STUDY OF RECOMBINATION CHARACTERISTICS OVER A WIDE FLUENCE RANGE IN REACTOR NEUTRON IRRADIATED Si

Justė Martinavičiūtė[1], Laimonas Deveikis[1], Tomas Čeponis[1]

[1]Vilnius University, Faculty of Physics, Institute of Photonics and Nanotechnology, Lithuania
juste.martinaviciute@ff.stud.vu.lt

Si is one of the most essential materials in high-tech applications, particularly in the fabrication of radiation-tolerant particle detectors and sensors used in high-energy physics and radiation monitoring. In these fields, the lifetime of non-equilibrium charge carriers is a critical parameter, as it serves as a sensitive indicator of material quality and lattice degradation [1]. Characterizing these recombination kinetics is essential for predicting the operational reliability and functional limits of semiconductor devices operating in harsh radiation environments.

In this work, Si samples were irradiated in the TRIGA Mark II reactor to induce displacement damage through the creation of primary Frenkel pairs and stable defect complexes, such as vacancies and related compounds [2]. These radiation-induced defects introduce deep energy levels into the bandgap that act as efficient recombination centers, directly dictating the speed of free charge carrier decay. To resolve these characteristics across a wide fluence range $(10^{12} - 10^{17}\,\mathrm{n/cm^2})$, two techniques were used. The microwave-probed photoconductivity (MW-PC) method was utilized for lower fluences to monitor nanosecond-range decay. However, at higher fluences, the increased density of recombination centers makes the kinetics ultrafast, exceeding the RC circuit constraints of the MW-PC system. Consequently, a femtosecond laser-based pump-probe (PP) method was required to resolve the picosecond-range kinetics in the most heavily irradiated samples. A comparative analysis of lower and higher irradiated Si was performed:

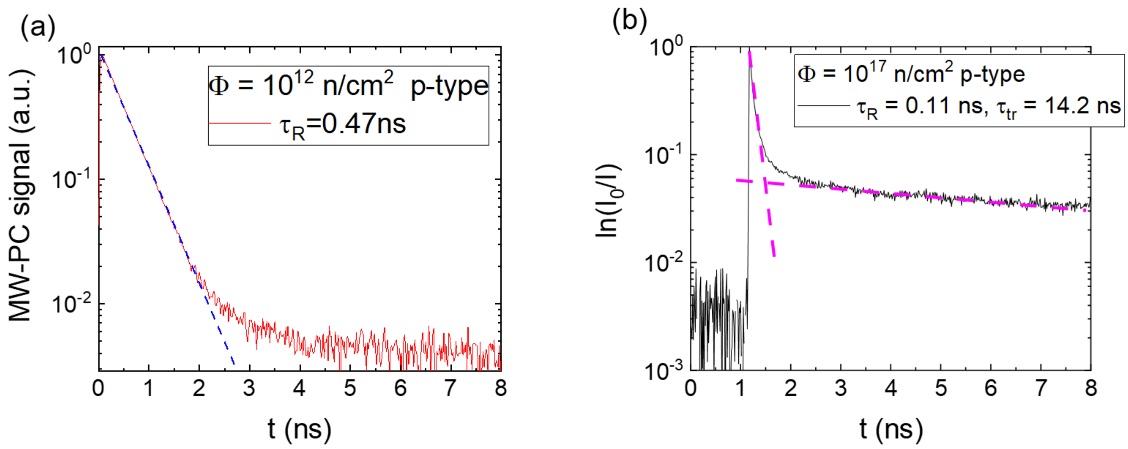

Fig. 1. (a) – MW-PC recombination kinetics at low fluence ($\varphi = 10^{12}\,\mathrm{n/cm^2}$). (b) – PP recombination kinetics at high fluence ($\varphi = 10^{17}\,\mathrm{n/cm^2}$).

Analysis of MW-PC and PP methods allowed us to determine the carrier lifetime in Si impacted by neutron irradiation. We found that the analysis of the recombination kinetics reveals a significant drop in carrier lifetime as the neutron fluence increases, from $0.47\,\mathrm{ns}$ at $10^{12}\,\mathrm{n/cm^2}$ to $0.11\,\mathrm{ns}$ at $10^{17}\,\mathrm{n/cm^2}$ fluence. A comparative analysis of these recombination characteristics and the methodology used to measure kinetics across a wide fluence range and various irradiation environments will be presented.

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[2] A. P. Dolgolenko, P. G. Litovchenko, M. D. Varentsov, G. P. Gaidar, and A. P. Litovchenko, "Particularities of the formation of radiation defects in silicon with low and high concentrations of oxygen," Physica Status Solidi (B), vol. 243, no. 8, pp. 1842–1852, May 2006, doi: 10.1002/pssb.200541074.