CdZnTe sensors manufacturing: from bare semiconductor crystal to detector

Over the years, Due2lab developed technologies and processes for the manufacturing CdZnTe (CZT) sensors, as well as for their electrical and spectroscopic characterization. These skills enable Due2lab to respond to its customers with tailor-made solutions, starting from the electrode design of the semiconductor sensor itself.

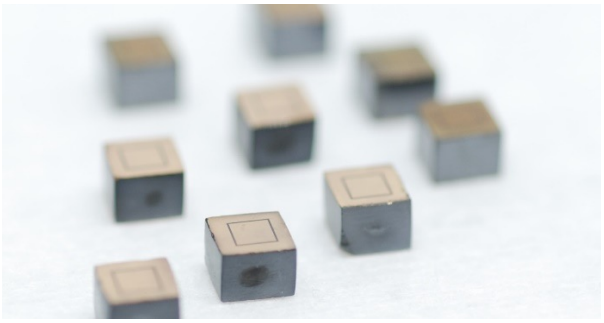
Due2lab sources CZT crystals from various manufacturers worldwide. The material is first certified by the producing company and subsequently characterized and validated by Due2lab according to the specifications of the application for which the material will be re-manufactured, often with more stringent requirements than those of the original manufacturer.

Besides standard spectroscopic grade CZT material, Due2lab recently developed an ad-hoc recipe for the manufacturing of high-flux CZT in collaboration with IMEM-CNR, which has been a milestone in the CZT refabrication skills.

The various types of sensors that Due2lab is capable of manufacturing are presented below.

Single-pixel sensors

Single-pixel sensors need one readout channel only (anode) and an electrode for polarization (usually applied to the cathode). They represent the simplest sensor geometry but provide excellent spectroscopic performance in the energy range 5 ÷ 120 keV.



Ref.: N. Zambelli, S. Zanettini, G. Benassi, A. Bettati, e A. Zappettini, «CdZnTe-based X-ray Spectrometer for Absolute Density Determination», IEEE Transactions on Nuclear Science, pp. 1–1, 2020, doi: 10.1109/TNS.2020.2996272.

Two types of single-pixel sensors are available:
- Square single-pixel detector with guard-ring
- Extended linear single-pixel detector with guard-ring

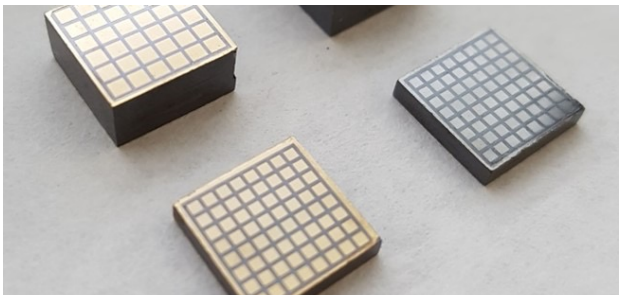
Material: low-flux CZT or high-flux CZT
Thickness: 1 ÷ 3 mm
Standard pixel size: 2 x 2 mm²
Dark current (@-850 V): 1 nA
Typical energy resolution @60 keV (Am-241): < 3%

Linear array multi-pixel sensors

The so-called “linear arrays” are sensors typically used in X-ray scanners for industrial production lines. When made of CdZnTe suitable high X-ray fluxes, they offer excellent spectroscopy at the typical fast working conditions of an industrial production line, which is a main challenge today for NDTs (non-destructive tests). The linear array geometry is modular, and several arrays can be lined up to extend the portion of material to be viewed.
Due2lab can produce arrays with up to 32-pixels and a 0.8 mm2 pixel pitch.

2D matrix multi-pixel sensors

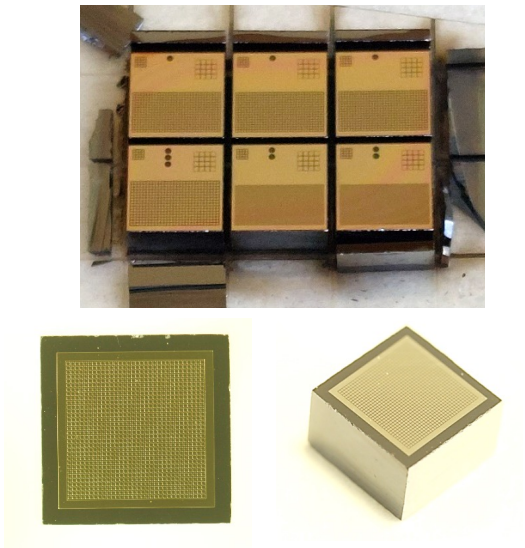
Due2lab is capable of manufacturing matrix pixel sensors starting from pre-sized crystals or through post-fabrication cutting (dicing).
For custom fabrication it should be specified the sensor dimensions (area and thickness), pitch, pixel width,



interpixel gap width, guard requirements, maximum and minimum distance of the pixels from the physical edge of the crystal.

