Eur. Phys. J. Plus (2025) 140:369
https://doi.org/10.1140/epjp/s13360-025-06291-3

THE EUROPEAN PHYSICAL JOURNAL PLUS

Regular Article

IBIC analysis of a linear position sensitive detector: model and experiment

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Received: 14 December 2024 / Accepted: 1 April 2025
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Abstract The ion beam-induced charge (IBIC) analysis of a commercial silicon photodiode configured as a position sensitive detector (PSD) for energetic charged particles is the subject of this report. Although the photodiode is designed for detecting the position of incident light and optimized for use in the UV region, we present evidence that it also performs well as a detector for ions, with energies in the MeV range. The device consists of a uniform *p*-type layer formed on a high-resistivity *n*-type semiconductor substrate, a pair of electrodes on both ends of the resistive layer, and a common electrode located on the backside of the substrate. The IBIC experiment was carried out at the Laboratory for Ion Beam Interaction of the Ruder Boskovic Institute in Zagreb (HR), using 2 MeV proton microbeam raster scanning the (2.5 mm × 0.6 mm) active area of the PSD. Each of the three electrodes was connected to independent standard NIM charge-sensitive electronic chain and the induced charge pulses associated with the position of individual ions were then digitized using a multi-channel analyzer interfaced with the SPECTOR software. The longitudinal charge collection efficiency profiles acquired from the top electrodes show linear behaviors with opposite slopes, whereas the profile relevant to the signals from the back electrode is almost constant. A model based on the IBIC theory satisfactorily interprets these results. It offers an alternative viewpoint to the commonly adopted Lateral Effect Photodiode principle and paves the way for the development of new PSDs for the identification of the impact position of a MeV ion with a resolution at the micrometer scale.

1 Introduction

Among the many types of devices capable of measuring the position of a light spot, position semiconductor sensors based on lateral photo effect [1] play an important role in various applications spanning from laser-tracking to synchrotron X-ray beam profiling [2].

A very common design of position sensitive devices (PSDs) consists on a photodiode with a resistive layer on the illuminated side with two (1D) or four contacts (2D) and a common electrode on the backside. The photocurrent gets split in the resistive layer in proportion to the resistance between the generation site and the contacts and the position of the incident light can be directly calculated from the ratio of the photocurrents.

The same devices have been investigated also for the measurement of position and energy of energetic charge particles [3–5]. In this case, the signal from the backside electrode is proportional to the particle energy, whereas the position signals are obtained from the charge fractions induced at the electrodes of the front-side resistive layer. These PSD's have found applications in Rutherford Backscattering Spectrometry/Channeling experiments [6] and for single electron/positron detection for emission channeling from radioactive atoms incorporated in crystals [7]. The position resolution in these works hardly fell below fraction of mm.

Ion Beam Induced Charge (IBIC) technique is an ideal technique to characterize such detectors [8]. Actually, charge signals from the sensing electrodes are detected synchronously with the incident position of ions, which are focused and scanned on the active area, in order to provide charge collection efficiency maps, which qualify the spatial sensitivity of the detector.

Noteworthy, IBIC technique is supported by a robust theoretical background [9], which models the relation between the incident particle position and the induced charge at the sensing electrode, in an alternative o complementary way of the commonly adopted charge division model [10, 11].

In this work, an experiment was designed and conducted to characterize a commercially available position sensitive photodiode by the IBIC technique. The experimental results, satisfactorily interpreted by a theoretical model based on the IBIC theory, demonstrate that this type of detector is suitable to be used as a position sensitive detector for charged particles.

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Published online: 07 May 2025