wjert, 2018, Vol. 4, Issue 3, 330-334. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.218

ON THE ROLE OF OXYGEN AND YTTERBIUM IN THE FORMATION OF RADIATION DEFECTS IN SILICON AFTER GAMMA-IRRADIATION

Sharifa B. Utamuradova*, Khojakbar S. Daliev., Shakhrukh Kh. Daliev and Mansur B. Bekmuratov

National University of Uzbekistan named after Mirzo Ulugbek, 100174, Tashkent, Republic of Uzbekistan.

Article Received on 25/03/2018 **Article Revised on 15/04/2018** **Article Accepted on 06/05/2018**

***Corresponding Author**
Sharifa B. Utamuradova
National University of Uzbekistan named after Mirzo Ulugbek, 100174, Tashkent, Republic of Uzbekistan.

ABSTRACT

In this work, using DLTS investigated the influence of oxygen content and ytterbium on the efficiency of formation of radiation defects in n-Si<Yb> irradiated by gamma-quanta of ^{60}Co. It is shown that a high content of optically active interstitial oxygen is dominated by the formation of the A-center in comparison with the E-center. It was found that the presence of ytterbium atoms in silicon leads to a slowdown in the process of radiation defect formation: the concentration of A-centers is 2 times less, and E-centers 5 times less in the samples n-Si<Yb> compared with control samples.

KEYWORDS: Silicon, oxygen, ytterbium, radiation defect, gamma irradiation.

INTRODUCTION

It is known that in silicon grown by the Chokhralsky method, exposed to radiation, various oxygen-containing radiation defects are formed depending on the impurity composition. In addition, the presence of impurities of rare earth elements in the silicon volume leads to an increase in the resistance of its parameters to the effects of radiation.[1-3] It is also known that the efficiency of formation of radiation defects in silicon and the kinetics of their annealing depend on the presence of various uncontrolled impurities, their content and state in the silicon lattice, the presence of several impurities and many other factors.[4-6]

MATERIALS AND METHODS

The aim of this work is to study the effect of oxygen content and ytterbium on the efficiency of formation of radiation defects in n-Si<Yb> irradiated gamma-quanta ^{60}Co by non-stationary capacitive spectroscopy (DLTS).

The single crystal silicon of n-type conductivity with resistivity ρ = 5÷40 Ohm.cm and the content of interstitial optically active oxygen N_O^{opt} in the range = $2\cdot10^{16}\div 8\cdot10^{17}cm^{-3}$ was used as the studied samples. Doping of silicon by rare-earth impurity - ytterbium was produced by growing silicon from the melt.

Irradiation of samples was carried out gamma-quanta ^{60}Co at 300 K with a flow rate of $3.4\cdot10^{12}$ quantum/cm$^2\cdot$s. The processes of radiation defects formation in n-Si<Yb> with different oxygen and ytterbium content were studied by DLTS on diffusion junctions created by high-temperature phosphorus diffusion. The area of the p-n junction did not exceed 0.15 cm^2. As an ohmic contact, Nickel was deposited chemically, sometimes antimony or aluminum was sprayed. DLTS spectra were measured in constant capacitance[7] and constant voltage modes.[8]

RESULTS AND DISCUSSION

Analysis of DLTS spectra shows that the introduction of ytterbium in silicon in the process of growing Si from the melt does not lead to the formation of any deep levels in forbidden zone of silicon, although according to the neutron activation analysis of ytterbium atoms present in the silicon volume in a sufficiently high concentration ($2\cdot10^{15}\div 4\cdot10^{17}$см$^{-3}$). This fact indicates that the ytterbium atoms introduced during the growing process are electrically neutral.

From measurements of DLTS spectra of silicon samples doped with ytterbium in the process of growing from melt and control non-doped samples before and after each irradiation cycle, the energy spectrum of the formed deep levels is determined. Note that in these samples N_O^{opt} was $8\cdot10^{17}$ cm^{-3}.

