Investigation of Platinum contacts on High-Flux CdZnTe

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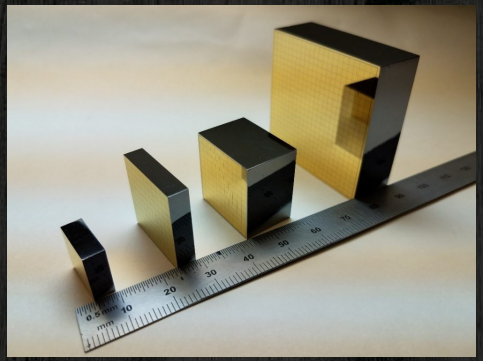
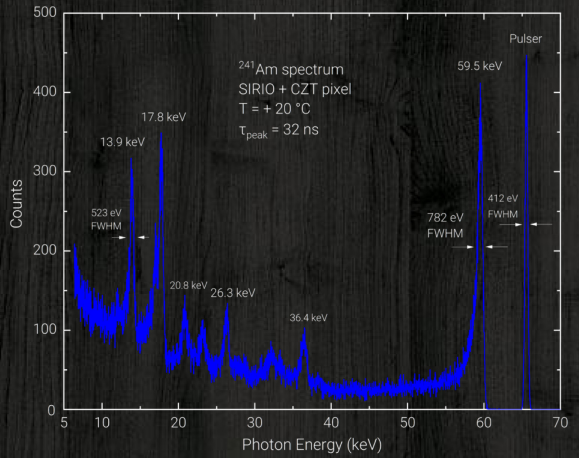
CdZnTe Radiation Detectors

Cadmium Zinc Telluride is a semiconductor used for radiation detectors



CZT characteristics:

- High atomic number (Z)
  → Excellent absorption efficiency
  (3 mm of CZT can stop >95% of 100 keV radiation)
- Optimal band gap
  → Room Temperature Operation
  (no cryo-system needed)
- High $\mu\tau$ product
  → Spectroscopic detector
  (<1% @ 122 keV)

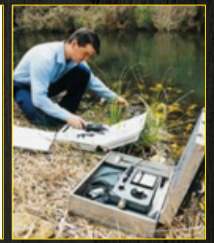


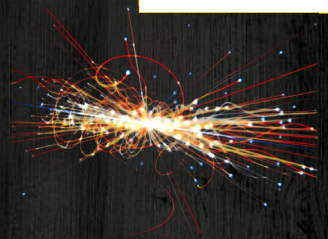
CdZnTe (CZT) is very appealing for direct X-ray detection in range 5-300 keV

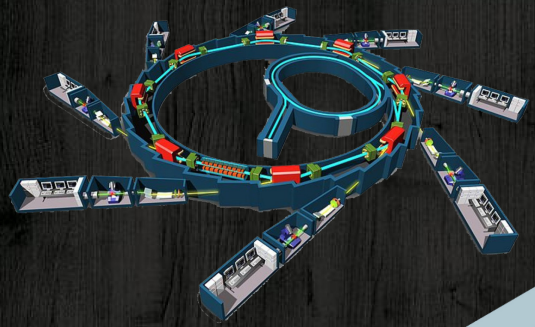
CdZnTe Radiation Detectors

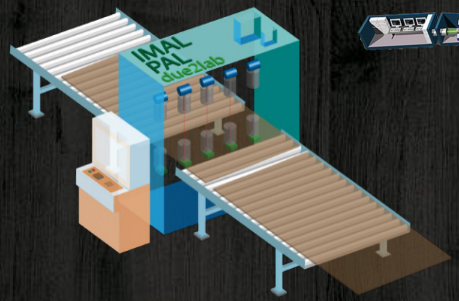
Application fields:

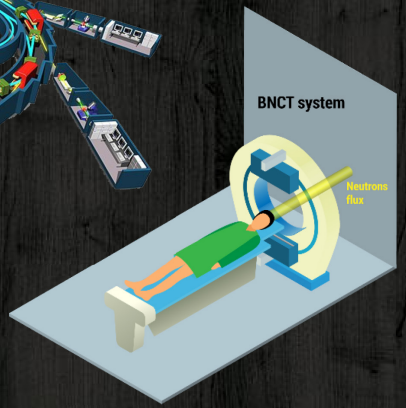
- Isotope recognition
- Astrophysics
- Medical therapy
- Particle physics
- Synchrotron detectors
- Non-Destructive Testing











Aim of the work

Some application required a sensor able to withstand to extremely **high radiation flux** (> 10^{10} ph/mm^2/s)

Under high photon flux, standard CZT is affected by a strong polarization due to hole trapping that leads to poor performances

