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Recent Test Beam Results of Radiation Hard 3D Silicon Pixel Sensors

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3D silicon sensors aimed for the ATLAS detector upgrade have been tested with a high energy pion beam from the CERN SPS in 2009. Two different beam telescopes with resolutions ranging between 2-5μm were used as external reference. Two types of sensors were tested: full-3D assemblies fabricated in Stanford and SINTEF Oslo, where the electrodes penetrate the entire silicon wafer thickness, and modified-3D assemblies fabricated at FBK-IRST with partially overlapping electrodes. In both cases three read-out electrodes are ganged together to form pixels of dimension 50×400μm. Data on the pulse height distribution, charge collection efficiency and charge sharing were collected for various particle incident angles and with and without a 1.4T magnetic field. Data from a planar sensor of the type presently used in the ATLAS detector were obtained at the same time to provide comparison.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

Available in PDF format including pictures at:
http://www.slac.stanford.edu/~phansson/vci2000/vci2010-abstract-atlas-3dsensors-per-hansson.pdf

The innermost layer (the B-Layer) of the ATLAS pixel tracking detector will begin to deteriorate after a fluence of 10^15 cm−2 1 MeV neutron equivalent expected to be reached a few years after the first CERN LHC collisions. The ATLAS collaboration has therefore decided to insert an additional layer inside the current B-layer; the Insertable B-Layer (IBL). For even higher luminosities the ATLAS detector requires a completely new inner tracking detector. The 3D silicon pixel design [1] is a prime candidate for both projects. The idea is to combine standard VLSI processing techniques with micro-machining allowing to place the electrodes perpendicular to the silicon wafer and penetrate through the substrate. The original full-3D design fabricated at Stanford and in parallel at SINTEF in Oslo [2], with fully penetrating electrodes, has been complemented by a modified 3D design by FBK-IRST in Trento and CNM in Barcelona [3, 4] in which the electrodes do not penetrate the entire substrate thickness. Both these designs provide advantages compared to standard planar sensors with electrodes on the surface of the wafer such as reduced depletion voltage, reduced capture of charge carriers, shorter charge collection time and smaller charge sharing region. All these areas give the 3D sensor advantages in the extreme radiation environment after the CERN LHC upgrades since they minimize further reduction of the signal size and thus improve the radiation hardness. Another important advantage of 3D designs is that they are suitable for so-called active edges where a deep trench is etched and heavily doped at the physical edge of the wafer transforming it into an active electrode. In this way the inactive region is reduced to as little as a few microns from the sensor edge.

The ATLAS experiment has established a R&D collaboration with the goal to prove the development, fabrication, characterization and testing of 3D silicon sensors for the ATLAS upgrade. A particular charge of the collaboration is to demonstrate that the 3D design is a safe sensor solution for the IBL. A fundamental part of this program are tests using 3D sensors connected to ATLAS read-out electronics in high energy charged particle beams. These high statistics test beams are important to measure the sensor performance with high energy particles and often facilitate the only way of measuring characteristics such as charge sharing and efficiencies. The ATLAS 3D collaboration test beams during 2009 consisted of four beam periods using high energy pions from the CERN SPS extending over approximately 7 weeks in total. During two of the periods the sensors where placed inside the 1.4T magnetic field of the Morpurgo dipole magnet[5] oriented to reproduce the ATLAS IBL symmetry. The reference particle tracks, triggered by a set of scintillators, were reconstructed using the Bonn Analysis Telescope (BAT) silicon micro-strip detector [6] and the high resolution EUDET beam telescope [7].

The tested assemblies included full-3D sensors with active edges fabricated at Stanford and SINTEF and double-sided double-type-column modified-3D sensors from FBK-IRST with a electrode column overlap in the range 110-150μm. In all periods they where contrasted with a planar pixel sensor of the type in the present ATLAS pixel detector. All sensors had a pixel size of 50×400μm with three read-out electrodes along the long direction and were bump-bonded to the ATLAS front-end electronics.

The overall efficiency, timing and pulse height distributions in terms of time-over-threshold were measured with and without magnetic field for various angles corresponding to the expected sensor layout of the IBL sensor. The resolution of the reference tracks were used to study charge sharing and collection properties in the electrode regions as well as active edge measurements.

References:

[1] S. I. Parker and C. J. Kenney and J. Segal, Nucl. Instrum. Meth. A 395, 328 (1997).

[2] T. E. Hansen et al., JINST 4, P03010 (2009).

[3] A. Zoboli, G. F. Dalla Betta, M. Boscardin, C. Piemonte, S. Ronchin, N. Zorzi and L. Bosisio, IEEE Trans. Nucl. Sci. 53, 2775 (2006).

[4] G. Pellegrini, M. Lozano, M. Ullan, R. Bates, C. Fleta and D. Pennicard, Nucl. Instrum. Meth. A 592, 38 (2008).

[5] M. Morpurgo, "A large superconductive dipole cooled by forced circulation of two-phase helium"Cryogenics, 411-414 (Jul 2009).

[6] J. Treus et al., Nucl. Instrum. Meth. A 490, 112 (2002).

[7] D. Haas, Proc. of the LCWS2007, (2007),http://www.eudet.org.

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