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Research Article

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Degradation of Solar Cells by Ionizing Radiation Based on Silicon Double-Barrier Nanostructures

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Abstract

Developed two - barrier structures with a nanostructured base based on silicon. Exposed to gamma radiation at the 60Co facility and analyzed the photoelectric properties of the resulting structures and proved that the use of these structures improves the photoelectric properties of traditional photovoltaic structures and creates a high integral sensitivity in the short-wavelength region of the spectrum. The effect of ionizing and penetrating gamma radiation on the photoelectric and photoluminescent parameters of the studied two-barrier structural converters has been studied. The effect of irradiation on the occurrence of leakage current both at the Schottky barrier and at the p-n junction was studied. It is shown that the two-barrier structure makes it possible to improve photoelectric receivers. It is also shown that double-barrier structures are superior in photoelectric parameters to photoconverters of single-barrier structures, and it is recommended to use them as solar cells.

The probability of exposure to radiation due to the occurrence of a leakage current has been studied both for a random type of Schottky barrier and for p-n junctions. It is shown that, in terms of photoelectric parameters, double-barrier structures are superior to photoconverters for use as solar cells. It is also shown that the two-barrier structure allows the improvement of photoelectric receivers. The effect of incident ionizing radiation on the appearance of current and charge carriers is studied both for the Schottky barrier type and for p-n- junctions. It is shown that, in terms of photoelectric parameters, double-barrier structures are superior to photoconverters for use as solar cells.

Keywords: Silicon Two Barrier Structures, P-N Junctions, Schottky Barriers, Ionizing Radiation, Effect Radiation, Photoelectric Parameters

1. Introduction

The effect of gamma radiation on the mechanism of current generation and transfer in a barrier structure of the Schottky type and in p-n junctions has been studied. It was found that the two-barrier structure makes it possible to improve the photoelectric parameters of the photoconverting structure. Double-barrier structures of photoconverters with high sensitivity in the short-wavelength region of the spectrum with a silicon-based nanostructured fabric have been developed. An increase in overall sensitivity and an increase in spectral sensitivity is one of many factors. The reliability of the operation of a double-barrier structure under conditions of increased radiation, as a converter of solar energy into electricity, as well as the study of resistance to the effects of ionization rays of solar radiation, is an urgent task and is the subject of our study. The influence of radiation on the mechanism of excitation of electric current at p-n junctions and on the effect of the structure as a whole is also being studied. It is shown that two-barrier structures have extremely high characteristics of conventional photovoltaic structures.

During its existence, silicon were the most important type of photo converters. To improve the photoelectric properties in the region of spectral sensitivity, some changes were made in the structure of the photo converter, which led to an increase in the value of the photocurrent in the short-wavelength region of the spectrum. Recently, the applied methods have been widely implemented [1-4]. An example is the structure of the Verizon group; pulling fields, etc., based on the low rate of explosive recombination. In this case, such a possibility, but in a planar version, can be created due to the field of the p-n-junction, which work in parallel implementation of the p-n-junction and the Schottky barrier. The study of the optical properties of thin silicon films from the dependence $(\alpha h\nu)^{\frac{1}{2}}$ makes it possible to determine the band gap for each film [5-7]. In all the studied films, the coefficient of the optical absorption edge is described by the relation:

$$V_{oc}=\frac{1}{1+b}\cdot\frac{kT}{q}\ln\left(\frac{(G)^2\ \tau_1\ \tau_2}{n_i^2}\right)+\frac{b}{1+b}\cdot\frac{kT}{q}ln\left(\frac{(G)^2\ \tau_1\ P_{po}}{n_i^2}\right)=V_I+V_B \quad (1)$$

where, $\alpha=5\cdot10^4\div10^5$ cm^{-1}. E_0- optical band gap for each film. B - coefficient of proportionality.

The value of B is determined by extrapolating depending on hv for each sample.

The value of B at x = 0 ÷ 1 is from 527 to 343 eV^{-1}, $cm^{1/2}$, respectively, E_0 =1,14···1,86eV for films with Au-(p-n-) Si.

The quadratic dependence (2) obtained theoretically for a model of Tauc which describes the density of states of the mobility gap [8,9].

The study of the features of photoluminescence (PL) of short-wavelength radiation in the visible spectrum for efficient c-Si solar cells is of great interest [8,9]. Thus, the task of increasing the efficiency of (c-Si) - photocells consists of two parts: 1 - re-emission of short-wavelength photons in the visible edge of the spectrum through the mechanism of direct optical transitions of the zone - zone silicon monohydrate, 2 - the effective conclusion of photo generated carriers across the spectrum of solar radiation.

