Eleventh International Workshop on Semiconductor Pixel Detectors for Particles and Imaging

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Design and optimisation of radiation resistant AC- and DC-coupled resistive LGADs

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High Energy Physics at future colliders demands a new generation of particle detectors with capabilities exceeding those of current silicon technology. For example, at the various e^+e^- machines (CEPC, CLIC, FCC-ee, and ILC), the key requests are low material budget and excellent spatial resolution, with modest requests for radiation resistance or precise timing ($\sigma_t < 50$ ps). On the other hand, at hadron machines (FCC-hh, HE-LHC, and SppC), the most challenging requests are the radiation resistance (fluences above 10^{17} 1 MeV n_{eq}/cm^2) and the spatial and time precision (pileup $\sim$ 1000 events/bunch crossing, $\sigma_t \sim 5$ ps/hit, $\sigma_x \sim 5$ μm/hit).

Among different ongoing R&D activities, thin silicon sensors that combine resistive read-out and internal gain, known as low gain avalanche diode Resistive Silicon Detectors (RSDs), represent a very promising technology solution. For example, excellent position and temporal resolutions (in the order of 10 μm and below 50 ps, respectively) have been observed at the DESY test beam facility on 450 μm-pitch prototypes with AC-coupled cross-shaped electrodes coming from the second batch of RSD sensors produced by FBK (RSD2). Moreover, their large pixel size will allow for a reduction in the number of read-out channels and thus help build 4D silicon telescopes with minimised power consumption.

However, using AC-coupled electrodes shows that, on average, 30% of the signal leaks outside the hit pixel, thus limiting the use of AC-RSDs in high occupancy environments. DC-coupled electrodes were investigated as a potential solution to improve signal containment within the pixel area. The concept of DC-coupled RSD (DC-RSD) has been finalised using an innovative mixed-mode approach to simulation (SPICE-based fast modelling and full 3D TCAD simulations of the sensor behaviour) that guided the design of their first production, presently in progress at Fondazione Bruno Kessler.

In this contribution, the design guidelines for DC-RSDs, as well as new strategies for signal confinement in AC-RSDs, will be shown. The impact of different sensor components (e.g. the coupling oxide and the resistive layer) is evaluated in the latter case. Moreover, a predictive analysis of both AC- and DC-RSD performance after irradiation carried out with state-of-the-art Technology CAD tools coupled with the last release of the Perugia radiation damage numerical model will be presented.

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