Volume: 6 Issue: III Month of publication: March 2018

DOI: http://doi.org/10.22214/ijraset.2018.3741

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue III, March 2018- Available at www.ijraset.com

Deep Level Transient Spectroscopy of Silicon, Doped by Zirconium

Shakhrukh Daliev[1]
[1]*National University of Uzbekistan named after Mirzo Ulugbek, 100174, Tashkent, Republic of Uzbekistan*

Abstract: By means of methods transient capacitance spectroscopy of deep levels and photo-capacitance studied the formation of defects in silicon, doped Zirconium. Discovered that diffusive introduction of zirconium into the silicon leads to the formation of three deep levels with fixed ionization energies of Ec-0.22 eV, Ec-0.42 eV and Ev+0.30 eV, and dominate the last two levels. It is established that the efficiency of the formation of deep centers associated with the atoms of zirconium increases with temperature diffusion and the cooling rate after diffusion.
Keywords: spectroscopy, silicon, defect, doping of the impurity, Zirconium.

I. INTRODUCTION

It is known that the formation of the defect structure of silicon is determined by the presence of specially introduced impurities, creating in the forbidden zone of silicon, a number of deep levels (DL) and has a significant influence on the electrophysical parameters of Si. To control parameters of silicon in recent years have increasingly used nontraditional doping impurities [1-4], examples of such impurities are refractory elements - atoms of hafnium, tungsten, zirconium, tantalum, etc. The purpose of this work was to study the energy spectrum of defects in silicon, doped with one of these elements, zirconium introduced in the Si diffusion method. The studies were conducted using nonstationary capacitance spectroscopy of deep levels DLTS and photo-capacitance .

II. EXPERIMENTAL SETUP

Doping of silicon by impurity of zirconium was carried out by diffusion method in a vacuum evaporated layer of metal Zr of high purity in the temperature range of 1000÷1250°C for 1÷50 hours. As control was used the samples of n - Si and p-Si heat-treated at the same temperature and time as the introduction of zirconium into the silicon.

For the doping used were n-Si with initial resistivity of 1 to 300 Ω·cm p-Si from 1 to 300 Ω·cm, the cooling rate of the samples after the diffusion of zirconium was varied from 0.1° C/s to 40-70°C/s.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The measurement results showed that in all samples n-Si after doping with zirconium to an increase in magnitude of the resistivity. In the samples p-Si of resistivity remains almost unchanged. For the samples Si, diffusion-doped with Zirconium, as well as subjected to control heat treatment were measured DLTS spectra and photo-capacitance. For carrying out capacitive measurements from the uncompensated crystals produced Schottky barriers by evaporation in a vacuum of gold on n-Si and antimony – on p-Si according to the technology described in [5]. As the ohmic contact is a chemically deposited Nickel or antimony evaporation.

DLTS spectra were measured in the regimes of constant capacitance and constant voltage [6, 7], and measurements of the spectra of photo-capacitance was carried out according to conventional techniques described in [7].

The dependence $1/C^2 = f(V_{reverse})$ determined from capacitance-voltage characteristics of all investigated diodes was linear. The concentration of ionized centers in the space charge layer in the diodes of the n-Si<Zr>, and also in p-Si<Zr>, determined on dependence $1/C^2 = f(V_{обр})$ at 300K, in good agreement with the concentration of acceptors in the initial silicon.

From measurements of the DLTS spectra of samples Si, diffusion-doped with Zirconium, as well as control samples, subjected to heat treatment (without any impurity of Zr) was determined the energy spectrum of deep levels. In Fig.1 shows the DLTS spectra of the samples n-Si and p-Si doped with zirconium at 1000°C and 1250°C followed by rapid cooling.

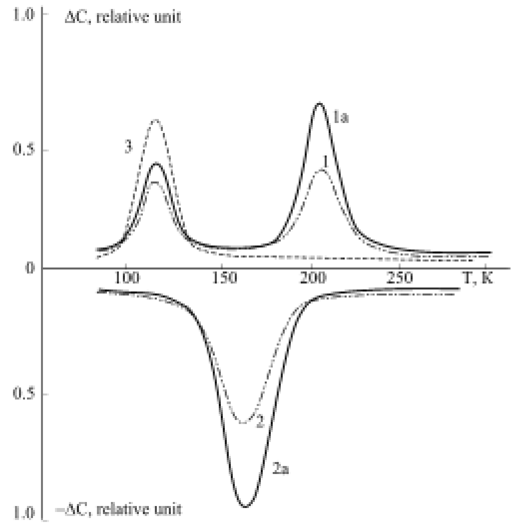


Fig.1.DLTS spectra of the samples n-Si and p-Si doped with Zr at 1000°C C and 1250°C (curve 1a, 2a), control samples (curve 3).

