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Nuclear Instruments and Methods in Physics Research B 266 (2008) 2142–2145

NIM B
Beam Interactions with Materials & Atoms

www.elsevier.com/locate/nimb

Performance of the SIRAD ion electron emission microscope

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Available online 15 March 2008

Abstract

An axial ion electron emission microscope (IEEM) is now working at the SIRAD irradiation facility of the INFN Laboratories of Legnaro (Italy). The IEEM is used to precisely reconstruct the impact points of single ions, information that may be used to determine the areas of a microelectronic device under test that are sensitive to single event effects (SEE). After describing the setup briefly reviewing its working principles, we show our first time resolved ion induced electron emission images of standard calibration targets. We also discuss a preliminary measurement of ion impact detection efficiency of the IEEM system and the available trigger signals for SEE studies. We finally make an assessment of ion electron emission microscopy at SIRAD and indicate future developments.

PACS: 61.80.Jh; 85.60.Gz

Keywords: Single event effects; Ion electron emission microscopy

1. Introduction: the SIRAD axial IEEM

When an energetic ion strikes a microelectronic device it induces current transients that may lead to a variety of undesirable single event effects (SEE). An important part of the activity of the SIRAD heavy ion facility at the 15 MV Tandem accelerator of the INFN Laboratories of Legnaro (Italy) concerns studying SEE in microelectronic devices destined for radiation hostile environments [1].

Recently, the SIRAD facility has been upgraded with an ion electron emission microscope (IEEM) [2,3]. The IEEM is used to reconstruct the positions of individual ion impacts on an irradiated surface by imaging the secondary electrons emitted during each ion impact. This information may be used to map the SEE-sensitive areas of an irradiated device under test (DUT). The IEEM works in an axial configuration: the ions pass down through the IEEM to impact the DUT orthogonally (Fig. 1).

The ion impact efficiency of an IEEM relies on a high electron yield per ion impact of the surface under study. Normally the surface of a semiconductor device under test (DUT) is a poor electron emitter. In addition the efficiency of electron collection and proper transport through the microscope can be altered by any target surface roughness. To standardize the target surface we place an ultra-thin free-standing gold flat membrane on top of the DUT. This approach ensures adequate secondary electron emission and near independence from the DUT.

The secondary electrons are collected and transferred by a commercial photon electron emission microscope (PEEM [4]) to the focal plane of the microscope where a micro-channel plate (MCP [5]) detector amplifies them in number and encodes the spatial information of the ion impact point on the DUT. The electronic avalanche generated by the MCP excites a phosphor to create photons that are extracted from the irradiation chamber through a view-port. The photons enter a beam splitter: part proceed

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0168-583X/$ - see front matter
doi:10.1016/j.nimb.2008.02.084