New Redlen high flux CZT → improved holes transport properties

Blocking contacts → to minimize the leakage current

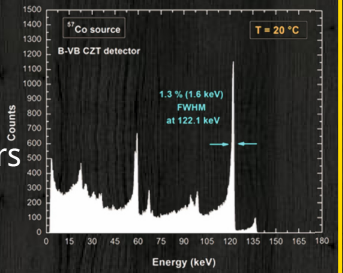
Unfortunately, usual contacts used for standard CZT may not be suitable for this new material

Standard CZT contacts

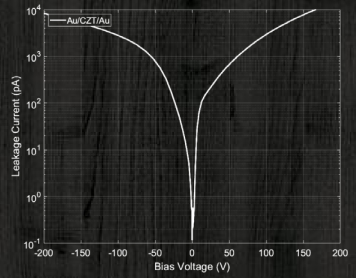
Gold

Standard gold electroless deposition technique developed in IMEM-CNR based on alcoholic solution

Standard grade CZT
Low leakage current and mechanically stable contact used for several detectors with different geometries.
Excellent spectroscopic performances



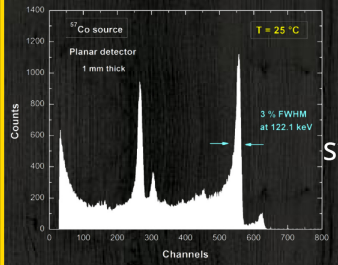
High-flux CZT
high leakage current >40 nA/mm^2 at 200V (1.5 mm-thick sample)



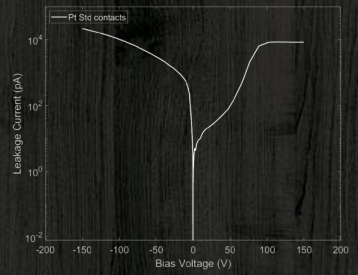
Platinum

Standard platinum electroless deposition technique developed in IMEM-CNR based on a mixed solution of methanol and DMF

Standard grade CZT
Low leakage current and mechanically stable contact tested in several samples.
Excellent hole collection capability and good spectroscopy



High-flux CZT
High leakage current >80 nA/mm^2 at 150V (1.5 mm-thick sample)



High-Flux CdZnTe

Enhanced holes transport properties

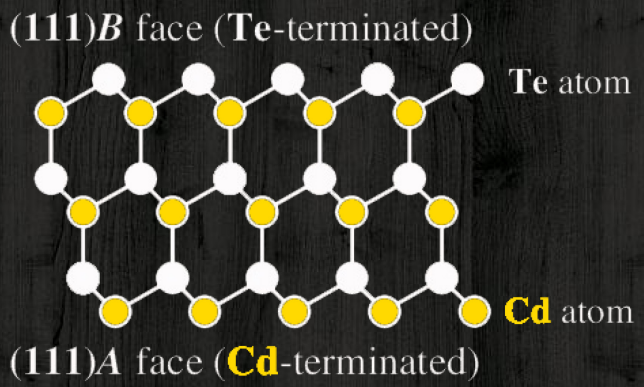
High-Flux CdZnTe produced by Redlen Technologies is oriented → cathode and anode are deposited on faces perpendicular to the crystallographic direction <111>

Material	$\mu_e\tau_e(cm^2/V)$	$\mu_h\tau_h(cm^2/V)$
CZT HF	$1.1 \cdot 10^{-3}$	$2.9 \cdot 10^{-4}$
CZT standard	$1.0 \cdot 10^{-2}$	$2.0 \cdot 10^{-5}$

Although CdZnTe is intrinsic, two faces are polar:

- Te-terminated (Te-face)
- Cd-terminated (Cd-face)

The same metal deposited on different faces could result in different behavior



New developed contacts

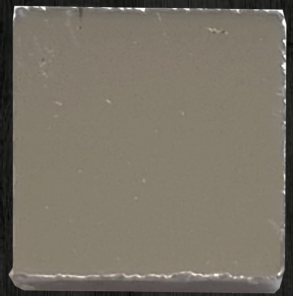
Development of contacts suitable to high-flux CZT is necessary

We focused our efforts on:

- Gold electroless contacts
- Platinum sputtered contacts

We performed a new study in order to obtain mechanically stable blocking contacts on the high-flux CZT Redlen material

The study is carried out in the frame of a joint project between IMEM-CNR and ESRF on pixelated detectors



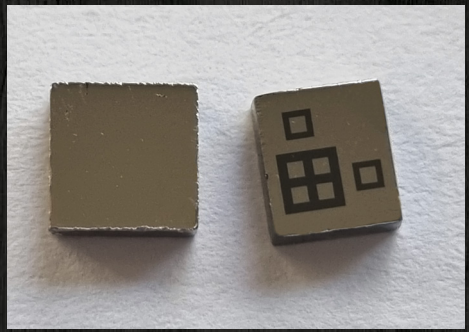
Test samples

Four detectors were realized with REDLEN High-Flux material. Detectors have the same geometry (5x5x1.5 mm^3) but different contact metals

