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Charge collection efficiency mapping of interdigitated 4H–SiC detectors

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ABSTRACT

The Ion Beam Induced Charge (IBIC) technique was used to map the charge collection efficiency (CCE) of a 4H–SiC photodetector with coplanar interdigitated Schottky barrier electrodes and a common ohmic contact on the back side.

IBIC maps were obtained using focused proton beams with energies of 0.9 and 1.5 MeV, at different bias voltages and different sensitive electrode configurations (charge collection at the top Schottky or at the back Ohmic contact).

These different experimental conditions have been modeled using a two-dimensional finite element code to solve the adjoint carrier continuity equations and the results obtained have been compared with experimental results. The excellent agreement between the simulated and experimental CCE maps allows an exhaustive interpretation of the charge collection mechanisms occurring in pixellated or strip detectors.

1. Introduction

In previous papers [1–3] we presented the mathematical formalism adopted to interpret IBIC experiment on the basis of a solid and rigorous theory founded on the basic laws of electrostatics [4,5]. The algorithm is based on the solution of the adjoint continuity equations for holes and electrons [6] and allows charge collection efficiency maps to be obtained with reduced computational efforts.

In order to validate this theoretical approach, several benchmark experiments were recently carried out at the Ruđer Bošković Institute (RBI) in Zagreb (HR) on 4H–SiC Schottky diodes [1]. Its electronic features and radiation hardness, combined with a well established process to fabricate nuclear detectors [7], make 4H–SiC an ideal material to perform such IBIC experiments. Moreover, the exhaustive electronic and ion/X-ray beam analyses performed in the last years on these devices provide well assessed input parameters for the calculation of CCE profiles and maps at the micrometer scale [7].

In the first of these experiments [1], the IBIC characterization of a Schottky diode array was carried out by mapping of the CCE at different bias voltages and led to the accurate definition of the active region underneath the sensitive electrode surrounded by a grounded guard ring.

Here we report on IBIC experiments on coplanar interdigitated electrodes with different sensitive electrode configurations and carried out at two different proton energies. The experimental results are compared with simulations for a deeper understanding of the physical mechanism of the induced charge collection in multi-electrode structures.

2. Experimental

The sample under test consists in a Schottky diode fabricated by Alenia Marconi on an n-type (40 μm thick, donor concentration: $N_D \approx 10^{15}\ cm^{-3}$) epitaxial layer produced by CREE Research company [8].

The back Ti–Pt–Au ohmic contact was deposited on the C face of the n+ substrate. The front Schottky contact consists of a pair of Ni_2Si–Au interdigitated finger combs with finger sizes of 50 μm in width and 700 μm in length. The gap between the fingers on opposing combs is 20 μm; combs are separated from the guard ring (50 μm in width) by a gap of 70 μm. A SEM image of the device is reported in Fig. 1.

The rectifying junctions exhibit 1.56 eV Schottky barrier height and reverse current lower than 0.1 nA at 100 V reverse bias voltage.

The bias voltage is applied at the back ohmic electrode with respect to the ground, which is connected to the guard ring and to the comb G. The connection to the charge sensitive preamplifier defines the sensitive electrode. In configuration A the preamplifier is connected to the back electrode and the comb S is grounded

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