Processing of these spectra and the calculations show that the diffusion introduction of atoms of zirconium in n-Si and p-Si leads to the formation of several deep levels with fixed energy of ionization. In samples n-Si< Zr> was observed deep levels with parameters E_c – 0.22 eV, $\sigma_n = 2\cdot10^{-15}$ cm^2 and E_c – 0.42 eV, $\sigma_n = 7\cdot10^{-16}$ cm^2 (Fig.1, curve 1 and 1a) and the samples p- Si<Zr> are observed deep levels E_v + 0.30 eV, $\sigma_p = 5\cdot10^{-15}$ cm^2 (Fig.1, curve 2 and 2a).
Analysis of measured DLTS spectra of the samples n-Si<Zr> and p-Si< Zr> shows that the presence of Zr in Si leads to the formation of deep levels with fixed energy of ionization, the dominant ones are the last two levels. It is established that the efficiency of the formation of deep centers associated with the atoms of zirconium increases with temperature diffusion T_{diff} and the cooling rate after diffusion υ_{cool}: the more T_{diff} and υ_{cool} , the greater the concentration of deep levels of zirconium.
Simultaneous measurements of the spectra of photo-capacitance showed (Fig. 2) that in the doped samples, observed relaxation capacity in the energy region hν ~ 0.22, 0.42 and 0.30 eV. This energy range coincides with the measurements of the DLTS spectra, which suggests that the thermal and optical ionization energy of the detected levels do not differ.

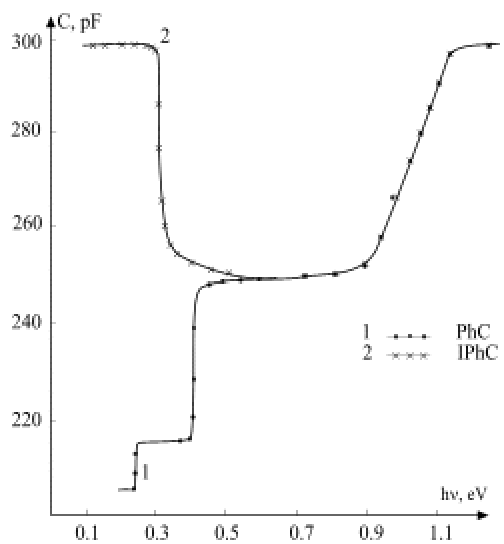


Fig.2. Typical spectra of the photo-capacitance (1) and photo-induced capacitance (2) samples of n-Si doped with Zr .

To determine the deep levels located in the lower half of the forbidden zone in the n-Si<Zr>, has been measured photo-induced capacitance. For this diode from the base was illuminated by a long time light with hν ≥ 1.4 eV. Measurement induced photo capacity showed that in the lower half of forbidden zone was discovered the only level