Typical DLTS spectra of n-Si and n-Si<Yb> samples with different contents of optically active interstitial oxygen and ytterbium irradiated with ^{60}Co gamma-rays are shown in figure 1 and figure 2. As can be seen from the DLTS spectra as a result of gamma-irradiation of control samples n-Si with interstitial content of the optically active oxygen $N_O^{opt} = 8 \cdot 10^{17}$ cm^{-3} introduces a new deep level with an ionization energy of E_c–0.17 eV (peak A) and the capture cross section of electrons $\sigma_n = 1 \cdot 10^{-14}$ cm^2 (Fig.1, curve 1). It is established that the values of parameters of this deep level coincide with the data of[1,3] and relate to the known radiation defect - complex vacancy-oxygen (A-centers).

The features of radiation defect formation in silicon with the content of interstitial optically active oxygen N_O^{opt} of the order $8 \cdot 10^{16}$ cm^{-3} were also investigated.

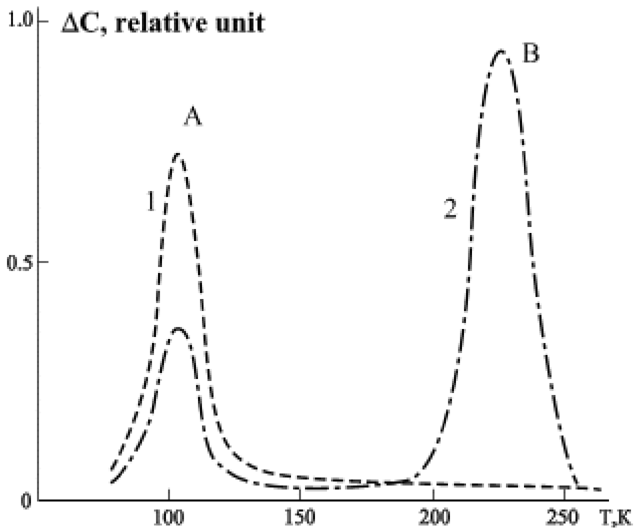

Fig. 1: Typical DLTS spectra of control samples Si with different oxygen content after gamma irradiation (curve 1: $N_O^{opt} = 8 \cdot 10^{17}$ cm^{-3}, curve 2: $N_O^{opt} = 8 \cdot 10^{16}$ cm^{-3}).

Discovered that the measurements of the DLTS spectra of these control samples of silicon (Fig.1, curve 2) showed that gamma-irradiation introduces besides A–centers, and another characteristic radiation defect: E-centre with an ionization energy of E_c-0.43 eV and a capture cross section of electrons $\sigma_n = 1.8 \cdot 10^{-15}$ см$^{-2}$. The concentration of the E-center in these samples at a dose of irradiation D = $8 \cdot 10^{17}$ quantum/cm^2 is $5.3 \cdot 10^{13}$ cm^{-3} and the concentration of the A-center of the order $1.8 \cdot 10^{13}$ cm^{-3}, i.e. about half an order of magnitude lower than the concentration of A–center in silicon with a higher oxygen content.

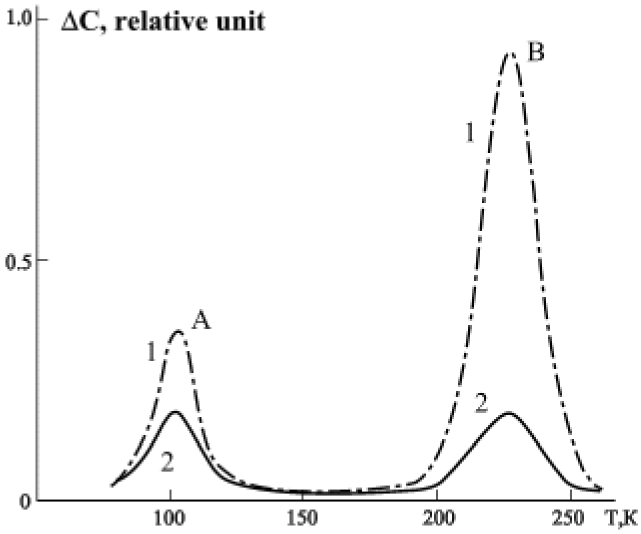

Figure 2: Typical DLTS spectra of n-Si control samples (curve 1) and n-Si doped with ytterbium (curve 2) after gamma irradiation: ($N_O^{opt} = 8{\cdot}10^{16}$ cm^{-3}).

