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FBK SiPM NUV-HD-MT technology: from an improved SPICE simulation to the timing performance

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Silicon Photomultipliers (SiPMs) have gathered interest in several fields from High Energy Physics experiments to biomedical applications thanks to their excellent energy and timing resolution, together with their low operating voltage, low cost, ruggedness and insensitivity to the magnetic fields. The modeling of the SiPM in terms of equivalent electrical circuit and the estimation of its electrical parameters are fundamental to properly simulate the device response for a proper front-end design and possibly tailor the sensor to match the requirements of the research experiments. Many efforts have been made in order to create a general and reliable equivalent electrical model and to simulate the SiPM response. Moreover, in the last years, excellent results in terms of timing performance have been achieved thanks to the improvement of the scintillator crystal materials, the electronics readout and the detector development. In this work we focused on the simulation of a single microcell (SPAD) and on the timing performance in terms of Single Photon Time Resolution (SPTR) of the recently introduced FBK NUV-HD Metal in Trench (MT) technology.
An improved SPICE simulation has been implemented by using a new model for the diode capacitance C_d. This is typically considered constant whereas in some SiPM technologies it has been found to change with the applied excess bias. The reliability of the model has been confirmed by extracting the electrical parameters of the SPAD at different excess bias and comparing the simulated and the measured overall single-cell response.
The SPTR measurement has been performed by using a femto-second laser with a wavelength of $390nm$ and by testing SPADs with different microcell sizes and different layout versions: with or without a metal mask outside the active area (capacitive coupling). Moreover, a $1mm \times 1mm$ and a $3mm \times 3mm$ SiPMs with $40\mu m$ cell size and M0 masking version have been tested. By using a high frequency readout electronics, we achieved an outstanding SPTR of about $\simeq 19ps$ and $\simeq 30ps$ FWHM for the SPAD and $1mm \times 1mm$ SiPM with $40\mu m$ M0 masking respectively.
We found that the single cell response simulated with the new model matches the experimental acquired signal with a discrepancy below 5%, which is a significant improvement with respect of the constant capacitance model. Moreover, further investigations will allow to understand the role of the metal masking in the timing performance and to discuss about limitations and future improvements.

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