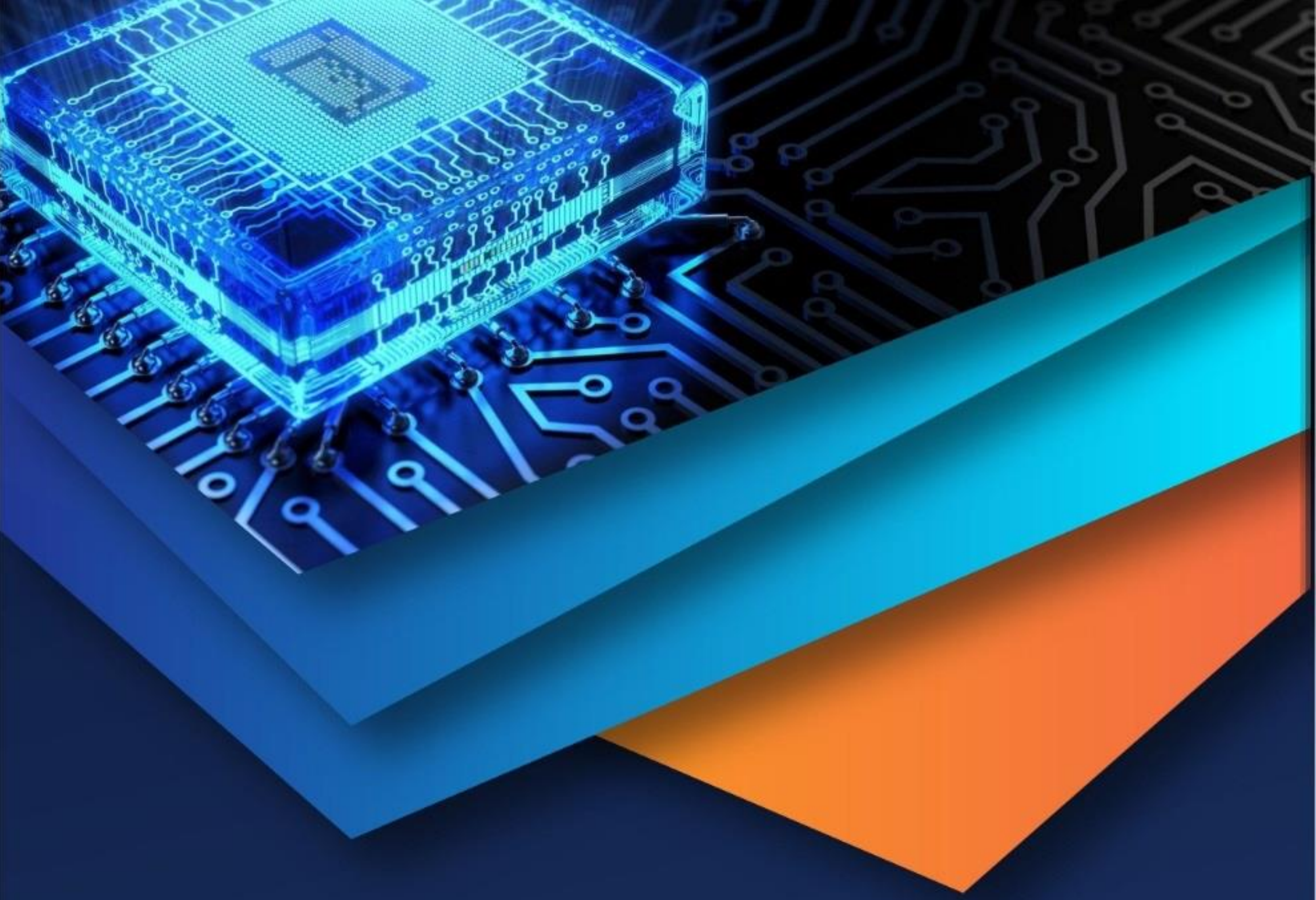
with ionization energy E_v+0.30 eV (Fig.3, curve 2). On the kinetics of filling levels by flow of minority carriers was measured the capture cross section of holes at the levels E_v+0.30 eV, which are associated with zirconium in silicon. The capture cross section of Zr at these levels were determined based on lgN=f(t) , it was 4.10^{-17} cm^2.
Parallel measurements of the spectra of DLTS and of photo-capacitance of the control heat treated samples of n-Si have shown that they have only a level with an ionization energy of E_c-0.22 eV, its concentration was of the order of N_{DL} = 10^{14} см^3, which is much higher than in the samples doped with zirconium. Hence, we can conclude that the atoms of zirconium in silicon are only the last two levels, namely the levels with the ionization energy E_c-0.42 eV and E_v+0.30 eV, and an E_c-0.22 eV is a defect in the heat treatment

IV. CONCLUSIONS

Thus, we can conclude that diffusive introduction of zirconium into the silicon leads to the formation of three deep levels with parameters $E_c - 0.22$ eV, $\sigma_n = 2\cdot10^{-15}$ cm^2 and $E_c - 0.42$ eV, $\sigma_n = 7\cdot10^{-16}$ cm^2 in n-Si< Zr>, the level E_v + 0.30 eV, $\sigma_p = 5\cdot10^{-15}$ cm^2 in p - Si< Zr>. It is established that only the last two levels, namely the levels with the ionization energy E_c-0.42 eV and E_v+0.30 eV, associated with the atoms of zirconium and silicon, and an E_c-0.22 eV is a defect of the heat treatment.
The efficiency of the formation of deep centers associated with the Zr atoms increases with increasing temperature diffusion T_{diff} and the cooling rate after diffusion υ_{cool} : the more T_{diff} and υ_{cool}, the greater the concentration of deep levels relating with Zr.

REFERENCES

[1] Daliev Kh. S., Utamuradova Sh. B., Bozorova O. A., Daliev Sh.Kh. A study of the characteristics of silicon doped hafnium by diffusion. "Reports of the Academy of Sciences of Uzbekistan", 2005, № 5, p. 21-23
[2] Utamuradov S.B., Daliev Sh.Kh. Rakhmonov J. C. Low-temperature annealing of the levels of zirconium in silicon . - DAN of the Republic of Uzbekistan, 2009, No. 6, pp. 45-47
[3] Utamuradova Sh.B., Rakhmonov J.S. Effect of irradiation on the properties of the levels of zirconium in silicon. Uzbek journal of physics, 2011, no. 4, pp. 272-275.
[4] Daliev Sh.Kh. A study of the influence of titanium and hafnium on the properties of volume and the interface Si-SiO_2 multilayer structures. UZB.Phys.zhurn., (Uzbek Journal of Physics), Vol. 19 (No. 1), 2017, pp. 24-28
[5] Daliev Kh.S. Utamuradova Sh.B., Daliev Sh.Kh. 2006.Technical Physics Letters, **32** 469 Pleiades Publishing, Inc.
[6] Lang D. V. (1974), “Deep-level transient spectroscopy: a new method to characterize traps in semi conductors”, J. Appl. Phys, Vol.45, Issue 7, pp. 3023-3027
[7] Berman, L. S., Lebedev A. A. 1981 Capacitive spectroscopy of deep centers in semiconductors (Moscow: Nauka) (in Russian).



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY