EDGELESS DETECTORS FOR HIHG ENERGY PHYSICS APPLICATIONS

Dr. Juha Kalliopuska

VTT Micro and Nanoelectronics, Tietotie 3, Espoo, PO. Box 1000, FI-02044 VTT, Finland
email: juha.kalliopuska@vtt.fi

VTT has a two decades experience, since 1989, on manufacturing and designing silicon radiation detector structures [1]. The first 3D process runs – processing of high aspect-ratio structures into the silicon bulk – were started at 2003, and consequently the first 3D detectors were fabricated [2-4]. Last year the first prototypes of the edgeless detectors were fabricated on 6” (150 mm) high resistive silicon-on-insulator (SOI) wafers. Electrical characterization of these detectors showed low leakage currents but very early breakdown voltage [5].

We have developed a straightforward and fast process to fabricate edgeless (active edge) microstrip and pixel detectors on 6" (150 mm) SOI-wafers. The process excludes all slow process steps, such as polysilicon growth, planarization and additional ICP-etching. We have successfully fabricated 150 µm thick p-on-n and n-on-n prototypes of edgeless detectors having dead layer at the edge below a micron. Fabrication was done on high resistivity n-type FZ-silicon wafers. The prototypes include 5x5 cm^2 and 1x1 cm^2 edgeless microstrip detectors with DC-, FOXFET- and PT-couplings. In addition, 1.4x1.4 cm^2 Medipix2 edgeless pixel detectors were fabricated [6].

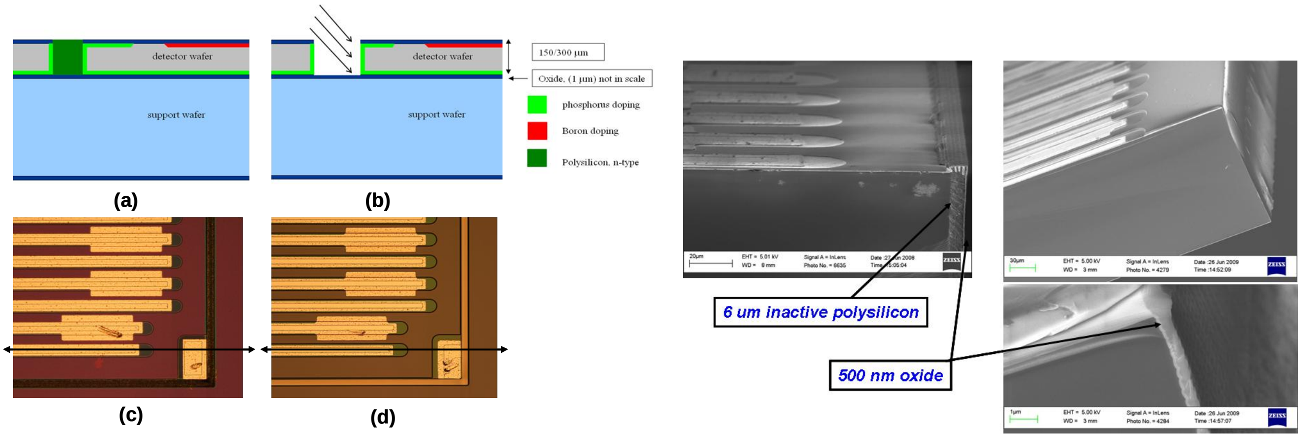

Fig. 1. (Left) The previous (a) and novel process (b) to fabricate edgeless detectors. (c) and (d) show images of the prototypes with a polysilicon filling of the trenches and with ion-implantation to the trenches, respectively. (Right) SEM images from the edge of the detectors.

Figs. 1(a) and (b) illustrate the main difference between the previous and novel process, i.e. the active edge is made with ion-implantation instead of polysilicon filling of the trenches. Figs 1(c) and (d) show images from the biasing corner of the active edge detectors. The inactive region in the novel approach is reduced to below a micron, as can be seen in Fig. 1 (right).

Presentation introduces leakage current, capacitance and breakdown voltage measurements of different DC-coupled microstrip designs and comparison of them with respect to the active edge distance and polarity of the detector. The active edge distances were 20 µm, 50 µm and 100 µm from the strips. A good uniformity in the measured parameters was observed for the inner strips. The parameters of the adjacent strip to the edge showed a dramatic dependence of the active edge distance. Leakage current and capacitance of the inner microstrips had the level of 50-70 nA/cm^2 and 580-660 pF/cm^2 at 40 V reverse bias for the p-on-n. For the n-on-n design the similar parameters were 116-118 nA/cm^2 and 930-960 pF/cm^2. The breakdown voltages were above 150 V for p-on-n prototypes and increased as a function of the active edge distance. To fully deplete the p-on-n detectors required twice as much reverse bias as is needed for the n-on-n detectors, *i.e.* 13-28 V [7].

