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Vertically integrated avalanche pixel sensors for charged particle detection

In this work, the implementation of a new type of silicon sensor based on Geiger-mode avalanche detectors is proposed. The sensor consists in a two-tier pixel array, where each pixel is based on two vertically aligned avalanche detectors, and the coincidence between two simultaneous avalanche events is used to discriminate particle-triggered detections from dark counts.
Thanks to the large avalanche gain, the detector thickness can be much smaller than in conventional particle detectors and the electronics much more compact due to the digital nature of the Geiger-mode avalanche signal. Therefore, a detector with these characteristics can potentially offer a low material budget, a fine segmentation and a low power consumption, in addition to a timing resolution in the order of tens of picoseconds. These features are appealing for a set of applications as, for instance, tracking and vertex reconstruction in particle physics experiments and charged particle imaging in medicine and biology.
A first two-tier proof-of-concept sensor was designed and fabricated in a commercial 150nm CMOS process in the framework of the R&D project APiX2 funded by INFN in Italy. The sensor consists of a 48x16 pixel array, and includes avalanche diodes of different sizes to evaluate the detection efficiency for different fill factors. Each pixel, having a 50um x 75um area, includes detectors and electronics on both layers, with the top-layer signal transmitted to the bottom layer using a vertical interconnection per pixel.
Bump bonding has been used for 3D integration, due to the accessibility and high yield offered by this technique in small-volume prototyping. The first measurements on two separate layers and on vertically-integrated sensor assemblies have confirmed the complete functionality of first prototypes and experimentally validated the proposed approach. A measurement campaign is on-going to fully assess the characteristics of the produced sensors. The test results obtained on the vertically-integrated sensors will be presented and the possibilities for future improvements with respect to this first prototype will be discussed.

Summary

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