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#11-101 Progress in MEMS-based silicon radiation detectors at FBK

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In the past few years, there has been an increasing interest toward micromachined silicon radiation detectors, which use fabrication techniques normally adopted for Micro-Electro-Mechanical Systems (MEMS). In particular, Deep Reactive Ion Etching (DRIE) by the Bosch process allows to obtain vertical electrodes in a variety of shapes and dimensions with high aspect ratio (depth to surface size), making it possible to exploit the 3rd dimension within the silicon substrate, and offering several interesting advantages over more traditional planar detectors.
The Microtechnologies Laboratory of Fondazione Bruno Kessler (FBK) in Trento, Italy, is one of the few processing facilities worldwide able to manage the fabrication challenges of micromachined silicon detectors. R&D activities in this field have started in 2004, mainly in collaboration with the University of Trento and INFN, and significant results have so far been obtained.
The most famous example are 3D pixel detectors, which represent the most radiation-hard solution for charged particle tracking in High Energy Physics (HEP) experiments. After contributing to the production of 3D pixels for the ATLAS Insertable B-Layer, the first application of these devices in a HEP experiment, we have recently developed a new generation of these devices, featuring very small-pitch (25 um x 100 um and 50 um x 50 um) and reduced active thickness (~150 um), able to cope with the severe operational challenges of the innermost tracking layers of the ATLAS and CMS detectors at the High-Luminosity LHC. Besides the traditional version using columnar electrodes, we have also recently fabricated 3D pixel variants using trenched electrodes, which allow for a more uniform electric field and weighting field distribution within the active volume, thus boosting the timing performance. This is a key feature to obtain a high 4D resolution (tracking + timing) as requested by future HEP experiments. We have also developed a variety of planar active-edge sensors oriented to the ATLAS and CMS tracker upgrades at HL-LHC and to X-ray imaging at Free Electron Laser facilities. In these device, deep trenches (either continuous or segmented) are used as field terminations at the sensor periphery, minimizing the edge extension and allowing for full signal sensitivity up to a few microns from the sensor physical edge.
Another example is that of 3D micro-structured silicon sensors for thermal neutron detection, where narrow and deep cavities are etched by DRIE and filled by proper converting materials (e.g., 6LiF, 10B), leading to an increased probability for neutron reaction products to reach the active volume, hence higher detection efficiency with respect to standard planar sensors. We have fabricated both 3D diodes and 3D pixelated sensors compatible with the TIMEPIX readout chip. The first prototypes have been assembled at ADVACAM and are currently under test in collaboration with the Czech Technical University in Prague.

In this contribution, we will address the main design and technological issues relevant to MEMS-based silicon detectors, and report selected results relevant to the above-mentioned case studies.

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