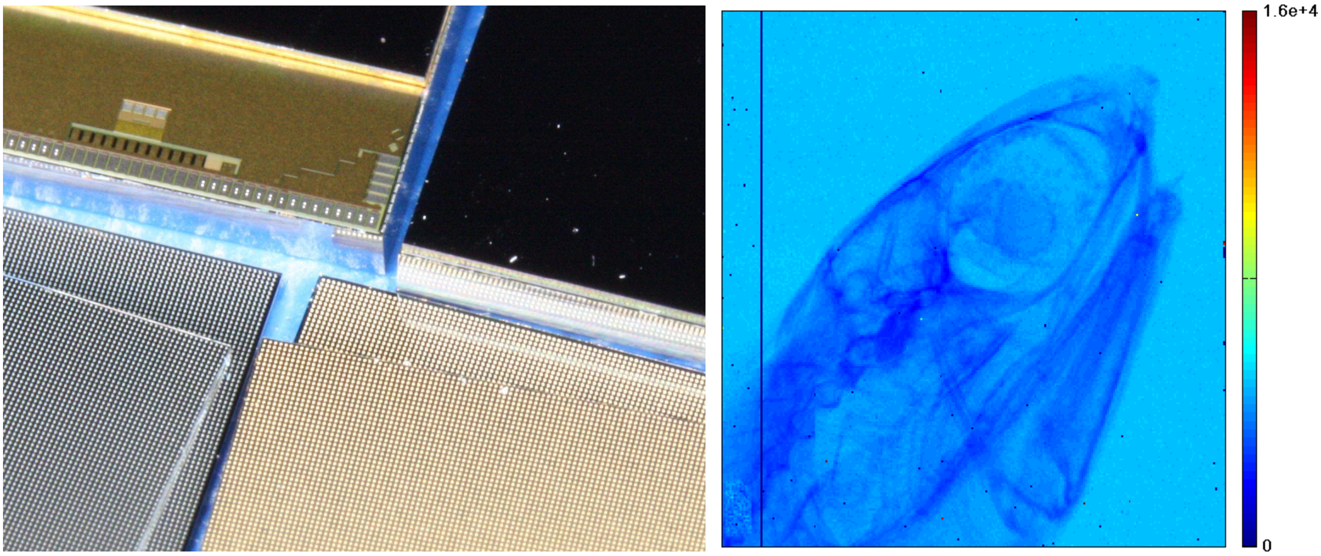

Fig. 2. (left) Medipix2 pixel detectors before and after UBM, and after flip-chip bonding to the Medipix2 ROC. (Right) First X-ray image of a fish with an n-on-n edgeless detector coupled to the Medipix2.

Presentation shows the first radiation response results of Medipix2 coupled edgeless detectors with varied radiation sources. Also, first X-ray tube images are presented for an edgeless detector with the active edge distance of 20 um, as shown in Fig. 2 (right).

References

[1] VTT webpage, http://www.vtt.fi/ and MICRONOVA: Center for Micro and Nanotechnology, http://www.micronova.fi/.

[2] S. Parker, C. Kenney and J. Segal: *3D - A proposed new architecture for solid state radiation detectors*, Nucl. Instr. Meth. in Phys. Res. A 395, (1997), p. 328-343

[3] S. Eränen, J. Kalliopuska et al., *Silicon semi 3D radiation detectors*, IEEE Nuclear Science Symposium, Conference Record 2004, Vol. 2, IEEE (2005), p. 1231-1235

[4] J. Kalliopuska and S. Eränen: *Measurements and simulations of silicon semi 3D radiation detectors*, Nucl. Instr. Meth. in Phys. Res. A 568, (2006), p. 22-26.

[5] J.Kalliopuska, et al., *3D processing on 6 in. high resistive SOI-wafers: Fabrication of edgeless strip and pixel detectors*, Nucl. Instr. Meth. in Phys. Res. A 607 (2009) 85–88.

[6] X. Llopart et al., *Medipix2, a 64k pixel readout chip with 55 µm square elements working in single photon counting mode*, IEEE Trans. Nucl. Sci. 49, (2002), p. 2279-2283.

[7] J.Kalliopuska, et al., *Alternative fabrication process for edgeless detectors on 6” SOI-wafers*, to be published in Nucl. Instr. Meth. in Phys. Res. A (2009).