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4H-SiC Schottky diode radiation hardness assessment by IBIC microscopy

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ABSTRACT

We report findings on the Ion Beam Induced Charge (IBIC) characterization of a 4H-SiC Schottky barrier diode (SBD), in terms of the modification of the Charge Collection Efficiency (CCE) distribution induced by 20 MeV C ions irradiations with fluences ranging from 20 to 200 ions/μm^2.

The lateral IBIC microscopy with 4 MeV protons over the SBD cross section, carried out on the pristine diode evidenced the widening of the depletion layer extension as function of the applied bias and allowed the measurement of the minority carrier diffusion lengths.

After the irradiation with C ions, lateral IBIC showed a significant modification of the CCE distribution, with a progressive shrinkage of the depletion layer as the fluence of the damaging C ions increases.

A simple electrostatic model ruled out that the shrinkage is due to the implanted charge and ascribed the perturbation of the electrostatic landscape to radiation-induced defects with positive charge state.

1. Introduction

Silicon carbide (SiC) has highly desirable physical and chemical properties that make it an ideal material for use in a wide variety of applications, ranging from micro-electromechanical systems [1], chemical sensing [2], quantum [3] and electronic devices. In this last field, silicon carbide, and in particular the 4H-SiC allotrope, plays a key role in power electronics [4] due to its large indirect band gap (~3.2 eV), large breakdown electric field (2 MV cm^{-1}), high electron mobility (900 cm^2 V^{-1} s^{-1}) and high thermal conductivity (400 W m^{-1} K^{-1}) [5]. One of the main elements of interest in this material is represented by the possibility of making SiC-based systems operating at high temperature [6] and, in general, in harsh environments [7], including the development of detectors operating in harsh ionizing radiation conditions [8]. Thanks to its high threshold energy for atomic displacement (24 eV for C and 66 eV for Si [9], to be compared with 21 eV in Si [10] and 50 eV for diamond [11]), SiC is an attractive candidate for the fabrication of radiation detectors [12] for applications ranging from laser-generated plasma diagnostics [13], high energy physics experiments [14], betavoltaics [15], x /gamma ray spectroscopy [16] to neutron monitoring [17] in fission reactors, in high-level radioactive waste [18] and fusion reactors [19,20].

The assessment of SiC radiation hardness is therefore important for the development of SiC detectors in radiation-intensive environments, and has been the object of several studies, aimed to identify main defects and the relevant recombination levels induced by radiation, which degrade the electronic properties of SiC devices [21–23].

This paper contributes to this subject by reporting the characterization of a 4H-SiC Schottky diode by the Ion Beam Induced Charge technique (IBIC). The advantages of this technique stems from using MeV ions both as damaging and probing agents, which allow both the characterization of the transport and electrostatic properties of semiconductors, as well as the study of damage induced by ion irradiation [24], on the availability of a robust interpretative model [25], and on the possibility of quantitatively mapping the charge collection efficiency (CCE) by using scanning focused ion beams [26].

The experiment here presented and discussed, consists of the IBIC analysis of a 4H-SiC Schottky diode, which was cleaved in order to expose its lateral cross section to 4 MeV proton microbeam to probe the CCE profile (first phase). Subsequently, selected areas of the frontal Schottky electrode were irradiated with 20 MeV C ion beam with different fluences (second phase). Finally, lateral IBIC analysis was performed in order to investigate the effects of the C ion irradiations on the CCE profiles (third phase).

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