wjert, 2024, Vol. 10, Issue 4, 01-04. Original Article ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 7.029

INFLUENCE OF YTERBIUM ATOMS ON THE FORMATION OF RADIATION DEFECTS WHEN IRRADIATING SILICON WITH ^{60}Co γ–QUANTUMS

Kh. S. Daliev[1], Sh. Kh. Daliev[2], M. B. Bekmuratov*[2], K. M. Fayzullaev[2] and Sh. A. Yusupova[3]

[1]Branch of the Federal State Budgetary Educational Institution of Higher Education. "National Research University MPEI", Tashkent, Uzbekistan.

[2]Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan.

[3]Ioffe Institute, Politekhnicheskaya Street 26, St. Petersburg 194021, Russian Federation.

Article Received on 23/01/2024 Article Revised on 12/02/2024 Article Accepted on 03/03/2024

***Corresponding Author**
M. B. Bekmuratov
Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan.

ABSTRACT

In this work, the influence of a rare earth impurity – ytterbium (Yb) on the process of formation of radiation defects in silicon under the influence of irradiation using non-stationary capacitance spectroscopy (DLTS) methods was studied. From the analysis of the measured spectra, it follows that the presence of Yb leads to a slowdown in the process of radiation defect formation: the concentration of the A-center in the n-Si<Yb> samples is 4÷5 times less than in the control samples.

KEYWORDS: rare earth element, ytterbium, silicon, DLTS, radiation defect, oxygen, oxygen-free, vacancy.

INTRODUCTION

It is known that doping single-crystal silicon with impurities of rare earth elements (REE) leads to an increase in the stability of its parameters to the effects of radiation.[1-2] This effect is explained by many authors by the presence of various rare earth inclusions in the Si lattice, which are effective sinks for vacancies created by irradiation. However, in the literature there is no consensus on the electrical activity of REE impurities and their interaction with radiation defects (RDs) and other impurities in silicon.

The purpose of this work is to study the influence of a rare earth impurity - ytterbium on the process of formation of radiation defects in silicon under the influence of irradiation using non-stationary capacitance spectroscopy (DLTS) methods. To carry out capacitance measurements on the samples under study, diode structures were manufactured using a well-known technique.[3] Measurements and processing of spectra are also described in detail in.[3,4]

MATERIALS AND METHODS

The samples studied were n-Si doped with Yb during growth from a melt with an initial resistivity of ρ=20 Ohm·cm. The total concentration of Yb atoms in the volume of single-crystalline Si was determined by neutron activation analysis; it was $3\cdot10^{16}\div7\cdot10^{17}$ cm^{-3} from the beginning to the end of the ingot. The control samples were n-Si samples with the same ρ and different oxygen content – the so-called "oxygen" Si with a concentration of optically active oxygen atoms $N_O^{opt} = 4\cdot10^{17}\div1\cdot10^{18}$ cm^{-3} and "oxygen-free" Si with $N_O^{opt} \leq 10^{16}$ cm^{-3}. The samples were irradiated at room temperature with ^{60}Co γ quanta with a flux intensity of ~ $3.2\cdot10^{12}$ $sq/cm^2\cdot s$.

RESULTS AND DISCUSSION.

From measurements of the DLTS spectra of Si samples doped with Yb during growth from the melt and control undoped samples before and after each irradiation cycle, the energy spectrum of the formed deep levels (DLs) was determined. Figure 1 shows the DLTS spectra of control n-Si samples (curve 1) and n-Si samples doped with ytterbium (2) after irradiation with ^{60}Co γ-quanta. Note that in these samples N_O^{opt} was $7\cdot10^{17}$ cm^{-3}. Analysis of the DLTS spectra shows that the introduction of Yb into Si during growth from a melt does not lead to the formation of any deep levels in the band gap of silicon, although according to neutron activation analysis, ytterbium atoms are present in the bulk of silicon in a fairly high concentration ($3\cdot10^{16}\div7\cdot10^{17}$ cm^{-3}).

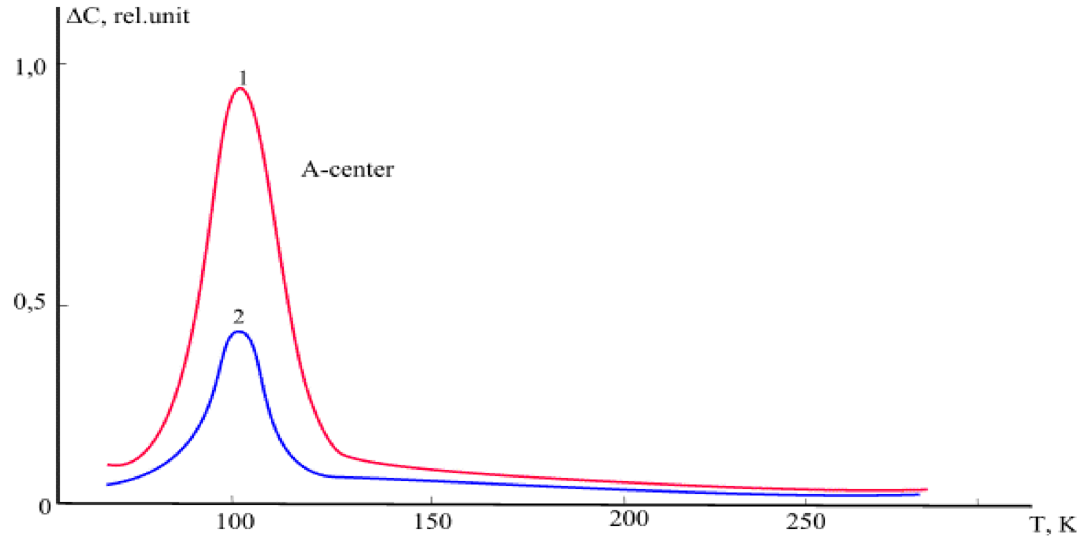

Fig. 1: DLTS spectra of control n-Si samples (1) and n-Si<Yb> samples (2) after irradiation with ^{60}Co γ-rays ("oxygen" Si, N_O^{opt} ~ 7·10^{17} cm^{-3}).

