ID de Contribution: **106**

Type: **15mOral**

New developments in 3D-trench electrode sensors

mardi 19 novembre 2024 15:00 (20 minutes)

Future experiments at high-luminosity hadron colliders will involve unprecedent levels of pile up, calling for precise time information at the pixel level to ease distinguishing between particle tracks. The unique geometry of 3D sensors enables to achieve very good timing performance, besides high radiation hardness. Remarkable results in terms of timing resolution have so far been reported for 3D sensors with columnar electrodes (~30 ps) [1] and even better with trenched electrodes from the INFN TIMESPOT project (~10 ps) [2], owing to a more uniform distribution of the electric field and weighting field. However, 3D-trench technology is more complex, and has still to be optimized. To this purpose, a new batch of sensors was designed at the University of Trento and fabricated at FBK within the AIDA Innova project.
Figure 1(a) shows the reticle layout, including pixel sensors and test structures (top right corner). The baseline pixel size is 55x55 μm^2, whereas a smaller version of 42x42 μm^2 has been introduced in test structures. Pixels come with two design variants for the ohmic trenches, either continuous (STD) or dashed (DSH). The former was already tested in the TIMESPOT batches, whereas the latter is new and aims at improving the fabrication yield. The performance of the two designs has been investigated by TCAD and AllPix2 simulations and found to be comparable [3]. Three different array sizes are present: 128x128, 64x64, and 32x32. The larger sensors are intended for future Read-Out Chips (ROCs) of the IGNITE (INFN) and Picopix (CERN) types, whereas the smaller ones are compatible with existing ROCs from the TIMESPOT project. Compared to previous productions at FBK, the batch has been processed with an improved technology aimed at increasing the yield and the number of devices on wafer. Figures 1(b) and 1(c) show the two reticle exposure plans used in the batch, featuring 18 and 29 printed blocks, respectively. Compared to just 11 blocks printed in the TIMESPOT2 batch, the device density is now much larger. Through the process, the wafer warp has been continuosly monitored, and a sufficiently low warp of ~80 μm has been measured at the end of the process also in case of the very dense wafer layout.
The batch was completed in June 2024 and initial electrical tests were performed on automatic probe station using a temporary metal layer. As an example, Figure 2 shows the total leakage current vs. reverse voltage curves measured on the larger pixel sensors of wafer 13 (18 reticle blocks). Most sensors have low leakage current, in the range of a few nA, and breakdown voltage higher than the measurement limit of 100 V, that is promising in view of functional tests.

[1] L Diehl et al., J. Instrum 17 (2022), C12003
[2] F Borgato et al., Front. Phys. 12 (2024) 1393019
[3] J Ye et al., J. Instrum 18 (2023), C11021

The authors acknowledge funding from the European Union's Horizon 2020 Research and Innovation programme under GA no. 101004761.

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Classification de Session: Timing with pixels

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