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Short Communication

The Spectral Sensitivity Characteristics Simulation of the Silicon *p-i-n*-structure with High Resistance "Wells"

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In the paper a simulation program for photovoltaic parameters of semiconductor devices and results of their investigation are presented. The results of the program usage based on an example of calculating the influence of the high-resistance "well" thickness in the silicon p-i-n-diode spectral response are discussed. For the accuracy of the program estimation it was compared the theoretical spectral characteristics of a silicon PIN-diode 5 kOhm substrate with the experimental data.

Keywords: Silicon *p-i-n* structure, Design optimization.

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1. INTRODUCTION

During using any kind of equipment using optical radiation is, in most cases, radiation detector determines the basic parameters of optical systems. The modern development of optical receiver is characterized by the further improvement of parameters and radiation detectors characteristics: sensitivity, response speed, the spectral sensitivity range, reliability and etc [1-3].

In order to optimize physical and topological structure of multilayer silicon structures software for spectral characteristics simulator Polisloi was developed. It is based on Borland Delphi 7 language. Program allows to re-create the simulated structure by layers, specifying the layers number, the material conductivity type, doping level and each layer thickness.

In order to expand the spectral sensitivity characteristics it was considered a structure with so-called "well" with an electron density 10^{12} cm^{-3} which should provide a better collection of photogenerated carriers (Fig. 1).

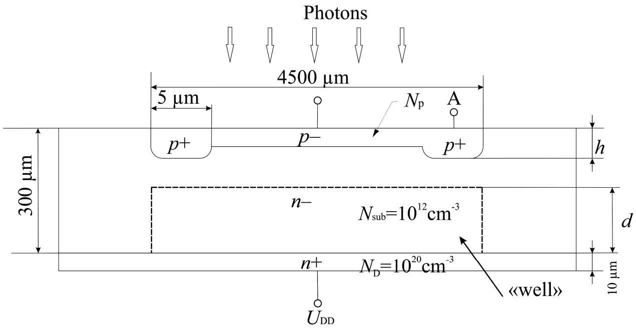

Fig. 1 – Silicon *p-i-n*-structure with high resistance "wells"

2. EXPERIMENTAL PROCEDURES

During simulation the influence of the thickness of the lightly doped "well" on the spectral sensitivity characteristics of the *p-i-n*-structure has been investigated. The total thickness of the lightly doped layer was 300 microns, thus, if the well thickness – 250 microns, the remainder part of the n-layer thickness was 50 microns. It is assumed that the addition of the lightly doped region should increase the structure sensitivity. Fig. 2 shows the change in *p-i-n*-structures sensitivity for different values of the structure thickness.

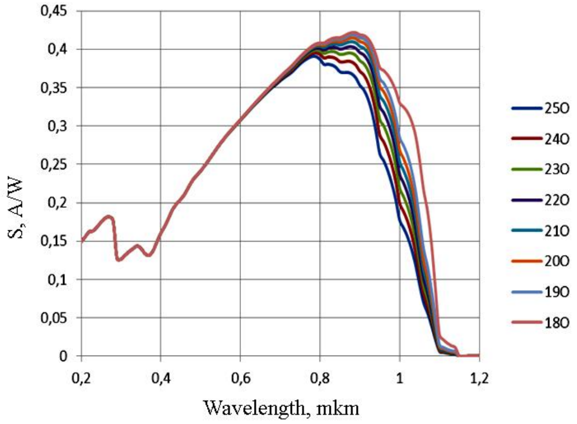

Fig. 2 – Dependence of the spectral sensitivity characteristics of *p-i-n*-structure vs the high resistance "well" thickness (180÷250 microns). The *p*-region doping level – 10^{17} cm^{-3}

For determination the spectral dependence of the photosensitivity spectral range was set, and in each monochromatic spectral region the photocurrent was detected. Moreover, in order to analyze the physical processes which were occurring in the structure and the subsequent the design structure optimization separately photocurrents generated separately *p*- and *n*- regions and the space-charge region were determined.

