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Lateral IBIC characterization of single crystal synthetic diamond detectors

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In order to evaluate the charge collection efficiency (CCE) profile of single-crystal diamond devices based on a p-type/intrinsic/metal configuration, a lateral Ion Beam Induced Charge (IBIC) analysis was performed over their cleaved cross sections using a 2 MeV proton microbeam. CCE profiles in the depth direction were extracted from the cross-sectional maps at variable bias voltage. IBIC spectra relevant to the depletion region extending beneath the frontal Schottky electrode show a 100% CCE, with a spectral resolution of about 1.5%. The dependence of the width of the high efficiency region from applied bias voltage allows the constant residual doping concentration of the active region to be evaluated. The region where the electric field is absent shows an exponentially decreasing CCE profile, from which it is possible to estimate the diffusion length of the minority carriers by means of a drift–diffusion model.

1 Introduction Diamond has extreme electronic and optical properties. The low intrinsic conductivity due to the wide bandgap, the high carrier mobility, the high thermal conductivity, the chemical inertness and the radiation hardness make it a good candidate as particle, UV and X-ray detector in many fields, especially in high radiation environments [1–4]. Although good results were obtained in the past using natural, high pressure high temperature (HPHT) and chemical vapor deposition (CVD) polycrystalline diamond, the last decade witnessed a vast improvement in the diamond detectors performances due to the development of homoepitaxial diamond (single crystal, SC) growth [5]. This material is characterized by high purity and low defect concentration, it exhibits long charge carrier lifetimes, high mobility and does not require a priming procedure before operation [6–8]. Recent results obtained in the detection of UV light [9], X-rays [10] and neutrons [11] with SC-diamond detectors are very promising.

Ion beam induced charge (IBIC) is a very suitable technique to characterise transport properties in wide band gap semiconductors employed as ionizing radiation detectors [12]. SC-diamond detectors were already studied by means of frontal IBIC [13]. In this Letter we report on the characterization of diamond SC Shottky diodes by means of lateral IBIC technique.

2 Experimental The device was developed starting from a single-crystal diamond grown by CVD technique at the laboratories of Rome "Tor Vergata" University. Diamond was grown on a HPHT substrate in a p-type/intrinsic layered structure by a two-step plasma-enhanced microwave CVD homoepitaxial deposition process. A cross-sectional schematic of the device is reported in Fig. 1. A commercial HPHT Ib single crystal diamond $4 \times 4 \times 0.4$ mm^3 in size was used as substrate. A ~ 20 μm thick heavily boron-doped (~10^{20} cm^{-3}) layer was first deposited on the HPHT substrate followed by the deposition of a 30 μm thick diamond layer with a net electrically active acceptor-like defect concentration of the order of 10^{14} cm^{-3} [10]. A circular Al contact with a diameter of 2 mm and 200 nm