Contribution ID: **21**

Type: **not specified**

Characterization of 3D and planar Si diodes with different neutron converter materials

Thursday, 9 October 2014 09:20 (20 minutes)

In the past few years, considering the shortage of ^3He, many interesting developments in solid-state thermal neutron detectors have been made (see e.g. [1] and references therein). These devices normally consist in PN junctions with high aspect-ratio cavities filled with neutron converter materials. The size of the cavities and the gap in between them are designed as a trade-off between neutron absorption within the converter material and detection of the reaction products within the silicon sensor, so as to maximize the neutron detection efficiency, for which very good values up to ˜50% have been reported.
Based on our experience with 3D sensors for High Energy Physics experiments, we have started the INFN HYDE (Hybrid Detectors of neutrons) project. As a first step in this activity, we have developed a new 3D sensor structure aimed at easing the deposition of converter materials while ensuring full compatibility with a pixelated read-out chip for neutron imaging applications. A first batch of 3D sensors, fabricated at FBK in 2012, has been extensively characterized. In order to ease the testing without need for bump-bonding, arrays of cavities have been shorted to obtain diode-like devices with only two electrodes. Electrical and functional tests of bare silicon sensors with alpha particles and laser beams have been carried out to gain deep insight into their characteristics. Moreover, functional tests of 3D sensors with coupled with different converter materials have been performed with fast and thermal neutrons. In spite of the non-optimized sensor geometries, encouraging results have been obtained [2]. However, given the device complexity, both in terms of topography and non-uniform charge collection behavior [2], the interpretation of experimental results was not straightforward, making it difficult to estimate the neutron detection efficiency and also to compare the measured data with Geant4 simulations. For this reason, we decided to perform additional tests using planar diodes covered with different converter materials (e.g., ^{10}B, ^{6}LiF, and polysiloxane [2]). Test devices are PIN diodes of 1.71x1.71mm^2 active area and 300 μm thickness, with leakage currents of ˜10pA and depletion voltage of ˜50V.
Experimental results have been collected and compared with simulations carried on Geant4 platform. Although the number of impinging neutrons in the experiments was not known exactly, thus preventing to extract the detection efficiency, the agreement between the measured and simulated spectra was good, thus validating the simulation approach that was later used for device optimization. The new sensor geometries to be implemented in the next fabrication batch and selected simulation results will also be presented.

References

[1] D. McGregor, et al., Journal of Crystal Growth, 379, 99 (2013).

[2] R. Mendicino, et al., JINST, 9, C05001 (2014).

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Session Classification: 3D Detectors