A Letters Journal Exploring the Frontiers of Physics

October 2013

EPL, **104** (2013) 28005
doi: 10.1209/0295-5075/104/28005

www.epljournal.org

Measurement and modelling of anomalous polarity pulses in a multi-electrode diamond detector

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received 15 September 2013; accepted in final form 28 October 2013
published online 22 November 2013

PACS 85.30.De – Semiconductor-device characterization, design, and modeling
PACS 29.40.Wk – Solid-state detectors
PACS 81.05.ug – Diamond

Abstract – In multi-electrode detectors, the motion of excess carriers generated by ionizing radiation induces charge pulses at the electrodes, whose intensities and polarities depend on the geometrical, electrostatic and carriers' transport properties of the device. The resulting charge-sharing effects may lead to bipolar currents, pulse height defects and anomalous polarity signals affecting the response of the device to ionizing radiation. This latter effect has recently attracted attention in commonly used detector materials, but different interpretations have been suggested, depending on the material, the geometry of the device and the nature of the ionizing radiation. In this letter, we report on the investigation in the formation of anomalous polarity pulses in a multi-electrode diamond detector with buried graphitic electrodes. In particular, we propose a purely electrostatic model based on the Shockley-Ramo-Gunn theory, providing a satisfactory description of anomalous pulses observed in charge collection efficiency maps measured by means of Ion Beam Induced Charge (IBIC) microscopy, and suitable for a general application in multi-electrode devices and detectors.

Introduction. – Solid-state multi-electrode detectors are widespread devices for radiation measurement. Segmented devices such as strip, drift, pixelated detectors display advantageous features such as high spatial resolution, low capacitance, low noise, thus matching the requests for high reliability, reproducibility and spectral resolution for radiation tracking and measurement in particle physics, photodetection, medical imaging and dosimetry [1]. On the other hand, in a multi-electrode device, the motion of free carriers generated by ionizing radiation induces a charge on the electrodes surrounding the active region. The sharing of the induced charge depends on the device geometry and the electronic properties of the material, and may lead to possible misinterpretations of measured signals, if compared with the response of detectors with large surface electrodes. Moreover, a solid understanding of the charge-sharing mechanism in multi-electrode devices provides an essential tool for the development of promising deterministic doping techniques (*i.e.* position-resolved single-ion implantation) for quantum computing applications [2,3].

In the past decades several limitations to the sensitivity of multi-electrode detectors were ascribed to charge sharing in commonly used silicon, cadmium zinc telluride (CZT) and germanium-segmented detectors. Pulse height defects and charge losses [1], charge collection efficiency (CCE) losses and spectra distortion [4–6], ambipolar transient current signals [7] and anomalous polarity pulses [8,9] have been reported so far. Specifically, we adopt the "anomalous polarity pulse" term to refer to an induced charge pulse having the opposite polarity to what would be detected in a standard device with two large parallel electrodes [9].

A few studies [1,8,9] proposed the Shockley-Ramo theory [10,11] and its extensions as the basis of the interpre-

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