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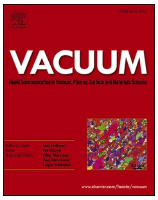

An ion beam spot size monitor based on a nano-machined Si photodiode probed by means of the ion beam induced charge technique

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ABSTRACT

In this work the utilization of the Ion Beam Induced Charge (IBIC) technique is explored to assess the resolution a 2 MeV Li + ion microbeam raster scanning a micrometer-sized FIB-machined hollows in a silicon photodiode. The analysis of the maps crossing the FIB machined structures evidenced a drop in charge collection efficiency across the perimeter of the hollows combined with a significant recovery of the signal amplitude at the center of the microstructures, thus forming a micrometer-sized feature which can be exploited to estimate the resolution of the probing beam. The results were interpreted according to numerical simulations based on the Shockley-Ramo-Gunn as originating from a FIB-induced surface space charge density.

These results offered additional information with respect to what achievable by a confocal photocurrent microscopy analysis of the same device, due to the significantly shorter focal depth of the latter with respect to the probing ion beam.

This study suggests the viability of an effective method to evaluate of the resolution of ion microbeams in processes and experiments, which could be beneficial in emerging fields (deterministic implantation, micro-radiobiology, ion lithography) demanding beam spot sizes below the micrometer scale.

1. Introduction

MeV ion beams are an appealing and versatile tool for the modification, functionalization and analysis of solid state materials [1]. The steady improvements in the last decade in the focusing and collimation of ion beams [2–6] offer enticing opportunities towards the functionalization of materials at the nanoscale [7,8] and the controlled introduction of individual dopants for single-defect engineering by means of ion implantation [9,10]. For processes involving the employment of MeV beams with spot sizes approaching the nanometre scale, the availability of tools for the accurate control on the beam size and resolution is crucial. The main techniques commonly adopted by the scientific community, such as STIM (Scanning Transmission Ion Microscopy), RBS (Rutherford back-scattering) and PIXE (Particle Induced X-ray Emission) rely on the imaging of patterned standards, e.g. TEM grids to assess the beam resolution [11–13] or resolution standards fabricated by proton beam writing [14,15]. Such approach has however the disadvantage of requiring a dedicated reference standard (typically different from the sample intended to be processed), a separate measurement system, and ion currents ranging from nA (as for PIXE or RBS) to fractions of fA (as for STIM or other single-ion detection techniques). These requirements might represent a limit to the accuracy of the estimation of the beam size at sub-μm scales nanoscale, and its implementation might turn to be unpractical for automated functionalization processes as well as for experiments requiring high positional accuracy and precision.

While the scientific community has recently started to integrate in the target samples themselves reference structures to be used as resources for single ion detection [16] with position sensitivity [10,17], the development of on-target diagnostic tools offering the assessment of the ion beam resolution is still currently unexplored. In this work the possibility to gain spatial information on the size of an MeV ion micro-beam based on charge collection efficiency (CCE) measurements is explored by means of a dedicated Ion Beam Induced Charge (IBIC)

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