation scale are represented at various doses and after annealing at T=400°C within 30 min. Annealing influences spectral characteristics slightly. With dose increase the radiation scale growth of photocurrent decreases.

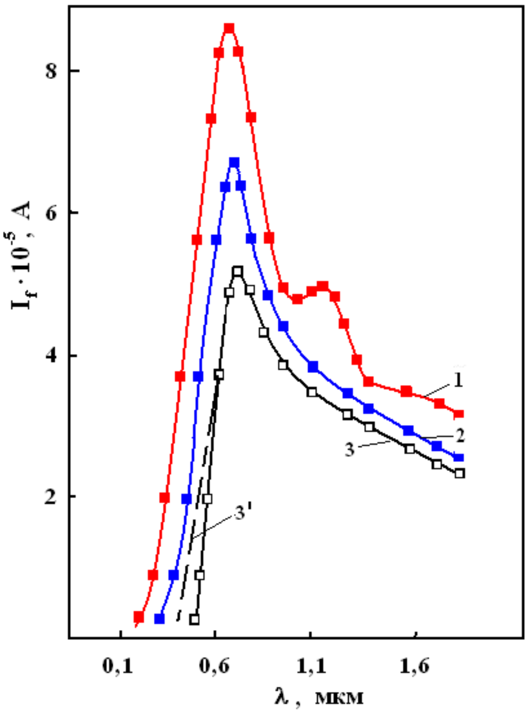

Figure 4: Spectral characteristic double-barrier structure after irradiation withgammarays:1-up irradiation, 2-dose 150krad. 3) dose of 200 krad. 3') annealedat T= 400°C for 30min

Conclusions

Thus, it is possible to claim that the main role in electric losses the studied silicon structures is played by the oxygen-containing centers (V2+O and V + O). At increase in a dose of radiation and increase in temperature of annealing, feature VAC and spectral characteristics are caused by change of resistance of n-Si (basic area of structure), the caused accumulation (at increase in a dose) or disappearance and reorganization (when annealing) radiation defects. It is known that the speed of capture by defect of electrons and (or) holes first of all depends on the section of capture and the provision of power level in the forbidden zone. These parameters in fact are the "individual" characteristic of defect [3,4]. When annealing structures there is a reorganization of dot radiation defects and their disappearance [5, 6]. Thus mainly there is an accumulation of the same defects. Comparison to literary data shows that the main role in photo-electric losses of the studied structures is played by the oxygen-containing centers (V2+O and V+O). At further increase in a dose of radiation there is an irreversible reduction of photosensitivity due to significant increase in resistance of base [7, 8].

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