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Determination of radiation hardness of silicon diodes☆

E. Vittone[a,*], J. Garcia Lopez[b], M. Jaksic[c], M.C. Jimenez Ramos[d], A. Lohstroh[e], Z. Pastuovic[f], S. Rath[g], R. Siegele[f], N. Skukan[c], G. Vizkelethy[h], A. Simon[i]

[a] Physics Dept., University of Torino and INFN, Torino Unit, via P. Giuria 1, 10125 Torino, Italy
[b] Departamento de Física Atómica, Molecular y Nuclear, Facultad de Física, University of Sevilla, Spain
[c] Ruđer Bošković Institute, Zagreb, Croatia
[d] Centro Nacional de Aceleradores, University of Sevilla, Spain
[e] Department of Physics, University of Surrey, Guildford, Surrey, United Kingdom
[f] Center for Accelerator Science, ANSTO, 1 New Illawarra Rd, Lucas Heights, NSW 2234, Australia
[g] Department of Physics & Astrophysics, University of Delhi, Delhi 110007, India
[h] Sandia National Laboratories, Radiation-Solid Interactions, PO Box 5800, MS 1056, Albuquerque, NM 87185, USA
[i] International Atomic Energy Agency, Vienna International Center, PO Box 100, 1400 Vienna, Austria

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ABSTRACT

In this paper, we describe an experiment aimed to measure the physical observables, which can be used for the assessment of the radiation hardness of commercially available silicon photo diodes commonly used as nuclear detectors in particle accelerator laboratories. The experiment adopted the methodology developed during the International Atomic Energy Agency (IAEA) Coordinated Research Project (CRP No. F11016) "Utilization of Ion Accelerators for Studying and Modelling Ion Induced Radiation Defects in Semiconductors and Insulators".

This methodology is based on the selective irradiation of micrometer-sized regions with different fluences of MeV ions using an ion microbeam and on the measurement of the charge collection efficiency (CCE) degradation by Ion Beam Induced Charge (IBIC) microscopy performed in full depletion condition, using different probing ions.

The IBIC results are analyzed through a theoretical approach based on the Shockley-Read-Hall model for the free carrier recombination in the presence of ion-induced deep traps. This interpretative model allows the evaluation of the material radiation hardness in terms of recombination parameters for both electrons and holes.

The device under study in this experiment was a commercial p-i-n photodiode, which was initially characterized by i) standard electronic characterization techniques to determine its doping and ii) the Angle-Resolved IBIC to evaluate its effective entrance window. Nine regions of $(100 \times 100)\ \mu m^2$ were irradiated with 11.25 MeV He ions up to a maximum fluence of $3{\cdot}10^{12}$ ions/cm^2. The CCE degradation was measured by the IBIC technique using 11.25 MeV He and 1.4 MeV He as probing ions.

The model presented here proved to be effective for fitting the experimental data. The fitting parameters correspond to the recombination coefficients, which are the key parameters for the characterization of the effects of radiation damage in semiconductors.

1. Introduction

Semiconductor detectors are used in mixed radiation fields where more or less high degree of radiation tolerance is required: space and avionic applications [1], high energy physics experiments [2], medical diagnostic imaging and therapy, industrial imaging and material processing. In particle energy spectroscopy, the radiation tolerance of detectors is a major issue, due to the rapid degradation of detector performances as function of the ion fluence [3]. This issue is amplified further in activities involving the ion beam focused down to the

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* Corresponding author.
E-mail address: ettore.vittone@unito.it (E. Vittone).

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