The influence of ytterbium atoms on the formation efficiency of radiation defects in silicon with different content of interstitial optically active oxygen N_O^{opt} was also studied. For fig.2 shows typical DLTS spectra of the samples n- Si<Yb> with N_O^{opt} about $8{\cdot}10^{16}$ cm^{-3} after gamma-irradiation.

It is established that as a result of gamma-irradiation in n-Si samples doped with an impurity of ytterbium, vacancy - oxygen (A-centers) complexes with a deep level of E_c - 0.17 eV and vacancy-phosphorus (E-centers) complexes with a level of E_c- 0.43 eV are also formed.

From the analysis and comparison of the measured DLTS spectra it follows that the presence of ytterbium atoms in silicon leads to a slowdown in the process of radiation defect formation: the A-center concentration in the samples n-Si<Yb> is 2 times less, and the E-center concentration is 5 times less than in the control samples n-Si (Fig.2, curves 1 and 2, peaks A and B).

CONCLUSIONS

Thus, the efficiency of radiation defects formation such as vacancy-oxygen (A-centers) and vacancy-phosphorus (E-centers) complexes significantly depends on the content of optically active interstitial oxygen and rare–earth impurity (ytterbium). At high oxygen content the $N_O^{opt} = 8{\cdot}10^{17}$ cm^{-3}, is dominated by the formation A-centers, when the content of the $N_O^{opt} = 8{\cdot}10^{16}$ cm^{-3}, is dominated by the formation of E-centers.

Comparison of DLTS spectra in irradiated control and doped samples shows that the presence of ytterbium atoms in the volume of silicon significantly reduces the formation efficiency of the detected radiation defects: in doped samples the concentration of A-centers is 2 times less, and E-centers 5 times less than in the control samples n-Si. This effect, apparently, should be associated with the peculiarities of the interaction of ytterbium atoms with defects introduced by irradiation.

ACKNOWLEDGEMENT

We express our sincere gratitude to the engineer Mrs. Kh.Aripdjanova for her assistance in preparing silicon samples for diffusion of ytterbium impurity and heat treatment.

REFERENCES

1. Shakhovtsov V. I., Shindich V. L., “Radiation effects in solids”. Kiev: Naukova Dumka, 1977; 88-102.
2. Physical processes in irradiated semiconductors / ed.S. Smirnov, Novosibirsk: Nauka, 1977; 256.
3. Emtsev, V.V. Emtsev, V.V. (Jr.), Poloskin D., Sobolev N. A., Shek, E. I., Michel Th., Kimerling L.C., “Impurity centers in silicon doped with rare earth impurities by dysprosium, holmium, erbium and ytterbium”. Semiconductors, 1999; 33(6): 649-651.
4. Karpov Yu. A., Petrov V. V., Prosolovich V. S., Tkachev V. D., “Radiation defects in silicon doped with erbium”. Semiconductors, 1983; 18(8): 1530-1532.
5. Antonenko R. S., Kornyushin S. I., Shakhovtsov V. I., “Radiation effects in silicon doped with gadolinium”. Semiconductors, 1976; 10(8): 1583-1586.
6. Monocrystalline silicon doped with some rare and transient elements. In the book. Doped semiconductor materials. Milwidsky M. G., Karpov Yu., Turov, B. M., Voronkov V. V., Kovaleva T. A., Moscow: Nauka, 1985; 97-102.
7. Lang D. V., “Deep level transient spectroscopy a new method to characterize traps in semiconductors”. J. Appl. Phys., 1974; 45(7): 6. 3023-3032.
8. Miller G.L., Lang D.V., Kimerling L.C. Capacity transient spectroscopy. - Ann. Rev. Mater. Sci., 1977; 7: 377-448.