

## Chromium compensated gallium arsenide sensor evaluation using photon counting readout electronics

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Gallium arsenide is extensively studied for about seven decades as an excellent material for semiconductor lasers, LEDs, and microwave electronics. GaAs has noticeable advantages over silicon and Cd(Zn)Te for radiation detectors. Particularly GaAs has higher electron mobility compared to Si and Cd(Zn)Te; higher average atomic number compared to Si; and lower probability and energy of the fluorescence photons compared to the Cd(Zn)Te [1]. These advantages result in a fast charge collection, good absorption efficiency up to 80 keV and a better uniformity compared to Cd(Zn)Te. Applications for the GaAs are foreseen in medical computed tomography (CT), mammography, small animal imaging, electron microscopy, synchrotrons, XFELs and non-destructive testing of composite materials.

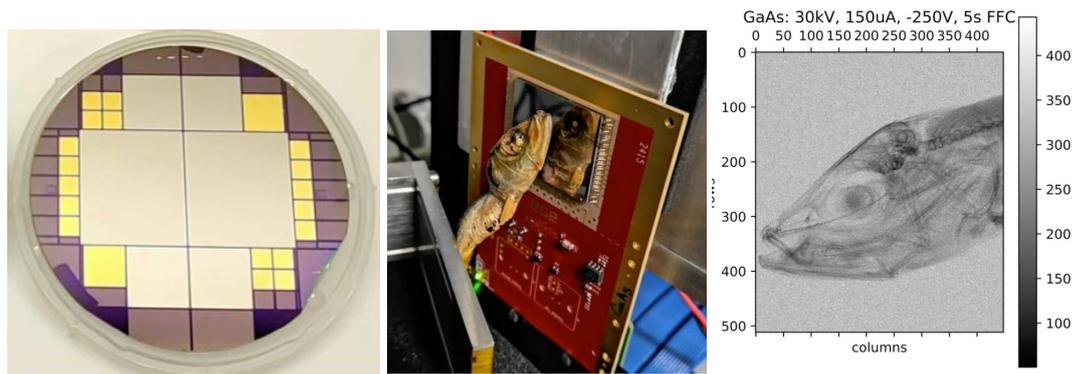
In frame of Eurostar GoNDT project [2], Advafab has developed radiation detectors by chromium compensation [3] of commercially available 3" n-type Liquid Encapsulated Czochralski (LEC) GaAs wafers. Wafers were annealed in quartz reactor; processed by polishing and CMP; and were patterned, metallized, and diced, as presented in Fig. 1.



**Figure. 1.** GaAs wafer after high temperature annealing (left), polishing and CMP (center), lithography and dicing (right).

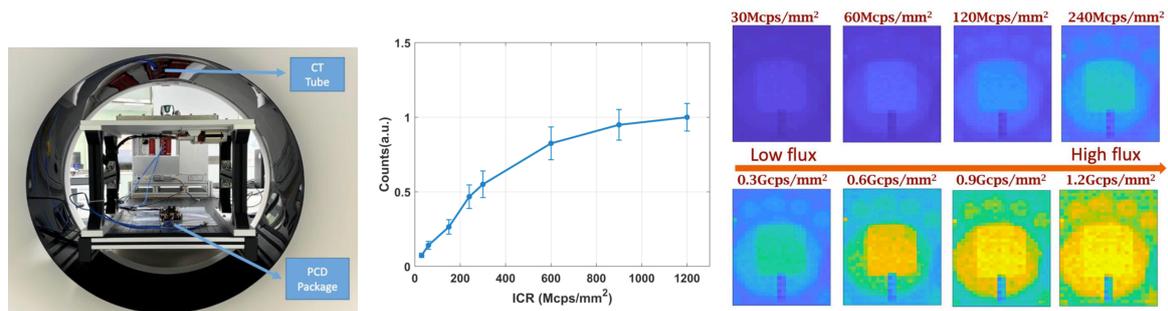
We have demonstrated a wafer-level processing of GaAs on varied thicknesses ranging from 220  $\mu\text{m}$  to 1 mm. Pixelized sensors with designs compatible with different readout ASICs have been fabricated. Individual diced sensors were flip-chip bonded to Timepix2 [4], Timepix3 [5], Medipix3 [6], Timepix4 [7] ASICs. Assemblies were evaluated to study the uniformity; sensor stability; energy resolution; charge transport properties and high X-ray flux operation.

The presentation summarises the GaAs performance results received from the contributing authors. It presents analytical evaluation of charge transport properties of different thicknesses of GaAs and their spectral response to Alpha and Gamma radiation. The pixel detector results represent the sensor uniformity, spectral resolution and high flux operation in different applications. The first GaAs Timepix4 detector results are shown in Fig. 2.



**Figure. 2.** Two Timepix4 500 um thick GaAs sensors fabricated on 3'' wafer (*left*). Photograph of the imaging setup where a fish is placed in front of the Timepix4 detector (*center*). First X-ray image of the Timepix4 GaAs detector (*right*).

The high photon flux operation has been evaluated using a medical CT X-ray tube in an open beam. It has been shown in Fig. 3 that Advafab's GaAs can tolerate and operate stably in extreme X-ray beam fluxes up to 1,200 Mcnt/s/mm<sup>2</sup>.



**Figure. 3.** Setup of the high flux measurement, where GaAs sensor is temporarily flip chip bonded to Photon counting readout electronics (*left*). Count rate dependence on the X-ray tube current demonstrating high flux tolerance of Advafab's sensor (*center*). Raw open beam images of Advafab's GaAs sensors at X-ray fluxes up to 1,220 Mcnts/s/mm<sup>2</sup> (*right*).

The presentation concludes that it is feasible to manufacture radiation sensors of chromium-compensated GaAs of different thicknesses for the photon counting applications with high uniformity and a good energy resolution that can operate at high X-ray fluxes.

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