2005 International Linear Collider Workshop - Stanford, U.S.A.

Status of the SOI Detector R&D

A. Bulgheroni*, M. Caccia, C. Cappellini
University of Insubria, Como, Italy
INFN - Sez. di Milano, Milano Italy
M. Jastrzab, M. Koziel, W. Kucewicz, H. Niemiec†, M. Sapor
AGH – University of Science and Technology, Krakow, Poland
P. Grabiec, K. Kucharski, J. Marczewski, D. Tomaszewski
Institute of Electron Technology, Warsaw, Poland

SOI sensors are novel ionising radiation detectors that exploit both device and support layers of a SOI wafer for integrating a pixel matrix and the readout electronics into a fully depleted monolithc device. The concept was validated through the production of several simple detector test structures made of 64 readout channels. The accomplishment of the feasibility study lead to the design and production of a first large scale completely functional matrix of 128×128. This paper presents the R&D state-of-the-art, focusing on the large area prototypes currently under test, and the future perspective of this technology.

1. INTRODUCTION

In current and in future high energy experiments, the fundamental task of vertex detection is and will be accomplished using pixel sensors with a micrometric resolution. The more and more demanding requirements in terms of spatial resolution, radiation tolerance and material budget are pushing the technology development toward a monolithic pixel architecture in which both the sensitive element and the front-end readout electronics are integrated in the same substrate [1–3].
The SOI pixel detectors are novel devices that exploiting the two layers of the SOI wafers merge the advantages of a fully depleted sensor and of a monolithc architecture. The main concept is based on the use of both silicon layers (device and support layers also called handle wafer) of wafer bonded SOI substrates, a sketch of the structure is presented in Figure 1.

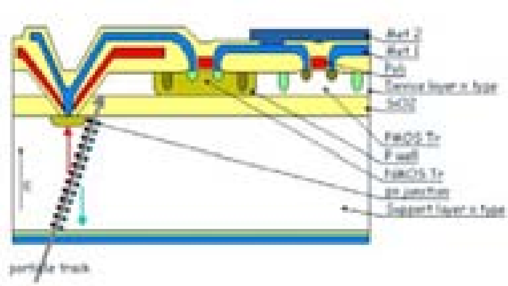

Figure 1: *A schematic view of the basic structure of an SOI pixel sensor. The sensitive element, a fully depleted p-n juction, is built in the high resistive support layer, while the readout electronics with both transistor types is implemented in the device layer.*

*Corresponding author: antonio.bulgheroni@mi.infn.it
†Scholarship-holder of Foundation for Polish Science

The front-end electronics required for the pixel addressing and readout is manufactured in the $\sim 1.5\ \mu$m thin device layer over the buried oxide, while the pixel matrix is created in the high resistive, 400 μm thick handle wafer [4]. The possibility of processing such a detector was pursued in the framework of the SUCIMA (Silcon Ultra-fast Cameras for electrons and γ sources in Medical Applications) [5] project which was supported by the European Commission[1]. The device concept was validated producing simple detector test structures consisting of 64 readout channels. Their sensitivity to ionising radiation were proved by laboratory tests with radioactive sources while the input dynamic range (from 2.4 fC to 185 fC) and the charge to voltage gain (3.6 mV/fC) were measured using an infrared pulsed laser. A dedicated description of the structure characterization results can be found for instance in [4].

2. DESIGN OF LARGE SCALE SOI SENSORS

Following the assessment of the design and technology, the first completely functional, full-size SOI sensors were designed, produced and are currently under test. The sensor configuration, in terms of integration time, dynamic range, granularity and active area of 2×2 cm^2, was imposed by the imaging requirements of the SUCIMA applications. The sensor prototypes were designed using a fully custom technology and produced in a non-standard process developed at the Institute of Electron Technology in Warsaw [6].

2.1. Overview of the sensor layout

The large scale sensor consists of 128×128 readout channels. Every cell includes a detector diode monolithically coupled to the readout channel and within a area of $150 \times 150\ \mu$m^2. The matrix is divided in four functionally independent quadrants, each with its own set of biasing and control lines and analog signal output. Such a solution allows using at least part of the device in case there are defects in the other areas and it increases the readout speed by allowing parallel analog sampling. The overall layout, in particular the position of the I/O bonding pads and the peripheral elements, has been designed keeping in mind the possibility of building longer detector ladders with reduced dead region in between.

2.2. First experimental tests

The SOI large scale sensors were only recently produced and their performance is currently under investigation. For this purpose the sensor was bonded on a dedicated printed circuit board and the data aquisition accomplished using a costum made DAQ system [7].