Tel: +39 0522 160 7010 - Fax: +39 0522 160 1375

Two types of 2D matrix multi-pixel sensors are available:
• Large pixel pitch (> 500 µm)
• Fine pixel pitch (< 500 µm)
Material: low-flux CZT or high-flux CZT
Thickness: 1 ÷ 2 mm
Sensor area: from 3 x 3 mm2 to 20 x 20 mm2 (larger upon request)
Pixel pitch: down to 50 µm



Two examples of fine pixel pitch 3x3x2 mm3 2D matrix multi-pixel sensors with guard-ring

Hemispherical sensors

Hemispherical detectors are used for gamma-rays spectroscopy applications where the photon energies to be detected rise up to a few MeV: in this case it is necessary to use large volumes CZT crystals to ensure a greater absorption capacity (higher sensitivity) of the system. The hemispherical geometry allows to read large volume of CZT with one single channel (one pixel only), combining excellent collection efficiency and spectroscopic resolution with ease of system assembly.

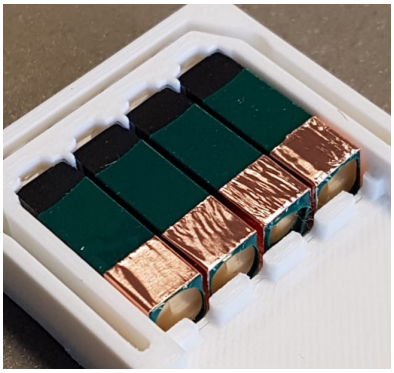
Hemispherical sensors with different volumes (10x10x5 mm3, 15x15x10 mm3, 20x20x10 mm3).

Ref.: V. Vicini et al., «Optimization of quasi-hemispherical CdZnTe detectors by means of first principles simulation», Sci Rep, vol. 13, fasc. 1, Art. fasc. 1, feb. 2023, doi: 10.1038/s41598-023-30181-2.

Material: low-flux CZT
Thickness: ≥ 5 mm
Sensor volume: from 0.5 cm3 to 4 cm3
Typical energy resolution @662 keV (Cs) < 2 % (raw spectrum)

Frisch-grid sensors

Frisch-grid sensors are CZT bars typically sized at 6x6x20 mm³, or larger. The charge-collecting electrodes (anode and cathode) are located at the two ends of the bar, while a non-collecting induction electrode is located on the lateral walls of the bar to create the most suitable internal electric field for better signal reading.



Signals coming both from anode and cathode are acquired in Frisch-grid sensors to correct for charge losses and improve spectroscopic performance. Frisch-grid sensors are employed for the detection of gamma rays, taking advantage of the greater absorption capacity along the length of the bar (20 mm).

Material: low-flux CZT
Thickness: ≥ 20 mm
Sensor volume: above 0.72 cm3
Typical energy resolution @662 keV (Cs) < 2.5 %

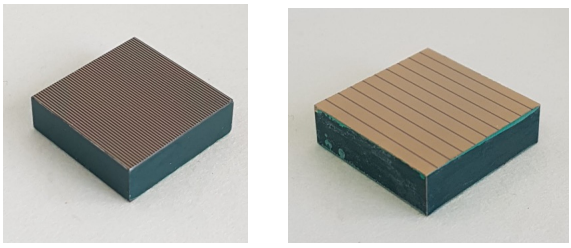
Tel: +39 0522 160 7010 - Fax: +39 0522 160 1375

3D strips sensors

3D strips detectors are characterized by an extremely innovative design, and they are typically used for niche applications such as astrophysics or nuclear medicine.
The great advantage offered by this type of geometry is its high spatial resolution combined with a lower number of electrodes with respect to 2D pixel sensors. Less electrodes means a significant reduction in the costs required for signal-readout electronics, which usually scale with the number of channels to be read.
Their realization is challenging, under a manufacturing point of view, since it requires a two-level patterning, i.e. segmentation of both the anode and cathode.

Ref.: L. Abbene et al., «Recent advances in the development of high-resolution 3D cadmium–zinc–telluride drift strip detectors», Journal of Synchrotron Radiation, vol. n/a, fasc. n/a, Art. fasc. n/a, ott. 2020, doi: 10.1107/S1600577520010747.
L. Abbene et al., «Potentialities of High-Resolution 3-D CZT Drift Strip Detectors for Prompt Gamma-Ray Measurements in BNCT», Sensors, vol. 22, fasc. 4, Art. fasc. 4, gen. 2022, doi: 10.3390/s22041502.
N. Auricchio et al., «A CZT 3D imaging spectrometer prototype with digital readout for high energy astronomy», Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, vol. 1047, p. 167869, feb. 2023, doi: 10.1016/j.nima.2022.167869.

Material: low-flux CZT
Sensor volume: 20x20x6 mm3
Anode strips size ≈ 150 µm
Typical energy resolution @662 keV (Cs) < 1.3 %



A 3D strips sensor: anodic stripes on the left, cathodic stripes on the right

Crystal size: 20x20x5 mm^3