Ion Photon Emission Microscope for Radiation Effects Microscopy

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Motivation—Semiconductor and microelectronic circuits and devices used in space and weapons are subjected to bombardment by high-energy cosmic ray ions. These interactions frequently result in reliability problems and unpredictable behavior.

Historically, laboratory-based, ion-induced radiation effects studies on semiconductors and devices have been performed using spatially-broad beams flooding the sample, generated from a high-energy, lab-based particle accelerator. Single-Event-Upset (SEU) cross-sections are then measured as a function of the ionizing power of the beam. While these approaches have been extremely valuable and productive for overall device characterization, they frequently do not enable the spatial pinpointing of the specific devices within a circuit involved in radiation sensitivity problems.

The goal of this research was to develop a new approach that could use the broad ion beams from an accelerator or radioactive source to pinpoint where Single Event Effects occur on a chip.

Accomplishment—With the Ion Photon Emission Microscope, or IPEM, spatially-resolved information is obtained from use of a single-event-counting, position-sensitive detection system. This detector determines the X-Y position of a single ion strike occurring among many in the broad incident ion beam, using an auxiliary photon-generating thin fluorescent film (ion-to-photon converter) located in the plane of the sample, a standard optical microscope and a Mepsicron™ single photon position sensitive detector. Figure 1 shows a schematic of the IPEM.

When this ion-strike spatial location is time-correlated with a specific observed SEU or charge collection problem event in the device under test, a detailed and quantitative map of radiation sensitivity is produced, which is of much greater interpretive and diagnostic value than are the traditional broad beam tests. Figure 2 shows an example of the IPEM imaging charge collection in an operational amplifier being studied for Single Even Gate Rupture with Lockheed Martin. An extended sample area can be analyzed and mapped without any point to point scanning, leading to potentially more rapid and comprehensive measurements. Also, since photons are being imaged, the analysis of the part or circuit can take place in air, ameliorating the need to put the samples into a vacuum chamber. Such in-air analyses are becoming common for Single Event Effects testing at large cyclotron facilities such as that at Texas A&M and Michigan State Universities.

Significance—The IPEM team won an R&D-100 Award in 2005 for this invention, and the unit is being marketed by Quantar Technology, Inc., as the 2600-IPEM Analyzer. We plan to develop an IPEM to operate at the Texas A&M Cyclotron lab for ultra high energy - heavy ion radiation effects microscopy in the near future.

Sponsors for various phases of this work include: Nuclear Weapons/Readiness in Technical Base & Facilities

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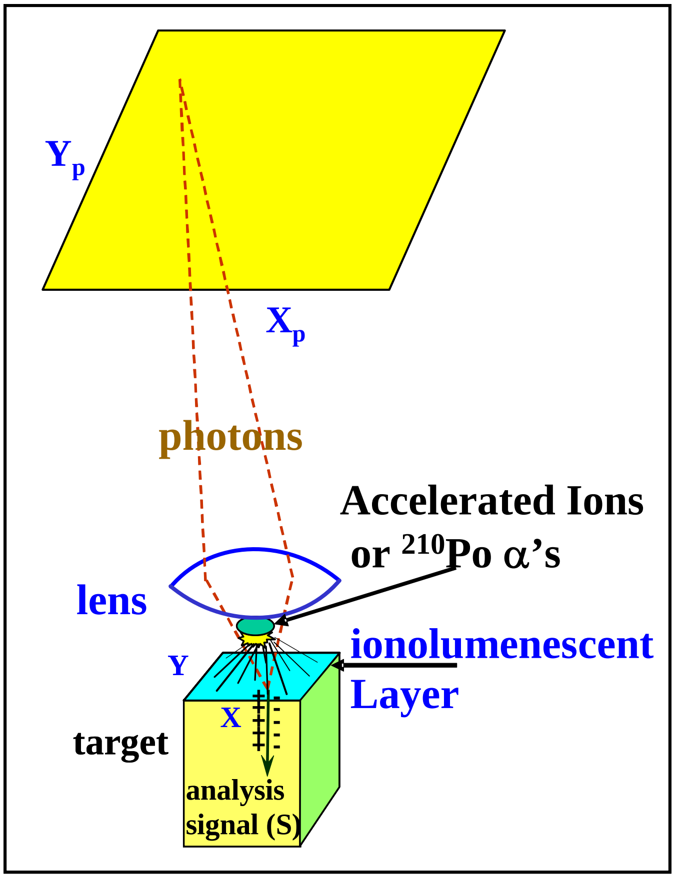

Figure 1. A schematic of the IPEM operating principle. The ion beam from a radioactive source or accelerator is placed as the target. The sample can be in either vacuum or external to the ion-source vacuum. Then, a very thin fluorescent film is placed over the DUT surface. This film produces one or multiple simultaneous photons in response to the passage of each incident ion from the source. These photons are then projected at high magnification through a conventional optical microscope onto a specialized, X-Y position-sensitive, single-photon-counting, microchannel-plate photon detector. Because this detector is single-event-counting, the event can be time-correlated with an upset event that may occur in the device under test (DUT). Spatial resolution (device spatial identification) is currently limited to approximately 1-2 micron FWHM. Between 50,000 and 100,000 detected ion strikes per second can be processed leading to relatively rapid data map development.

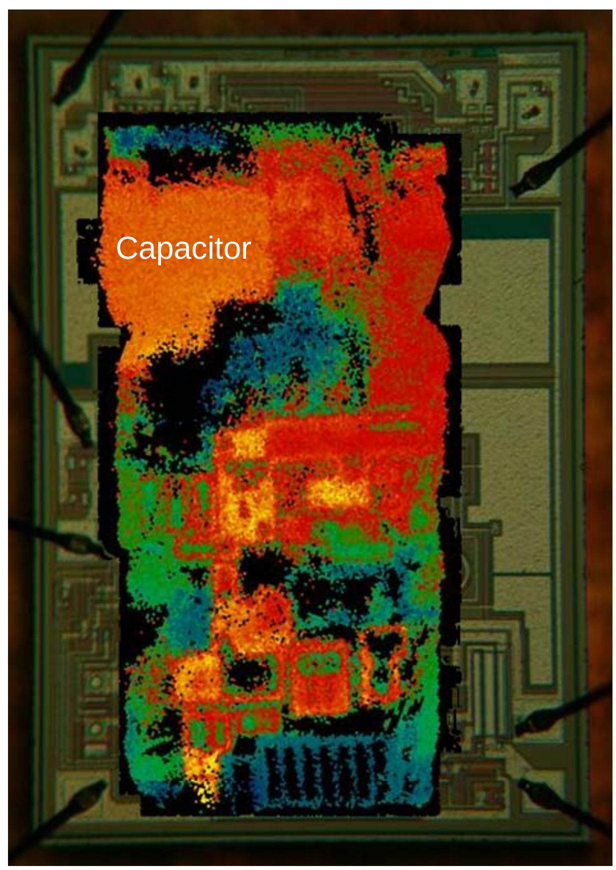

Figure 2. An example of IPEM-Ion Beam Induced Charge (IBIC) is shown in this figure, where the IBIC image is plotted on top of a photo of the die. This die is 2x3mm, and several IPEM-IBIC images were overlayed to produce this charge collection map. The sample is an operational amplifier that is being studied jointly with Lockheed Martin Corporation for Single Event Gate Rupture. While the alpha particles cannot induce a gate rupture, this IBIC image is useful to identify regions of high charge collection, and clearly identifies the large capacitors of the op amp, one which is labeled in the figure. The uniformity of the IBIC signal across these capacitors shows that they were manufactured correctly.