Angle resolved IBIC analysis of 4H-SiC Schottky diodes

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I. INTRODUCTION

A new experimental procedure based on the ion beam induced charge collection (IBIC) has been used to characterize semiconductor detectors and devices. It consists in measuring the charge collection efficiency (η) as a function of the angle of incidence (α) of a strongly penetrating MeV ion beam focused onto a partially depleted semiconductor detector. The one-dimensional model, based on the drift-diffusion model derived from the Shockley-Ramo-Gunn's theorem, gives the theoretical background to fit the $\eta(\alpha)$ curve and to estimate both the extension of the depletion layer, the dead layer thickness and the minority carrier diffusion length.

To illustrate the analytical capability of this technique, a 2 MeV proton beam was focused at different incident angles onto a 4H-SiC Schottky diode.

II. EXPERIMENTAL SET-UP

The IBIC experiment was carried out at the microbeam facility of the Legnaro Italian National Laboratory using a 2 MeV proton beam partially focused to an area of about 100x100 μm; the sample was mounted on a rotating holder connected to a goniometer allowing the orientation of the sample with respect to the incident ion trajectory with an uncertainty of 1°. The IBIC signal processed by a standard charge sensitive electronic chain (ORTEC 142A preamplifier, ORTEC 572 amplifier with shaping time of 2 μs) was acquired using an analog-to-digital converter by Canberra (model 8701) interfaced with a PC board.

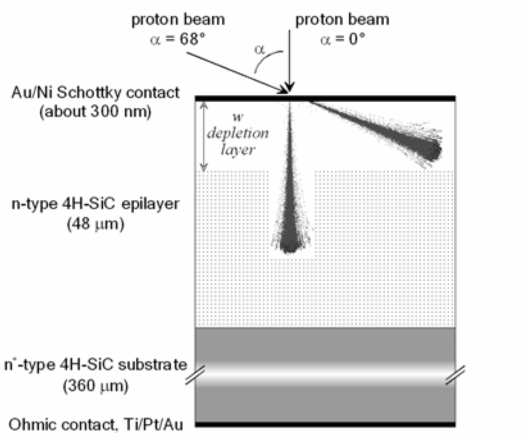

FIG.1: Scheme of the experimental set-up

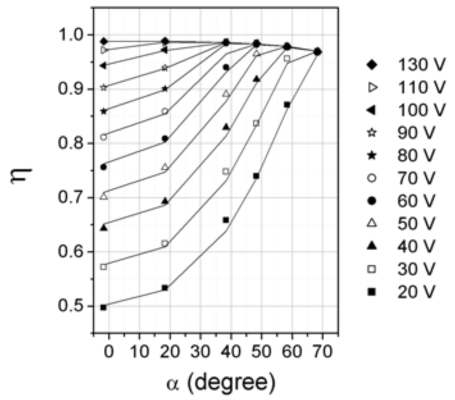

FIG.2: Charge collection efficiency as function of the angle of incidence for different bias voltages. Symbols=experimental data; lines: curve fits

The structure of the 4H-SiC diode (sample M) is reported in [1]. The epitaxial layer was grown at the Institut für Kristallzuchtung of Berlin (Germany) on a commercial, low defect density, substrate from CREE Res. Inc. The diode was fabricated by Alenia Marconi Systems by realizing the ohmic contact on the whole back of the substrate (C-face) and the circular (F = 5 mm) Schottky barrier on the surface (Si-face) of the 4H-SiC epilayer by evaporation of Ni and Au.

Figure 1 shows the scheme of the experimental set-up.

III. RESULTS AND DISCUSSION

Fig. 2 shows the $\eta(\alpha)$ curves evaluated at different applied bias voltages. At low bias voltages, the curves show a minimum at $\alpha \approx 0°$, i.e. when the ion beam is normal to the electrode, whereas η is maximum at $\alpha \approx 70°$.

Such curves have been interpreted considering an extension of the simple one-dimensional drift-diffusion model [2], commonly used to evaluate the transport properties of semiconductor devices. In this model the charge induced at the electrode is given by two contributions: one from carriers generated within the depletion region and drifted towards the electrode by the strong electric field, assuming that the transit time is much shorter than the carrier lifetime, the other from minority carriers generated within the neutral region and injected by diffusion into the depletion region.

The generation profile along the direction normal to the sensing electrode is a function of the incidence angle, as is