As can be seen from the DLTS spectra (Fig. 1, curves 1 and 2), as a result of γ-irradiation, both in the control n-Si samples and in the n-Si<Yb> samples, a new level is introduced with an ionization energy of E_C-0.17 eV and electron capture cross section $\sigma_n = 1\cdot10^{-14}$ cm^2.

The parameter values of this deep level refer to known radiation defects - vacancy-oxygen complexes (A-centers). From the analysis of the measured spectra it follows that the presence of Yb leads to a slowdown in the process of radiation defect formation: the concentration of the A-center in the n-Si<Yb> samples is 4÷5 times less than in the control samples. Moreover, the higher the ytterbium concentration, the lower the concentration of radiation defects. The features of radiation defect formation in "oxygen-free" silicon doped with ytterbium were also studied.

Measurements of the DLTS spectra of control samples of "oxygen-free" silicon (Fig. 2, curve 1) showed that γ-irradiation introduces into them, in addition to A-centers, another characteristic radiation defect - an E-center with an ionization energy of E_C-0.43 eV and a cross section electron capture σ_n=1.8·10^{-15} cm^{-2}. The concentration of the E-center in these samples at an irradiation dose of F=8·10^{17} sq/cm^2 is 4.2·10^{13} cm^{-3}, and the concentration of the A-center ≈ 2.5·10^{13} cm^{-3}, i.e. approximately an order of magnitude lower than the concentration of the A-center in "oxygen" Si (Fig. 1, curve 1).

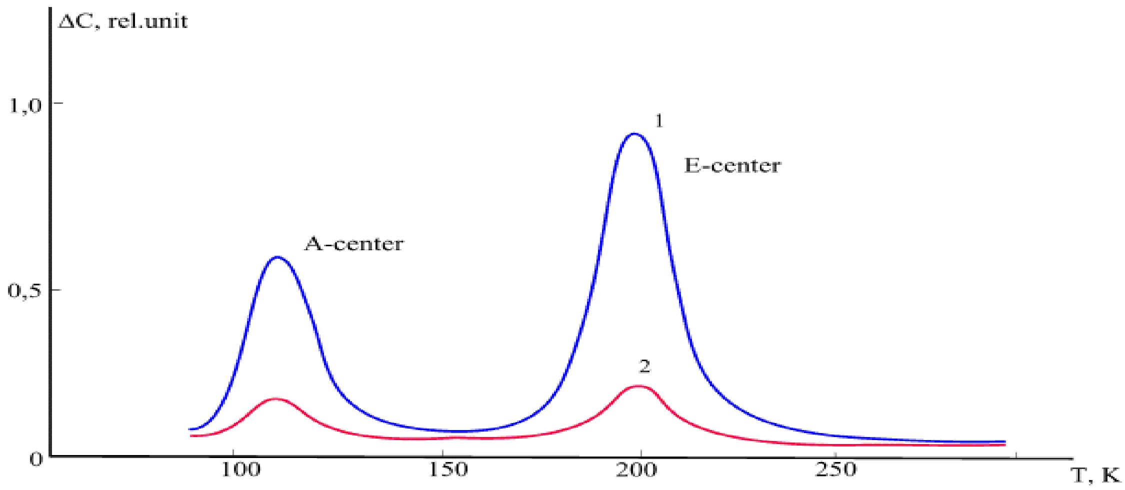

Fig. 2: DLTS spectra of control n-Si samples (1) and n-Si<Yb> samples (2) after irradiation with α-quanta of ^{60}Co oxygen-free Si, $N_O^{opt} \leq 10^{16}$ cm^{-3}).

A comparison of the DLTS spectra in irradiated control and doped samples shows that the presence of Yb in the bulk of Si leads to a significant decrease in the concentration of both levels of radiation defects. The concentrations of both A-centers and E-centers are almost an order of magnitude lower in irradiated n-Si<Yb> compared to control irradiated samples (Fig. 2, curve 2).

CONCLUSION

Thus, the presence of ytterbium atoms in the bulk of silicon significantly reduces the efficiency of the formation of the known radiation defects A-centers (vacancy-oxygen complexes) and E-centers (vacancy-phosphorus complexes). This effect, apparently, should be associated with the peculiarities of the interaction of ytterbium atoms with defects introduced by irradiation.

REFERENCES

1. Shakhovtsov V. I., Shindich V. L. Radiation effects in solids. Kyiv: Naukova Dumka, 1977; P. 88-102.
2. S. Smirnova. Physical processes in irradiated semiconductors / Ed.- Novosibirsk: Nauka, 1977; 256 p.
3. Zainabidinov S. Z., Daliev Kh.S. Defect formation in silicon. Tashkent: University, 1993; 192 p.
4. Berman L. S., Lebedev A.A. Capacitive spectroscopy of deep centers in semiconductors. L., Nauka, 1981; 170 p.