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SiPM development at FBK for the barrel timing layer of CMS

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The peculiar features of SiPMs, such as their compact size, insensitivity to magnetic fields, low power consumption and mechanical robustness make them very promising as photosensors in calorimeters and precision timing detectors in the future generation of high energy physics experiments. In these contexts, a critical aspect is the radiation hardness of the silicon detector. Currently available technologies show performance deterioration at fluencies of about 1e10 neq/cm2, and compromised single photon counting capabilities at fluencies of about 1e13 neq/cm2.
At FBK, dedicated technological improvements of SiPMs are in progress for the barrel timing layer (BTL) of CMS experiment, in view of the high luminosity phase of LHC (HL-LHC). In the current design of the detector upgrade, SiPMs will be used for double-side readout of LYSO:Ce scintillating bars with a length of 50 mm and a base area of 3×3 mm2.
In recent studies, FBK NUV-HD Low Field SiPMs showed improved performance after irradiation compared to conventional NUV-HD technology. The dark current of NUV-HD Low Field SiPMs after irradiation at 5e13 neq/cm2 showed a temperature coefficient of 1.77/10℃ compared to 1.65/10℃ obtained with conventional NUV-HD technology . This fact is attributed to the reduction of field-enhanced generation in Low Field technology. NUV-HD Low Field technology was selected as the baseline for this development, allowing a significantly reduced dark noise level if SiPMs are operated at a temperature of -30℃ or lower.
The SiPM technology development for the upgrade of BTL detector combines a small cell size with a modified version of NUV-HD Low Field. The small cells provide a low microcell gain, of about 3e5 at an excess bias of 3 V, which results in a small direct crosstalk probability (<10%). Moreover, the small microcell capacitance allows to obtain a fast recharge time constant (10 ns), which reduces cell occupancy. The electric field engineering resulted in a faster rise of the triggering probability as a function of the excess bias compared to NUV-HD Low Field. The photon detection probability (PDE) of the technological version that has been selected in the R&D phase is of about 27% at 420 nm at an excess bias of 3 V and it saturates at about 45% at high excess bias (˜10 V).
FBK SiPMs optimized for BTL were tested after irradiation up to 1e13 neq/cm2, showing performance in line with the requirements of the experiment, when operated at -30℃ and at low excess bias (about 2 V). In the next months, FBK will run a preproduction of SiPMs for BTL, based on the results of the R&D phase. The preproduction will aim to demonstrate performance and reliability of the developed technology. Advanced packaging solutions will be tested to provide a radiation hard device, suitable for long term operation in the high luminosity phase of LHC.

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