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Study of ion induced damage in 4H-SiC

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Abstract. The damage produced by 2 MeV protons on a 4H-SiC Schottky diode has been investigated by monitoring the charge collection efficiency as the function of the ion fluence. A new algorithm based on the Shockley-Ramo-Gunn theorem has been developed to interpret the experimental results. The fitting procedure provides a parameter which is proportional to the average number of active electrical traps generated by a single ion, which can be profitably used to estimate the radiation hardness of the material.

Introduction

4H-SiC Schottky diodes have been recently fabricated showing good performances as radiation detectors [1]. The wide band gap, large saturation velocity, large breakdown voltage and high thermal conductivity make this material a very attractive alternative to silicon for ionizing radiation detection applications. Moreover, the radiation hardness has often been considered an important quality of this material, which makes SiC an ideal candidate for detectors operating in high radiation damage environments. In order to evaluate the radiation hardness of 4H-SiC Schottky diodes, we have performed an experiment which follows the experimental procedure described in [2]. The behavior of the Charge Collection Efficiency (CCE) has been monitored as the function of the fluence of 2 MeV protons. The experimental data have been analyzed with a one-dimensional model which provides the charge collection profile as a function of the ion fluence. The model is valid only for relatively low ion fluences, since it assumes a direct proportionality between the trap density and the ion fluence; moreover, it considers a frozen vacancy distribution, as evaluated by a Monte Carlo computer code [3].

Experimental

The measurements were carried out at the ion microbeam facility of the Ruđer Bošković Institute in Zagreb (HR) using a 2 MeV proton beam focused to a spot size of less than 5 μm. The sample consisted in an array of 16 Schottky electrodes with dimension 0.4x0.4 mm^2 fabricated by Alenia Marconi on an n-type (net doping concentration: 5x10^{14} cm^{-3}) epitaxial layer purchased from CREE Research company. Details on detector fabrication can be found in [1].

Figure 1 shows an Ion Beam Induce Charge (IBIC) map of two electrodes. The charge collection efficiency is encoded in grey scale, from the lowest (black) to the highest (white) values. The bias voltage was 34.2 V, corresponding to a depletion region of about 7 μm as evaluated by C-V measurements, not reported here. The map shows damaged regions due to previous IBIC measurements. In particular, the white arrow in Fig. 1 indicates the 83x86 μm^2 region in detector 1, which was scanned by the proton beam up to a final fluence of 4x10^{10} protons·cm^{-2}. Figure 2 shows the evolution of the average IBIC signal measured during proton irradiation of this small area. After a fluence of 4x10^{10} protons·cm^{-2}, the charge collection efficiency is about 30% less than in the non-irradiated zone.