ID contributo: **39** Tipo: **non specificato**

Near-Ultraviolet Sensitive deep-junction (NUV-DJ) SiPMs, a new SiPM technology optimized for big physis experiments and timing applications

mercoledì 21 febbraio 2024 16:30 (20 minuti)

Over the last few years, Fondazione Bruno Kessler (FBK, Trento, Italy) has gained experience in the development of several Silicon Photomultiplier (SiPMs) technologies. The SiPM is a solid-state photodetector, sensitive to single-photons, which is becoming the device of choice in different applications, ranging from the big physics experiments to medical applications, such as time-of-flight positron emission tomography (TOF-PET), in which a fast timing is a strong requirement.
Following this direction, FBK is developing a new SiPM technology, called Near-Ultraviolet Sensitive deep-junction (NUV-DJ). The development is being carried out using an external silicon foundry. The NUV-DJ microcell (SPAD, Single Photon Avalanche Diode) is based on a p-type, high-resistivity, epitaxial layer, grown on top of a low-resistivity n-type bulk. Conversely to traditional FBK SiPMs, the high-electric field region is located deeper in the device. This allows electrons to trigger the avalanche also when the carriers are photo-generated deeper below the surface by longer wavelength photons, thus enhancing the avalanche triggering probability.
In the first production, several 8-inch wafers were manufactured, and the main process and layout split were tested. We carried out an extensive characterization, including the current-voltage characteristic, photon detection efficiency (PDE), the primary noise rate, single photon time resolution (SPTR), and coincidence time resolution (CTR) using LYSO scintillators. The measured breakdown voltage in all the wafers was aligned with the expected values from the TCAD simulations. The best layout and process split showed a maximum excess bias (limited by the so-called second divergence of the correlated noise) larger than 20 V, confirming the effectiveness of the new SPAD structure and the good optical isolation between microcells. The PDE showed unprecedented values of 70% (including a nominal fill factor of 80.8%), at 420 nm of wavelength and 10 V of excess bias. Moreover, we measured a SPTR of 60 ps FWHM at 20 V of excess bias, for a 4x4 mm^2 SiPM and a CTR of less than 100 ps FWHM using a 2.76x2.76x18 mm^3 LYSO:Ce crystal at 10 V of excess bias.
These results are state-of-art as regards timing and PDE, thus very interesting for TOF-PET applications using either LYSO, LSO, BGO, LaBr3 crystals or in an experiment where a high PDE in the NUV region is a requirement.

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Classifica Sessioni: SiPM2