DLTS STUDY OF NEUTRON BOMBARDED SILICON DETECTOR

Jakub Rybár[1], Arpád Kósa[1], František Dubecký[2], Miroslav Petrus[1], Ľubica Stuchlíková[1], Jana Benkovská[1], Ladislav Harmatha[1], Pavol Hrkúť[3], Daniel Baček[4] and Peter Kováč[4]

1. Institute of Electronics and Photonics, Slovak University of Technology in Bratislava, Ilkovičova 3, 812 19 Bratislava, Slovakia

2. Institute of Electrical Engineering, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovakia

3. Institute of Informatics, Slovak Academy of Sciences, Dúbravská cesta 9, 845 07 Bratislava, Slovakia

4. Biont, a.s., Karloveská 2929/63, 841 04 Bratislava, Slovakia

E-mail: jakub.rybar@gmail.com

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1. Introduction

Silicon based detectors are used in various applications as particle and radiation detectors. Their radiation resistance became important in relation to spectrometric applications in harsh environments of soft X-rays emitted by hot plasmas together with neutrons and gamma rays. It is essential to understand the response of the detector structure to the neutrons and gamma radiation which produce different structural defects in the base material and also in its structure. These defects can be characterized by electrical and deep-level parameters describing their trapping activity in the device. The defects produced include vacancies, interstitials and divacancies. Divacancies are stable up to the temperature of about 600 K, whereas vacancies and interstitials are mobile except of very low temperatures [1]. The aim of the present study is to monitor and evaluate deep-level states introduced by neutron bombardment in spectrometric radiation detectors based on Si.

2. Experiment

The investigated Schottky barrier structures are made of n-type Si with the net donor concentration 9.7×10^{14} cm^{-3}. Circular contact with area 6×10^{-3} cm^{2} was formed by evaporation of Al in dry, high vacuum apparatus. The sample was twice bombarded by

neutrons under neutron with the estimated integral fluxes 3×10^{10} (dose #1) and 6×10^{10} (dose #2). The capacitance of detectors at zero bias gives a value of 35 pF.

Before and after each neutron bombardment the sample was evaluated by DLTS (deep level transient spectroscopy) technique [2] using apparatus BIO-RAD DL 8000 DLTFS. The measured spectra were evaluated with Software Dlts 2.6. During each measurement different combinations of set parameters were applied and evaluated.

3. Experimental results

Three sets of the measurements were done: state before the bombardment, after 1st and 2nd neutron bombardment, labeled as dose #1 and #2, respectively. Parameters of each measurement are described in the figures. Fig. 1 compares the three cases and shows the deep-levels peaks within the temperature range 80 K÷400 K. According to DLTS theory, each peak in the spectrum represents a deep level state in the material. Peak amplitudes correspond to the state concentration. It should be noted that the detected peaks in Fig. 1 cannot be easily compared, due to different scales used.

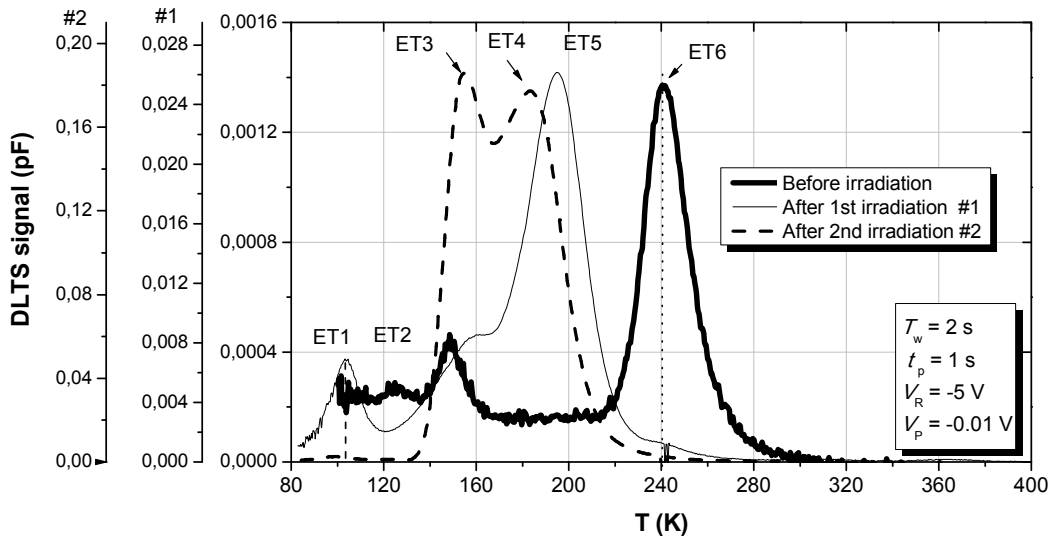

Fig. 1: *DLTS spectra: comparison before and after 1st and after 2nd neutron bombardment (I).*

Fig. 2 presents intensity comparison of different peaks in different set of measurements. In comparison with signal after 1st and 2nd neutron bombardment the peaks in signal before irradiation are irrelevant. We can detect some new peaks and observe intensity increase of these peaks after 1st and 2nd neutron bombardment. That shows the dependence of these defects on the amount of neutron bombardment. It is clear that defects ET1, ET3, ET4, and ET5 are neutron bombardment dependent.