3. RESULTS AND DISCUSSION

For approving the results reliability which was obtained by the developed simulation program, additional calculations were carried out in a specialized software environment ISE TCAD. This software allows fully construct the entire process step during producing the final structure and analyze the operation of the device in electric mode. One advantage of TCAD is a possibility of creating two-dimensional structures, which is currently, is not realized in the developed program. As the initial one has been selected, structure shown in Fig. 1 with the thermal oxide with thickness – 100 nm. Fig. 3 and 4 shows the calculated spectral characteristics obtained in the developed program and TCAD for maximum concentration in a light doped *p*- layer – 10^{16} cm $^{-3}$. For convenience, the results were normalized by the area of the final structure. As it could be seen good correspondence in obtained results has been achieved.

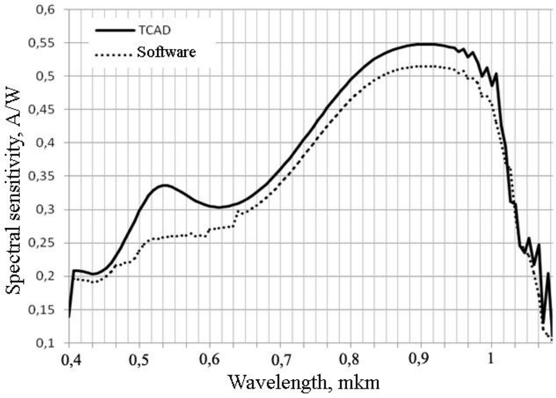

Fig. 3 – Theoretical spectral characteristics of *p*-*i*-*n*-structure

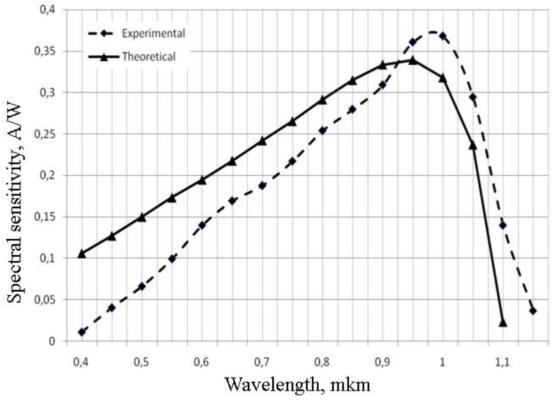

Fig. 4 – The spectral sensitivity of *p*-*i*-*n*-diode

The spectral characteristics of *p*-*i*-*n*-structures without a "well" produced based on high-quality plates Silicon electronic with Phosphorus doping – 5000 (thickness – 420 microns) were investigated. Ohmic contact to the reverse side was carried out by diffusion of phosphorus (P) c followed by drive-in diffusion step at $T = 1000$ °C. A second ohmic contact was formed by ion doping with B 60 keV and a dose of 500 microCi/cm^2. Boron implantation as a thin surface layer of the diode was formed with a depth about 0.4 microns. The passivating oxide thickness over the active region was 20 nm. For p^+ areas ohmic contacts were made by depositing Al with thickness – 1 mm, annealing the Al was made at $T = 475$ °C.

Fig. 4 presents results of the theoretical calculation of the Polisloi program and experimental data -spectral sensitivity of *p*-*i*-*n*-structures at reverse bias of 20 V. It can be noted quite good correspondence between the calculated and experimental results.

4. SUMMARY

The Polisloi program allows estimate the structural parameters influence on the basic photovoltaic p-i-n-diode characteristics [4]. Based on the developed program designed spectral dependences of *p*-*i*-*n*-diode with different high-resistance “well” thicknesses were calculated. The program allows a reliable accuracy to determine the main parameters of the *p*-*i*-*n*-diode, which is confirmed by comparing the calculation results of the spectral characteristics of the *p*-*i*-*n*-diode on the substrate with the resistance 5 kOhm with the experimental data.

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