Preliminary tests revealed some problems with the production yield and only a small fraction of the tested sensors exhibited satisfactory operation of the readout electonics for at least three detector quadrants.

Nevertheless a preliminary test of the sensor sensitivity to ionizing radiation was performed using a ^{90}Sr radioactive source (Figure 2).

Other tests to measure further detector characteristic as the charge collection and detection efficency are now on going.

3. CONCLUSION

The paper addresses the development of a first completely functional, full-scale particle detector based on SOI technology for the integration of the readout electronics with a fully depleted pixel detector. The design aspects

[1]Contract number: G1RD-CT2001-00561

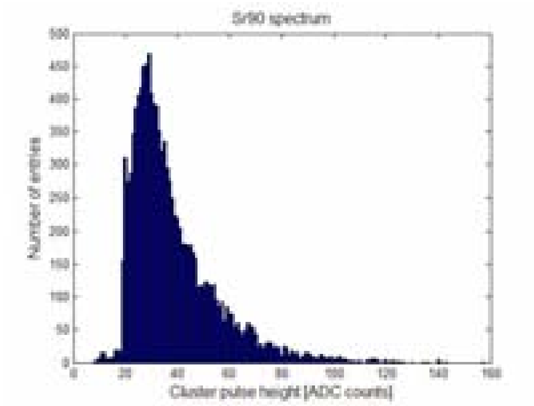

Figure 2: *Measured distribution of β particles from* ^{90}Sr. *The plot is showing sensor sensitivity to ionizing radiation and the obtained low charge-to-voltage gain is on purpose kept low to allow higher dynamic range as foreseen by the SUCIMA applications.*

of the SOI sensor along with some basic measurement results are discussed. The performed tests indicate some problems with the production yield, due to the complexity of the SOI detectors technology and the large area of the device and for good sensors the sensitivity to ionizing radiation has been proved. Other tests to fully characterized this new sensor technology are now on going.

References

[1] P. N. Burrows, A CCD vertex detector for a high-energy linear e+ e- collider, Nuclear Instruments and Methods in Physics Research A 447 (2000) 194–201.

[2] R. Turchetta, J. D. Brest, B. Casadei, G. Claus, C. Colledani, W. Dulinski, Y. Hu, D. Husson, J. P. Le Normand, J. L. Riester, G. Deptuch, U. Goerlach, S. Higueret, M. Winter, A monolithic active pixel sensor for charged particle tracking and imaging using standard VLSI CMOS technology, Nuclear Instruments and Methods in Physics Research A 458 (2001) 677–689.

[3] R. H. Richter, L. Andricek, P. Fischer, K. Heinzinger, P. Lechner, G. Lutz, I. Peric, M. Reiche, G. Schaller, M. Schnecke, F. Schopper, H. Soltau, L. Strüder, J. Treis, M. Trimpl, J. Ulrici, N. Wermes, Design and technology of DEPFET pixel sensors for linear collider applications, Nuclear Instruments and Methods in Physics Research A 511 (2003) 250–256.

[4] A. Bulgheroni, M. Caccia, K. Domanski, P. Grabiec, M. Grodner, B. Jaroszewicz, T. Klatka, A. Kociubinski, M. Koziel, W. Kucewicz, K. Kucharski, S. Kuta, J. Marczewski, H. Niemiec, M. Sapor, M. Szelezniak, D. Tomaszewski, Monolithic active pixel detector realized in silicon on insulator technology, Nuclear Instruments and Methods in Physics Research A 535 (2004) 398–403.

[5] M. Caccia, et al., Silicon ultra fast cameras for electron and γ sources in medical applications, Nuclear Physics B (Proc. Suppl.) 125 (2003) 133–138.

[6] J. Marczewski, K. Domanski, P. Grabiec, M. Grodner, B. Jaroszewicz, A. Kociubinski, K. Kucharski, D. Tomaszewski, W. Kucewicz, S. Kuta, H. Niemiec, M. Sapor, M. Caccia, SOI Active Pixel Detectors of Ionizing Radiation – Technology and Design Development, IEEE Transactions on Nuclear Science 51 (3) (2004) 1025–1028.

[7] A. Czermak, A. Zalewska, B. Dulny, B. Sowicki, M. Jastrzab, L. Nowak, Data acquisition system for Silicon Ultra fast Cameras for electron and γ In Medical Applications (SUCIMA imager), in: M. Barone, E. Borchi, C. Leroy, P. G. Rancoita, P. L. Riboni, R. Ruchiti (Eds.), Astroparticle, particle and space physics, detectors and medical physics applications, World Scientific, 2004, pp. 360 – 365.