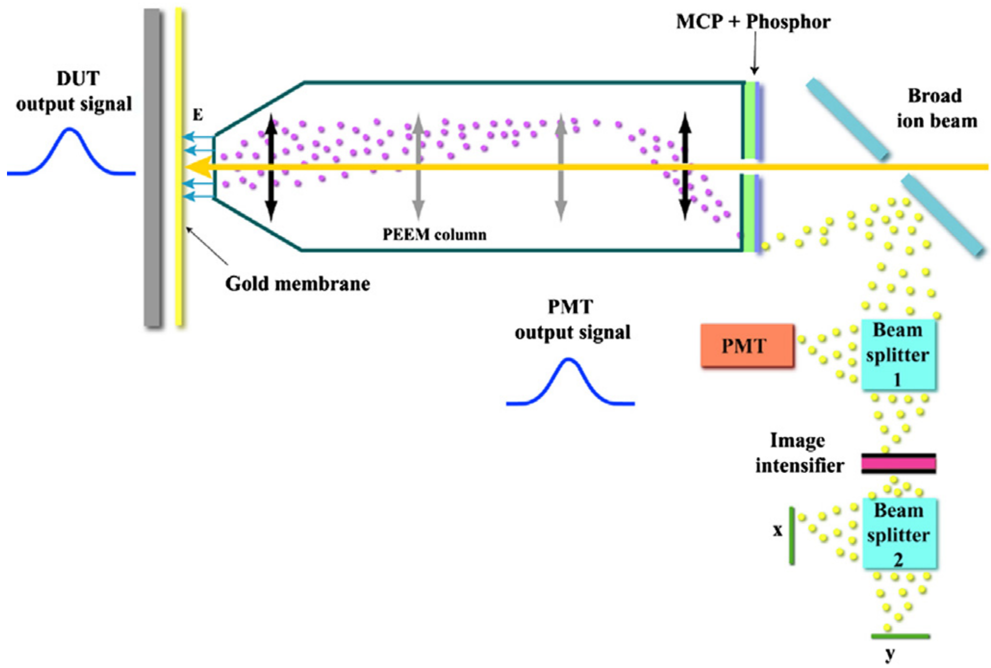

Fig. 1. Schematic of IEEM setup.

toward a photomultiplier tube (PMT), used to generate a fast trigger signal, the rest are reflected towards an image intensifier. The regenerated image is then transported onto a fast photon position sensitive detector which allows the determination of the position of the luminous spot (see Fig. 2).

The axial configuration is parallax free, but it requires that the MCP and phosphor stack have a central hole to allow the passage of the ion beam to the target. We use a large 4 cm chevron (two-stack) MCP + phosphor (P47) stack with a 8 mm central hole. A 45° mirror, with central hole, is needed to extract the photon signal off-axis.

A specially designed irradiation chamber was installed at the end of 2005 after a major upgrade of SIRAD. It is box-like shaped and a whole side opens like a drawer to allow easy access to the sample holder mounted on the floor of the drawer. Two flanges are oriented at 75° respect to the beam axis and are aimed at the target plane: one hosts an external UV lamp used for focusing the IEEM, the other one houses an optical microscope system that aids the positioning of the DUT.

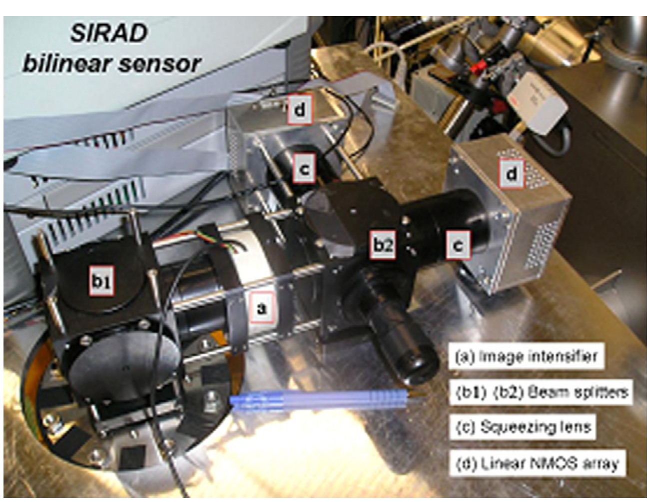

Fig. 2. The bilinear detector system. The optical signal is reflected upwards by a mirror and out a viewport into a first beam splitter (b). Part of the signal is detected by a PMT (not shown), the rest is reflected horizontally, regenerated by an image intensifier (a) and sent to a 2nd beam splitter (b). Each copy of the image is squeezed and detected by a linear NMOS array (d).

2. The imaging sensor and first axial images

The resolution of an IEEM is controlled by the contrast diaphragm inside the PEEM that selects electrons with proper trajectories in a limited energy range. We use a diaphragm with a large 300 μm aperture to maximize the transmission efficiency of the secondary electrons onto the focal plane MCP detector. The contrast diaphragm also acts as a collimator for the broad ion beam.

For IEEM applications we developed a novel fast light-spot position sensor based on two orthogonal linear NMOS arrays [6]. To determine the position of the bright light-spot generated by an ion, the light signal is split by a beam splitter into two copies, representing the x and y coordinate respectively and each of them is separately detected by a linear array sensor. An FPGA-based system processes and fits the incoming digitized data from the two linear sensors in parallel and the position of the light-spot is determined. The event reconstruction (i.e. the match of corresponding x and y) is implemented at software level