Detector are equipped with full-area cathode and a customized pixelated anode (pixel size is 500x500 μm^2 with 200 μm gap)

Samples:

SAMPLE NAME	CATHODE CONTACT <111> - Te face	ANODE CONTACT <111> - Cd face
PP	Platinum	Platinum
PA	Platinum	Gold
AP	Gold	Platinum
AA	Gold	Gold

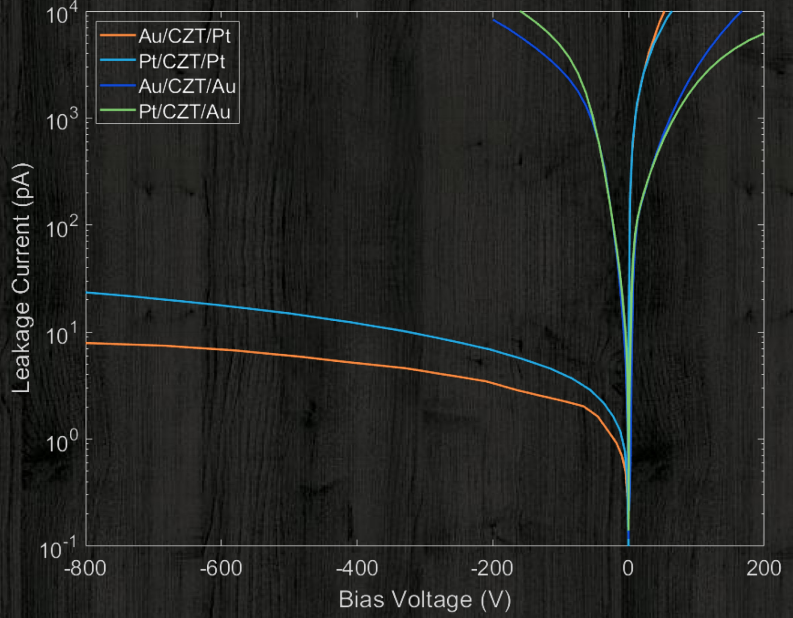


Current-Voltage characteristics

Bulk leakage current were measured from the four detectors

AA and PA detectors had a large leakage current (about 40nA/mm^2 at -200V)

AP and PP detectors were the most promising samples (about 40pA/mm^2 at -800V)



Current-Voltage characteristics

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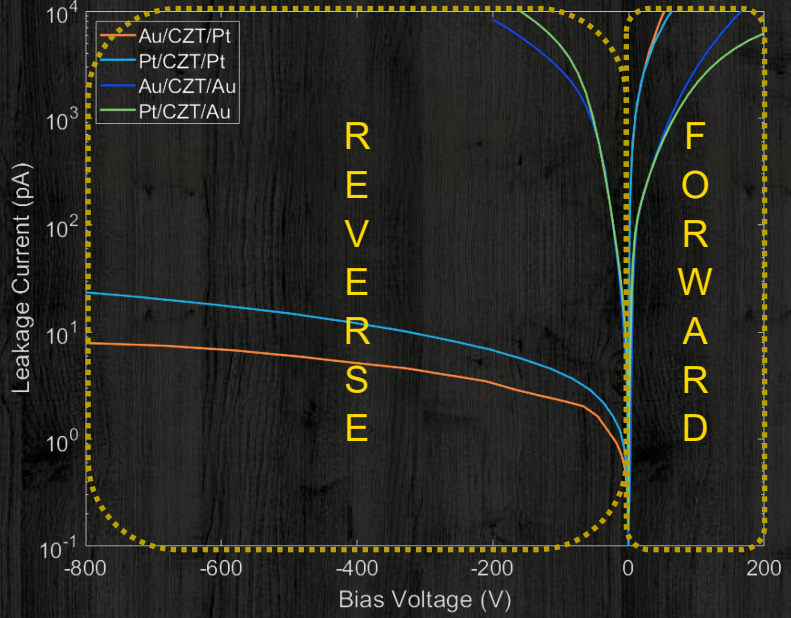
From IV it is possible to deduce:

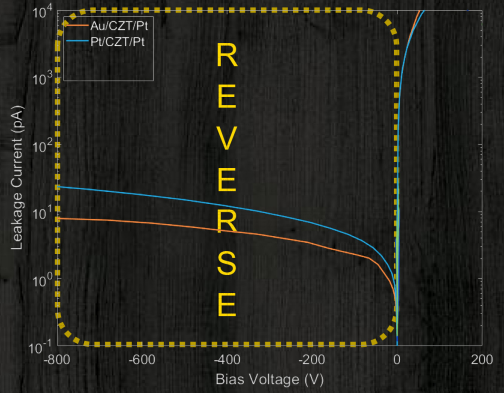
- PP sample shows extremely high rectifying ratio (>10^4), so same metal on different faces can behave differently
- Au and Pt on Te-terminated surface behave similarly
- Pt on Cd-terminated face is necessary to ensure low leakage current