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

$$\nu_S=\frac{\nu_{ex}+\nu_\xi}{2} \quad (2)$$

where, ν_{ex}- the frequency of the exciting radiation;
ν_ξ- frequency fluorescent light.

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. Spectral rules of photoluminescence due to the fact that the absorption of the exciting photon with energy.

$$W_B=h\nu_B \quad (3)$$

where, h - Planck constant;
ν_B- the frequency of the exciting radiation,

$$W_1=h\nu_1 \quad (4)$$

where, ν_1- fluorescent light frequency.

The energy difference W_b – W_1 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.

$$H\nu_1=h\nu_b+\alpha kT \quad (5)$$

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.

2. Technique of Experiment and Discussion of Results

We have obtained and studied the features of two-barrier structures from the dimension base, created on the same plane. The advantages over traditional compositions are shown. To create planar photo detectors with internal amplification, a structure with an Au-Si Schottky barrier was created. A p-n-type structure on a silicon substrate is used as the starting material.

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 photodetectors 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 (figure 1) [10,11].

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 [12,13].

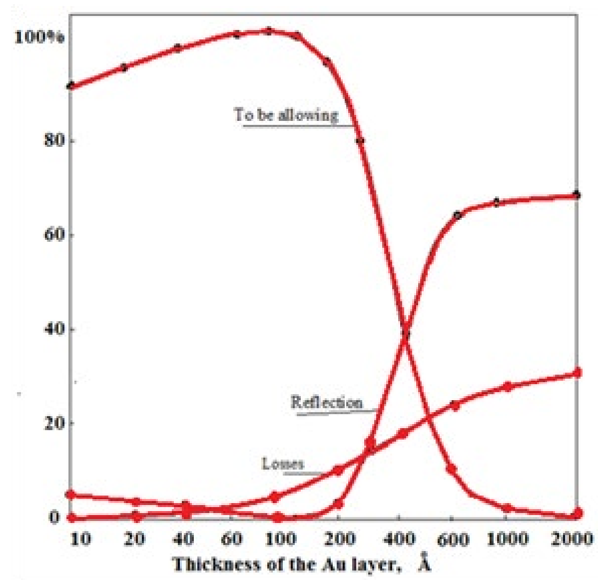

Figure 1: The Dependence of Reflection, Absorption and Conductivity of the Metal (Au) Thickness in the Structure

when an additional forward voltage appears at the emitter junction, which enhances the injection of holes from the emitter into the base. The injected holes, reaching the collector junction, cause an additional increase in the collector current. Since the total collector current is proportional to the internal gain, the increase in spectral sensitivity is as high as 100 mA/W.

The purpose of work consists in studying of influence of a charging condition of no equilibrium vacancies on processes occurring during radiation and silicon heat treatment with $N_n = 10^{16} cm^3$, and also clarification of the mechanism of increase in integrated sensitivity of two-barrier structures of rather ordinary photo diodes.

In figure 2 spectral characteristics of two-barrier structure before radiation are shown, at the room temperature at the return tension of $U_{cont.}$ = 0V, and U_{cont}. = 0,5V. From drawing it is visible that with growth of the enclosed return shift on p-n- transition photocurrent increases what to lead to photosensitivity growth, at an optimum choice of the return tension on p-n- structure transition [14,15].

At further increase in U_{cont} spectral sensitivity falls. Such behavior of Sλ connected with growth of area of a volume charge and improvement of coefficient of collecting of photocarriers. With a further growth of Ucont because of overlapping of zones, photo injection of BSh is blocked and the structure works in a mode of one photo diode (figure 2).

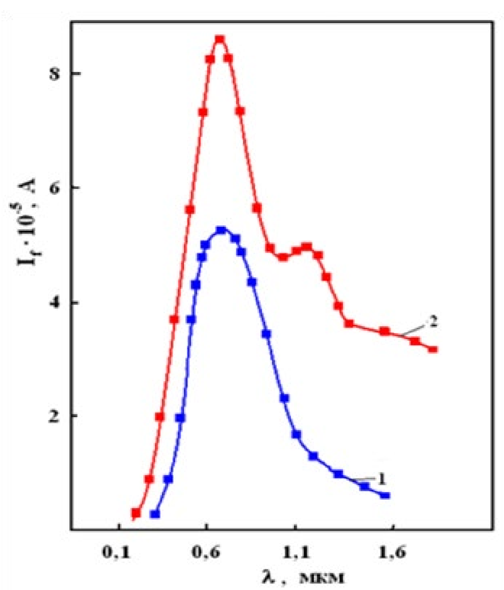

Figure 2: Spectral Characteristic of the Double-Barrier Structures to Radiation

1. $U_{rev.}$=0V; 2. $U_{rev.}$=0.5 V. T = 300 K

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 Ta = 200-450 K.

