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Silicon photomultipliers: new structures for improved radiation hardness

Silicon Photomultipliers (SiPMs) are single-photon sensitive detectors that continue to attract increasing interest in several industrial and scientific applications that require fast detection speed, high sensitivity, compactness, insensitivity to magnetic fields and low bias voltages. In particular, the SiPMs are used in high-energy physics (HEP) experiments, and for the readout of scintillators in gamma-ray detectors for space experiments. In such applications they receive a significant dose of radiation (e.g. protons, electrons, neutrons, ⋯) which degrades their performance.
During the last years, at FBK (Trento, Italy) we have been developing many different technologies for SiPMs and SPADs, optimized for different applications. We also studied extensively the effects of ionizing energy loss (IEL) effects and non-ionizing energy loss (NIEL) effects (i.e. bulk displacement damage) on many different SPAD and SiPM technologies. These highlighted the important role of electric-field enhancement on the primary noise generation, especially from the defects created by bulk damage during irradiation. As well we seen an important effect of IEL increasing charges in the dielectrics, which in turn create spurious electric field peaks in the devices, thus increasing the primary and the correlated noise.
Based on such results, we started specific technological improvements aimed at improving the radiation hardness of novel SiPMs technologies. We are currently working on several directions. Among the most promising: i) we are exploiting the reduction of the high-field active area, with a novel SiPM structure based on charge-focusing mechanisms, and ii) we are working on active control and draining of radiation-induced charge in the dielectrics. We performed TCAD simulations, and we obtained preliminary results from irradiations with protons and X-rays showing potentiality of such novel structure in reducing the radiation degradation effects on SiPMs structures.

Workshop topics

Sensor materials, device processing & technologies

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