wjert, 2018, Vol. 4, Issue 1, 78 -81. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 4.326

THE EFFECT OF RADIATION ON FUNDAMENTAL PARAMETERS OF A SILICON-BASED SEMICONDUCTOR STRUCTURE

***Dr. Karimov A. V., Rahmatov A. Z., Yodgorova D. M., Kuliev Sh. M., Bebitov R. R.**

Physical-Technical Institute SPA «Physics-Sun» Academy of Sciences of the republic of Uzbekistan. 100084, Tashkent, Bodomzor street, 2B.

Article Received on 30/10/2017 Article Revised on 20/11/2017 Article Accepted on 11/12/2017

***Corresponding Author**
Dr. Karimov A. V.
Physical-Technical Institute SPA «Physics-Sun» Academy of Sciences of the republic of Uzbekistan. 100084, Tashkent, Bodomzor street, 2B.

ABSTRACT

We report the results of the study of influence of radiation on voltage drop and resistivity of silicon power diodes. It was shown that the increase in the voltage drop in samples exposed to radiation is largely associated with the increase in the resistivity of the base region.

KEYWORDS: Silicon, radiation, voltage drop, resistivity.

INTRODUCTION

Currently, silicon tends to be the main material of semiconductor industry and is widely used in the production of semiconductor structures for various purposes. Variety of solar cells, diode and transistor structures are manufactured on its basis. Their performance is largely determined by the behavior of the base region in the operation mode.

With regard to stand-alone power supply systems, the study of the effect of radiation on single crystalline silicon which is the backbone of solar cells and power diodes represents a significant issue. The study of radiation effects on semiconductor structures could help to determine the scope of their reliable performance as well as their degradation properties.

It is well known that, external influences such as temperature, radiation and light influence basic parameters (mostly efficiency) of solar cells[1] and the static parameter of diode structures (forward-connected voltage drop). In the absence of current variations and in the presence of time-constant direct current, one can expect reliable operation of the power supply for relatively prolonged period.

In the present paper, we report the results of investigation of how voltage drop depends on electron beam irradiation of silicon power diodes and how it affects resistivity of the sample. The silicon material serves as the base region of photo-converters and diode structures.

EXPERIMENTAL AND DISCUSSION

The samples under investigation represent single crystalline silicon and diffusion diodes with p^+-p-n-n^+-structure with a base region thickness of ~150 µm (ingot was silicon doped with phosphorus with resistance of 4 Ω·cm).[2] For irradiation of samples with beam of electrons we used the accelerator type U-003 IYF of the Academy of Sciences of Uzbekistan. The average energy of electrons during irradiation of the investigated diodes were in the range of (7÷7.5) MeV with intensity of about ~ $(2.5\div3)\cdot10^{11}$ $cm^{-2}s^{-1}$. The accuracy of fluency of electrons (F_e), was ~ ±15%.

Only those diodes were exposed to radiation that were characterized with minimal variation in main parameters before radiation i.e., the forward voltage drop U_F =0.75÷0.9 V at forward current I_F =10A, reverse current I_R ~ 0.5-0.7 µA and 0.7– 1.0 µA at reverse voltage U_R = 100 V and 200 V, respectively. The reverse resistance recovery time was $\tau_{rr} \leq 2.8\pm0.2\cdot10^{-6}$ s at reverse current of I_F =1A, I_F/I_R =1 and the reference level of the reverse current of 0.1 A. Each lot of diodes consisting of 10 pcs was exposed to specific level of radiation.

Depending on the parameters of the base region and the selected operating current, the forward voltage drop value changes respectively. Thus, in transistor structures with the thickness of the base region ranging from 1.0 to 3.0 µm and at fluxes of electron irradiation of $F_e > 5\cdot10^{12}$ cm^{-2} the forward voltage drop changes slightly across the whole range of trend of the flux of electrons.[3]

However, in the studied samples of power diodes as the dose of electron irradiation increases, we witness the increase of the voltage drop for a given value of current. Thus, when a direct current turns out to be 10A, the voltage drop increases from 0.93 V to 1.1 V. (Fig. 1).