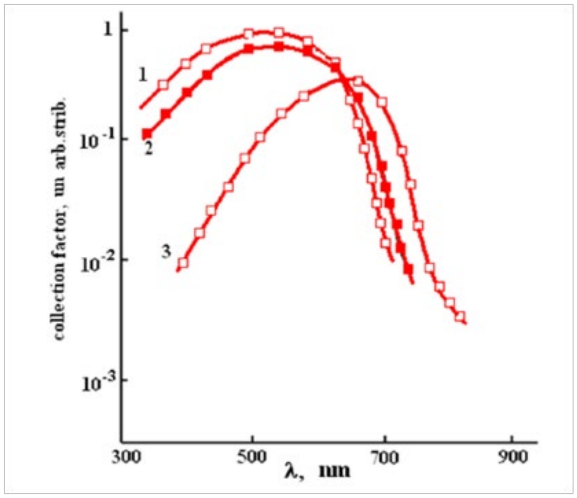

Figure 3: The Dependence of the Gathering of the Wavelength of Incident Radiation: 1. Double-Barrier Structure; 2. Schottky Barrier; 3.p-n- Junction

The analysis VAC (figure 3) and spectral characteristics showed that recombination currents increase in process of increase in a dose of radiation. Annealing of diodes leads to decrease in recombination currents. At Ta temperature ≈ 300◦C there is an annealing and reorganization of divakansion 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 (figure 4).

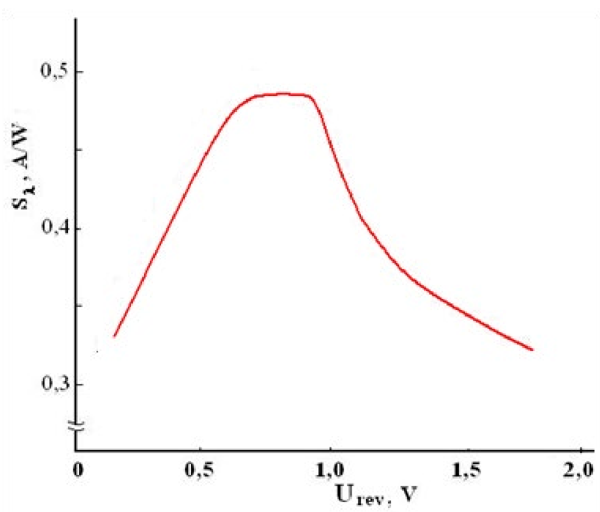

Figure 4: Dependence of the Spectral Sensitivity of the Structure the Applied Reverse Bias the p-n-Junction

It can be explained with growth of a photo response of BSh connected with accumulation of a charge and improvement of coefficient of collecting.

In figure 5 curves of spectral dependence of photocurrent before and after radiation scale are represented at various doses and after annealing at T=400oC within 30 min. Annealing influences spectral characteristics slightly. With dose increase the radiation scale growth of photocurrent decreases.

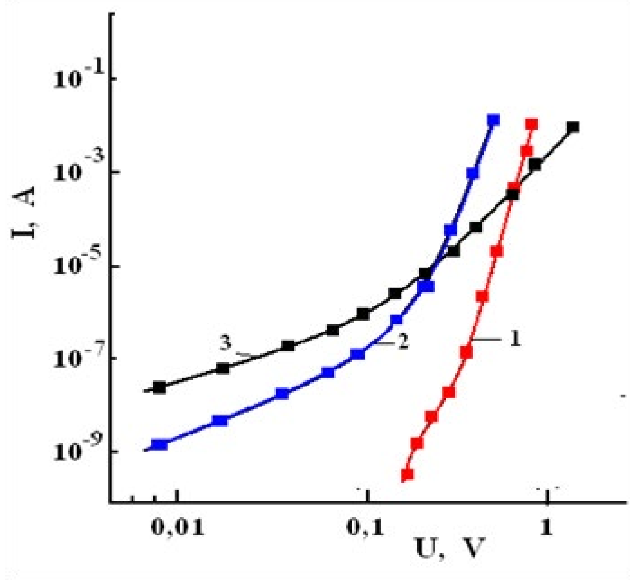

Figure 5: Volt-Ampere Characteristics of p-n-junction 1. original. 2. Dγ = 100krad. 3. Dγ = 200krad. Annealing Results are in Significant

In figure 6 photo luminescence spectra of samples irradiated with gamma rays' spectral rules of photoluminescence due to the fact that the absorption of the exciting photon with energy.

