Development of edgeless high-Z sensors for endless medical detectors

M.J. Bosma*

Large surface areas

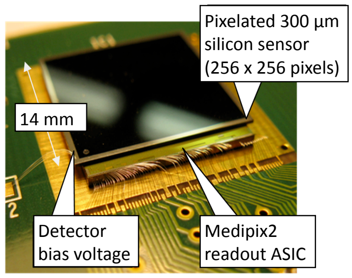

Figure 1. *The Medipix chip with the I/O periphery wire bonded to the carrier board. A segmented 300 µm thick silicon sensor is bump bonded on top.* **[1]**

The development of the Medipix chip (Fig. 1) has reached a stage at which it has become very attractive for a wide range of applications, among which medical X-ray imaging. Since a medical object is often much larger than one single chip, research is aimed at enlargement of the surface area by means of tiling.

In order to obtain a large active tessellation with minimal dead area, two aspects are being considered within the Hidralon project:

i. the amount of dead material (i.e. wire bonds and readout chip periphery) between the individual sensors (Fig. 2);
ii. the inactive sensor area along the edges.

Both must be reduced to a minimum.

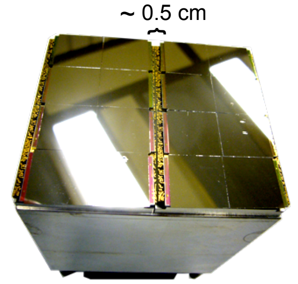

Figure 2. *A tessellation of the current Medipix2 assemblies. The I/O bond pads at one side of the chip are responsible for the dead area in between of ~ 0.5 cm wide.*

Edgeless

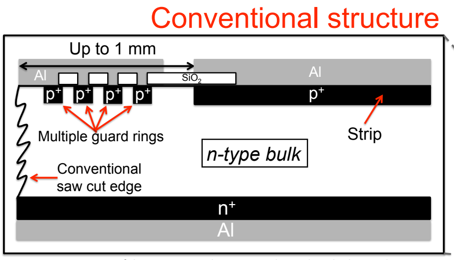

Figure 4. *Cross section of the sensor near the saw cut edge with multiple guard rings.*

The conventional sensor structure contains one or multiple guard rings, in order to reduce the diffusion contribution to the leakage current from surface irregularities at the cut sides. Especially at high voltage operation (e.g. in harsh radiation environments), the inactive area – consisting of several guard rings – between the strips or pixels and the cut edge can be up to 1 mm (Fig. 4).

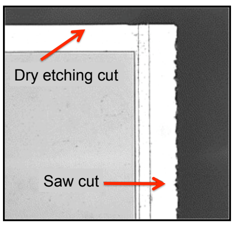

Figure 5. *Dry etching cut compared to a diamond saw cut.* **[2]**

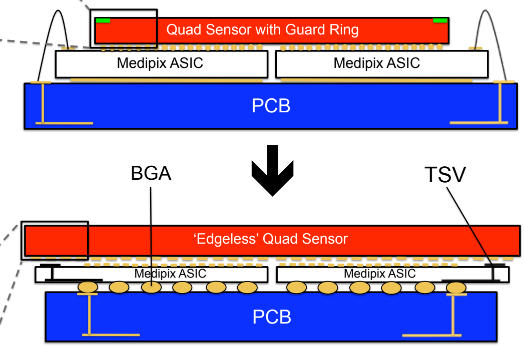

Figure 3. *Top: Current quad design, consisting of four tiled Medipix2 assemblies. Bottom: Quad design with the future TSV- and BGA-technology. Figures based on* **[3]**.

A new technology different from wire bonding is developed for the connection of the periphery pads to the carrier board, in such a way that the PCB is not sticking out from underneath the Medipix chip anymore. The front- and backside of the chip will be interconnected by *Through-Silicon-Vias* (TSV) – etched holes through the silicon wafer. These TSV's are then connected to the PCB via a *Ball-Grid-Array* (BGA), as you can see in Figure 3.

In this way, the sensor is the largest and the assembly can be tiled on 4 sides.

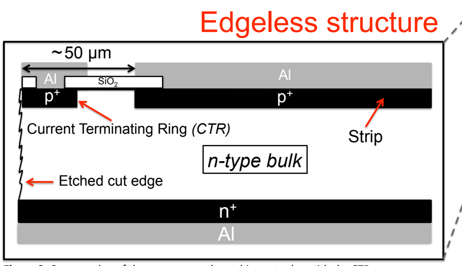

Figure 6. *Cross section of the sensor near the etching cut edge with the CTR.*

In order to reduce the diffusion current at the sensor sides, etching processes and new laser cutting techniques are examined, both of which offer the advantage of low surface damage (Fig. 5). The conventional guard ring is replaced by an n- or p-doped *Current Terminating Ring* (CTR) to minimise the inactive area between the pixel matrix and the cut edge (Fig. 6). In this way, the inactive area could be reduced to 50 µm, even at high potential drops. Currently, such edgeless structures made of silicon are under study.

High-Z materials

For medical X-ray imaging applications, the typical energy domain is 30 – 120 keV. Compared to silicon, high-Z direct conversion materials (e.g. CdZnTe and GaAs) are better suited. These have a much higher absorption efficiency (Fig. 7): for example, in 300 µm thick silicon the energy of 50 keV X-ray photons is absorbed for only 3%, whereas the efficiency is more than 84% in a layer of CdZnTe of the same thickness. The higher absorption efficiency and sensitivity are essential properties that will benefit the image capture efficiency. This could reduce the equivalent dose to which the patient is exposed. Moreover, these sensor materials have a high intrinsic quality (i.e. high spatial and energy resolution), which could increase the diagnostic value of the images.

These characteristics and the high count-rate capability at room temperature make both CdZnTe and GaAs a good detector solution for medical applications. Still, fabrication of mono-crystalline high-Z materials is an immature technology. We will study the influence of the different process steps on the detection properties and the edge effects specifically.

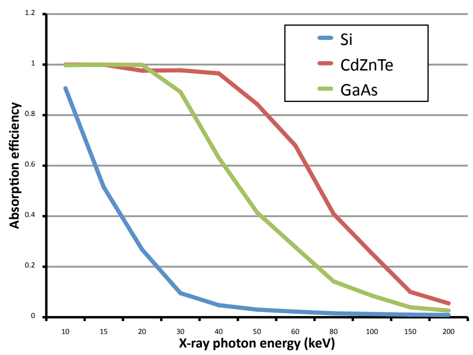

Figure 7. *The Absorption efficiency as a function of the X-ray photon energy for layers of 300 µm thick Silicon, CdZnTe and GaAs. The values are based on the X-ray mass attenuation coefficients from* **[4]**.

* National Institute for Subatomic Physics (Nikhef), Amsterdam, The Netherlands. e-mail: *mbosma@nikhef.nl*

[1] http://aladdin.utef.cvut.cz/ofat/_Common_/MedipixChip.png
[2] G. Pellegrini et al., "**Edgeless detectors fabricated by dry etching process**", Nuclear Instruments and Methods in Physics Research A, Vol 563, Issue 1, p. 70 – 73.
[3] Z. Vykydal et al., "**The RELAXd project: Development of four-side tilable photon-counting imagers**", Nuclear Instruments and Methods in Physics Research A, Vol 591, Issue 1, p. 241 – 244.
[4] NIST, National Institute of Standards and Technology, http://physics.nist.gov/PhysRefData/XrayMassCoef/cover.html