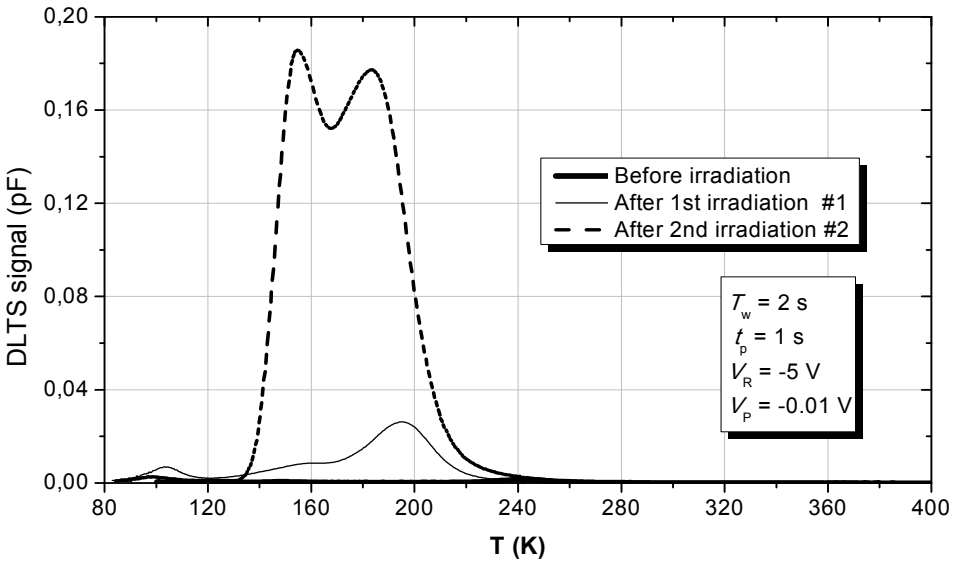

Fig. 2: *DLTS spectra: comparison before and after 1st, and after 2nd neutron bombardment (II).*

The ET3 signal intensity rise of cca 1400% is observed in Fig. 2 when comparing signals after 1st and 2nd neutron bombardment. From the change of ET4 and ET5 after 1st and after 2nd neutron bombardment it can be seen that those two peaks are very close. It is suggested that those two defects are closely linked if not one defect that is changing according to the amount of neutron bombardment.

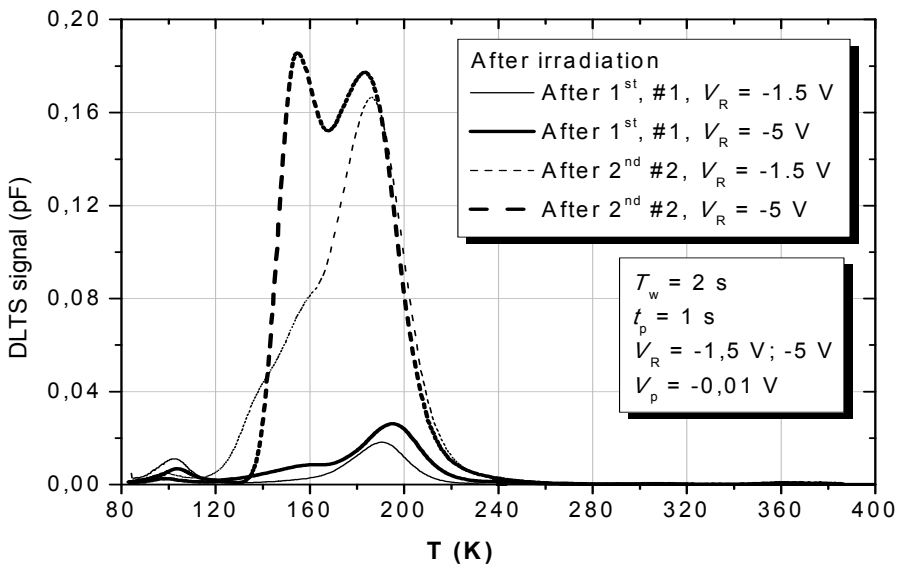

Fig. 3: *Comparison of two DLTS spectra after 1st and 2nd neutron bombardment taken with different measurement parameters.*

Fig. 3 compares two measurements revealed with different measurement parameters. It is clear from Fig. 2 that ET3 defect appears after applying V_R = -5 V.

4. Conclusion

After evaluation of the measured DLTS spectra, following defects were found and successfully evaluated their apparent activation energies and capture cross sections: ET1 (0.153 eV; 7.1×10^{-18} cm^2), ET3 (0.417 eV; 1.54×10^{-12} cm^2), ET4 (0.315 eV; 8.94×10^{-18} cm^2), ET5 (0.52 eV; 8.98×10^{-16} cm^2), ET6 (0.431 eV; 1.29×10^{-17} cm^2). Defect ET2 could not be evaluated and further measurements and study of the defect is needed. Defect with parameters of ET4 has already been observed in literature as arising from a positive charge state of a defect which may be viewed as a carbon-oxygen molecule bonded within a divacancy [3, 4]. ET3 has been identified as Pd impurity [5]. ET1 has been identified in literature as vacancy [6]. Better knowledge about the neutron induced deep-level defect states require further experimental as well as theoretical study. The detector testing performed after the neutron bombardment demonstrates full degradation of its spectrometric performance already after the first dose [7]. Hence, long term operation under neutron fluency required another semiconductor material, more resistant to the damage by neutrons such as GaAs, SiC or diamond.

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