Nuclear Instruments and Methods in Physics Research B 404 (2017) 259–263

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Ion Beam Induced Charge analysis of diamond diodes

J. Lehnert [a,b], J. Meijer [a], C. Ronning [c], D. Spemann [a,b], E. Vittone [d,*]

[a] University Leipzig, Institute for Experimental Physics II, Department Nuclear Solid State Physics, Linnéstr. 5, D-04103 Leipzig, Germany
[b] Leibniz Institute of Surface Modification, Physical Department, Permoserstr. 15, D-04318 Leipzig, Germany
[c] Friedrich-Schiller-University of Jena, Institute for Solid State Physics, Max-Wien-Platz 1, D-07743 Jena, Germany
[d] University of Torino, Physics Department and NIS Interdepartmental Centre, via P. Giuria 1, 10125 Torino, Italy

ARTICLE INFO

Article history:
Received 6 September 2016
Received in revised form 11 January 2017
Accepted 13 January 2017
Available online 31 January 2017

Keywords:
Diamond diodes
Ion Beam Induced Charge (IBIC) technique
Luminescent centers in diamond
Electroluminescence

ABSTRACT

Diamond based p-i-n light-emitting diodes, developed to electrically drive single-photon sources in the visible spectral region at room temperature, have the potential to play a key role in quantum based technologies. In order to gain more insight into the charge injection mechanism occurring in these diodes, we carried out an experiment aimed to investigate the electrostatics and the charge carrier transport by the Ion Beam Induced Charge (IBIC) technique, using 1 MeV He microbeam raster scanning of p-i-n structures fabricated in a high purity diamond substrate, using lithographic masking and P and B ion implantation doping.

Charge Collection Efficiency (CCE) maps obtained at low ion fluence, show that induced charge pulses arise only from the P-implanted region, whereas no IBIC signals arise from the B-implanted region. This result suggests the formation of a slightly p-type doped substrate, forming a n^+-p-p^+, rather than the expected p-i-n, structure.

However, for high fluence scans of small areas covering the intrinsic gap, CCE maps are more uniform and compatible with a p-i-n structure, suggesting the occurrence of a "priming effect", which saturates acceptor levels resulting in a decrease of the effective doping of the diamond substrate.

1. Introduction

One of the most interesting features of diamond diodes is electroluminescence induced by charge injection in recombination centers and, remarkably, in individual single nitrogen-vacancy (NV) centers located in the intrinsic region [1]. The possibility to develop diamond optoelectronic devices with stable, room-temperature, electrically driven single-photon sources is a key technology with a broad range of application ranging from quantum communication, computing and metrology [2]. The electrical control of the charge state of NV centers in diamond requires the control of the Fermi level in the diamond band-gap, which has been successfully achieved by incorporating the luminescent center in an intrinsic diamond layer sandwiched between graphitic/-graphitic electrodes [3] or in p-i-n structures with graphitic ohmic contacts [4–6]. However, for the optimization of these devices and their standardization in the perspective of their large scale production, an accurate and spatially resolved characterization of their electrostatic features is essential.

This analysis can be effectively carried out by the Ion Beam Induced Charge (IBIC) technique, which has been widely proven to be suitable to provide valuable information on the electrostatic and transport characteristics of semiconductor/insulator electronic devices [7,8]. Besides, it is of high interest in the field of quantum technology, for example, for its potential to accurately measure the ion strike location for single atom deterministic doping [9,10] in silicon and for the detection of single low energy ion (Si, 200 keV) in diamond for the optimization of the production yield of single color centers [11].

However, to our best knowledge, IBIC technique has not been so far applied to the electronic characterization of p-i-n diamond structures, in order to extract electric field profiles, and carrier diffusion/drift lengths as done for example in Si, GaAs, SiC junction or Schottky diodes [7,12].

In order to explore the potential of IBIC in this field, in this paper, we report on the first IBIC analysis of diamond-based p-i-n light-emitting diodes capable of single-photon emission in the visible spectral region at room temperature [4].

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

http://dx.doi.org/10.1016/j.nimb.2017.01.021
0168-583X/