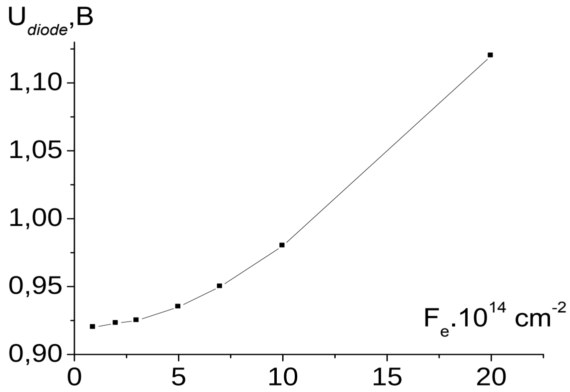

Fig. 1: Voltage drop on the power diode as a function of electron beam irradiation.

Thus, the forward voltage drop at a given current on the diode is:

$$U_{direct} = U_{p-n} + U_b + U_k. \qquad (1)$$

In turn, the voltage drop across the *p-n* junction is determined by the expression:

$$U_{p-n} = \frac{kT}{q}\ln\left(\frac{J \cdot N_b}{qS_{p-n}n_i^2} \cdot \sqrt{\frac{\tau_b}{D_b}}\right) \qquad (2)$$

where N_b - is the concentration of dopants in the base; τ_b, D_b - the lifetime and the diffusion coefficient of minority carriers.

In contrast to transistor structures with thin base region, the observed increase in the voltage drop across the power diode for a given current can be explained by the increase of the voltage drop in its base region:

$$U_b = j_{direct} W_b \rho \qquad (3)$$

where: W_b - the thickness of the quasi-neutral region of the base; ρ - the resistivity of the base.

The above assumption is based on the fact that the power diode has p^+-p-n-n^{+-}structure with thickness of about 235 µm, of which 55 µm happens to be the overcompemsated region of p-type and whereas 45 µm region turns out to be p+-type, and the base region (135 µm) is an n-type silicon with a resistivity of 4 Ohm·cm. As the thickness of the base after exposure to radiation remains practically the same, then the increase in voltage drop after radiation can be attributed to the increase of resistivity of the base due to the generated radiation centers.[3]

The studies of the effect of radiation exposure had shown that in a wide range of doses for neutrons up to the fluencies of $F_n = 5 \cdot 10^{12}$ cm^2 the resistivity of the underlying silicon power diode remains almost unchanged. Later, however, at doses of neutrons F_n $2 \cdot 10^{15}$ cm^2 we have witnessed an exponential increase in the resistivity of the base (Fig. 2), which proves the availability of the mechanism of radiation sensitivity of the base region.

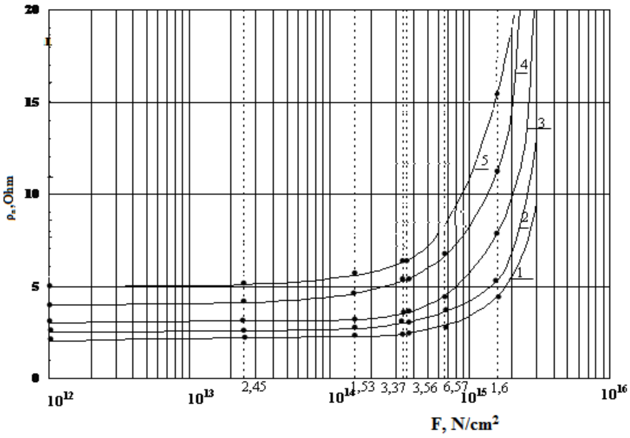

Fig. 2: The resistivity of the single crystalline silicon as a function of integral radiation flux.

CONCLUSION

Given the fact that the thickness of the base region virtually does not change after being exposed to radiation, we explain the increase in voltage drop due to radiation by the increase of the resistivity of the base caused by radiation-induced centers and reduction of concentration of majority carriers.

REFERENCES

1. Onishchuk S.A. Degradation of solar elements at neutron and proton radiation / News of Higher Education Institutions of the Physicist, 2007; 2: 40-45.
2. RUZ patent. No. IAP 04571 of 22.08.2012 Bulletin, No. 9 28.09.2012 of. The crystal blocking diode. Rakhmatov A.Z., Karimov A.V., Yodgorova D.M., Abdulkhayev O.A., Buzrukov U.M., Kalandarov Zh.Zh.
3. Ladygin E.V., Konovalov L. S., Orlova M.N., Ruchkin M.V., Logov P.B., Surma A.M. Increase in quick action and radiation resistance of power silicon diodes with application of radiation technological process//Questions of atomic science and technology. Ser.: Physics of radiative effects on the radio-electronic equipment. – Kiev, 2006; 1-2: 29-37.