A multi-electrode two-dimensional position sensitive diamond detector

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ABSTRACT

In multi-electrode devices, charge pulses at all the electrodes are induced concurrently by the motion of the excess charge carriers generated by a single ion. This charge-sharing effect is such that the pulse amplitude at each sensitive electrode depends on the device geometry, its overall electrostatic configuration, and the charge transport properties of the detecting material. Therefore, the cross-analysis of the charge pulses induced at each electrode offers implicit information on the position of the ion impact. In this work, we investigate the two-dimensional position sensitivity of a diamond detector fabricated by deep ion beam lithography. By exploiting the ion beam induced charge technique, the device was exposed to a 2 MeV Li^+ ion micro-beam to map the spatial dependence of the charge collection efficiency (CCE) on the nominal micro-beam scanning position. The combination of the CCE maps revealed a two-dimensional position sensitivity of the device with micrometric resolution at the center of the active region.

Ion beams are consolidated tools for the characterization and functionalization of materials and electronic devices and detectors and are commonly adopted for materials manufacturing processes.[1–3] The availability of dedicated setups for the delivery of focused or collimated ion beams with sub-micrometer resolution[4–7] has enabled the flourishing of spatial-resolved experimental techniques for the characterization of the charge transport properties of detectors and semiconductors,[8,9] the effects of radiation damage on their response,[10–13] and the analysis of single event effects in microelectronic devices.[14,15] Conversely, the availability of real-time position-sensitive single-ion detectors could enable the controlled dose delivery at the micrometric scale for the assessment of radiation damage at high doses,[16] the selective functionalization of materials,[17,18] or the implementation of cell culture irradiation protocols for micro-radiobiology experiments.[19,20] It would also enable to obtain high spatial sensitivity on individual ion strike position without the need for focusing or collimating ion optics elements.

Recent works have explored the possibility to exploit the implantation targets themselves as resources for position-sensitive single-ion detection.[21–23] Particularly, the exploitation of charge-sharing effects in multi-electrode devices to both sense the impact of individual keV and MeV ions in solid state detectors and concurrently retrieve their impinging position has been proposed.[24–26] Specifically, it was shown that the evaluation of the induced charge shared between multiple electrodes could be used to detect the ion strike location with sub-micrometer precision. Despite the premises, these results were, however, based on simple one-dimensional geometries and offered a limited (i.e., few μm) position-sensitive detection regions. In this work, we present a proof-of-concept experiment based on the ion beam induced charge (IBIC)[27] technique to determine the ion beam impact point position of a MeV ion. The methodology requires initially the acquisition of charge collection efficiency (CCE) maps by three sensitive detectors located at the vertices of an equilateral triangle, which is the active area probed by a scanning focused MeV ion beam. The measurements of the charges induced at the three sensing electrodes by a MeV ion impacting the active area, combined with the three CCE maps, enable the identification of the impact position of a MeV ion with the same mass and energy with a resolution at the micrometer scale. The detector was fabricated on a commercial $3 \times 3 \times 0.3\ mm^3$