9th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors, Hiroshima, Japan

Contribution ID: **28** Type: **ORAL**

Radiation hardness tests of double-sided 3D strip sensors with passing-through columns

Tuesday 3 September 2013 14:20 (20 minutes)

An improved technology for double-sided 3D sensors with passing-through columns has been developed at FBK in collaboration with the University of Trento and INFN for the fabrication of 3D pixels for the ATLAS IBL [1]. The IBL production was successfully completed in 2012, with good results in terms of electrical characteristics and yield. On the same production wafers (p-type, 230±20 µm thick), different sets of 3D test diodes were included, as well as 3D strip sensors (1 cm2 area, 80 µm pitch). The latter are very useful, since they allow for functional testing with LHC-compatible read-out without need of bump bonding. Moreover, radiation hardness tests can be carried out up to very large fluences, since the sensors can be irradiated separately from the read-out electronics.

We have previously reported on the characterization of non-irradiated 3D strip sensors coupled to the ALIBAVA system [2]. All tested sensors have shown to be fully efficient already at low voltage (~10V), with noise values (from 1 to 1.5 ke- rms) compatible with the relatively high strip capacitance (~10pF). Measurements have been carried both on sensors with integrated coupling capacitors and biased by punch-through, and on DC-coupled sensors by using external R-C chips. Results are qualitatively similar, but, due to non-optimized coupling capacitors, higher S/N values are obtained with R-C chips.

Later, nine of these strip sensors were irradiated with protons at the Karlsruhe cyclotron at four different fluences (2E15, 5E15, 1E16, and 2E16 neq/cm2), and are currently being tested at the University of Freiburg. The measurement plan includes functional tests with a position resolved laser and a 37 MBq 90Sr beta source system, as well as electrical tests to assess the operation of the punch-through bias after irradiation. Initial results from the beta source tests are encouraging: the noise is not significantly affected by radiation, provided that the sensors are properly cooled to reduce leakage current, and the charge signal can be clearly distinguished from the noise already at ~25 V bias. The maximum values of the collected charge are in good agreement with previous tests carried out in Freiburg with the same setup on 3D strip sensors from CNM irradiated at the same fluences [3]. As an example, a sensor irradiated at 2E15 neq/cm2 collects 13.3±0.7 ke- at 120 V, and a sensor irradiated at 2E16 neq/cm2 collects 6.5±0.4 ke- at 200 V. However, it should be noticed that a sharp, surface-related breakdown prevents FBK sensors to be operated at higher voltages which would lead to charge multiplication effects.

At the conference we will report selected results from the characterization of all irradiated sensors, in comparison to pre-irradiation results. The charge collection efficiency will also be compared to that measured on irradiated 3D pixel sensors belonging to the same FBK production [4] and to TCAD simulation predictions.

REFERENCES

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Author: DALLA BETTA, Gian-Franco (INFN and University of Trento)

Co-authors: BETANCOURT, Christopher (Freiburg University); Dr GIACOMINI, Gabriele (FBK); JAKOBS, Karl (Albert-Ludwigs-Universitaet Freiburg (DE)); Ms THOMAS, Maira (Albert-Ludwigs-Universitaet Freiburg (DE)); Dr POVOLI, Marco (University of Trento); BOSCARDIN, Maurizio (FBK Trento); ZORZI, Nicola (Fondazione Bruno Kessler - FBK); Dr MENDICINO, Roberto (INFN and University of Trento); KUEHN, Susanne (Albert-Ludwigs-Universitaet Freiburg (DE)); PARZEFALL, Ulrich (Albert-Ludwigs-Universitaet Freiburg (DE))

Presenter: DALLA BETTA, Gian-Franco (INFN and University of Trento)

Session Classification: Session 4

Track Classification: Pixels (including CCD's) - Charged particle tracking