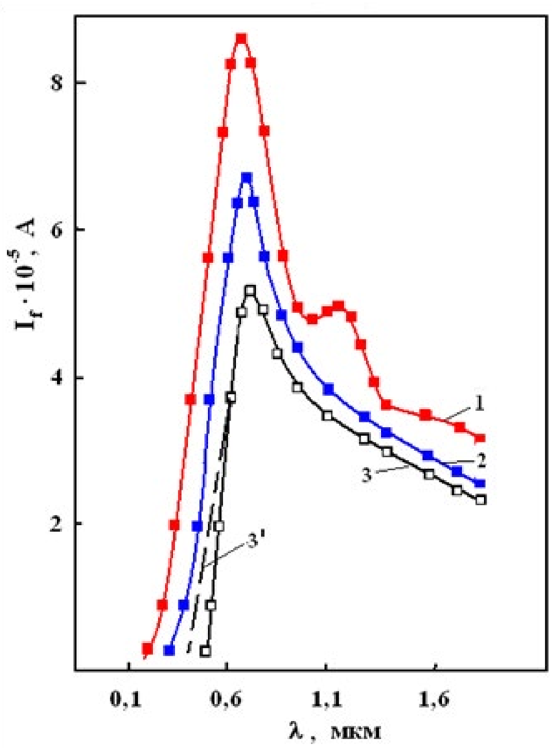

Figure 6: Spectral Characteristic Double-Barrier Structure After Irradiation with Gamma Rays: 1-up Irradiation, 2-dose 15 kGy, 3) dose of 20 kGy., 3') Annealed at T= 400° C for 30min

In figure 7 Relaxation of Photo Conductivity When Excited It Rectangular Pulse

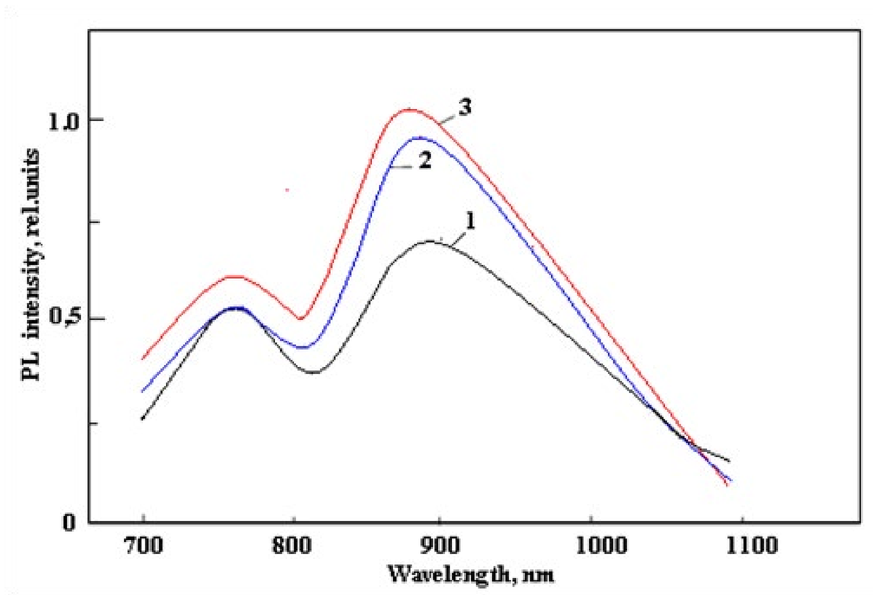

Figure 7: PL Spectra of Samples Irradiated with Gamma Rays: 1- Prior to Irradiation, 2- Dγ – 15 kGy., 3) Dγ – 20 kGy.

3. Conclusion

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.

When annealing structures there is a reorganization of dot radiation defects and their disappearance.

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.

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