Current-Voltage characteristics

Focusing on Reverse bias:

IV behavior depends only on the metal on anode (Cd-face) →
Leakage current is dominated by holes



Current-Voltage characteristics

Focusing on Reverse bias:

IV behavior depends only on the metal on anode (Cd-face) → Leakage current is dominated by holes

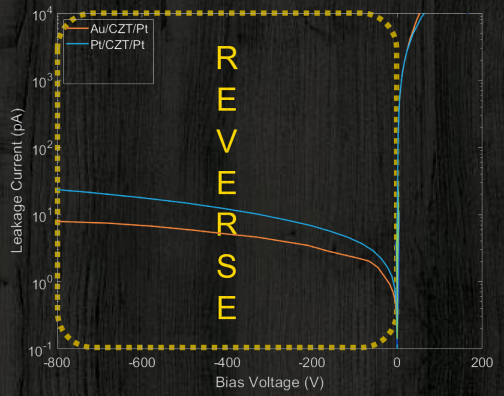
Pt on Cd-face is necessary to limit the holes injection

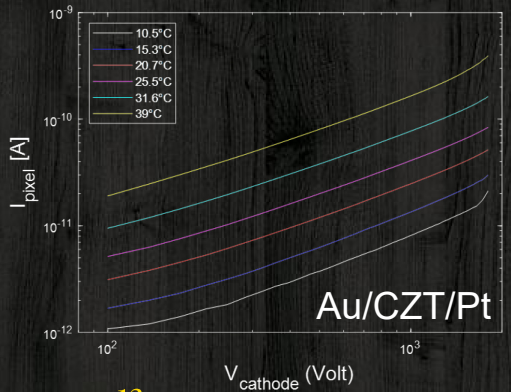
A deep investigation of electrical properties of AP and PP were carried out at UNIPA:

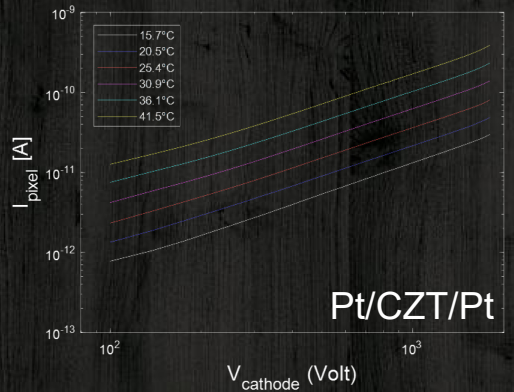
- IV at different temperatures
- Up to 2400V! (~200pA/mm^2 @ 20°C)
  Crucial in extremely high flux conditions

Curves fitted with ITD model:

- ϕ_{B0} is about 780 meV
- Presence of oxide layer between Pt and CZT







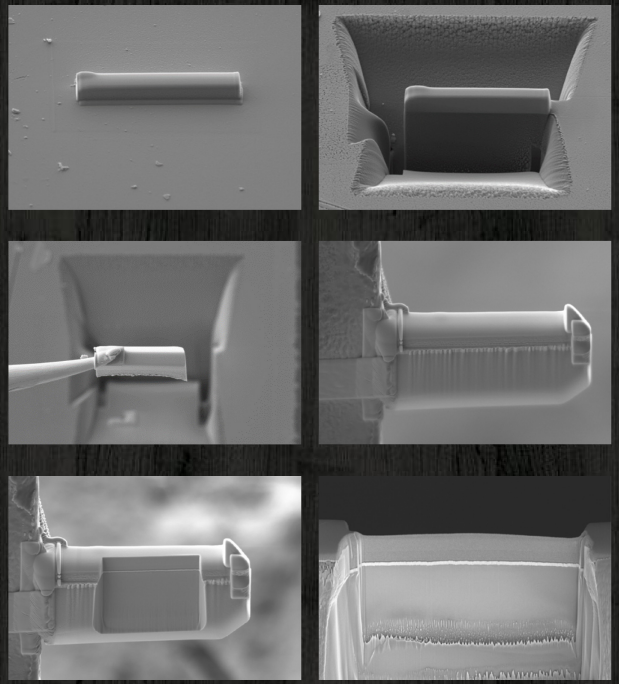
Structural and Compositional analysis of Pt contact

Lamella (thin cross section of metal-CZT junction) of Pt contact

Lamella prepared by FIB lift-out technique and analyzed by TEM

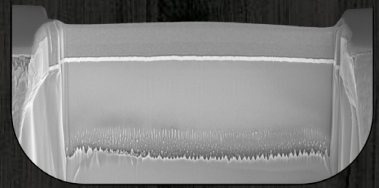
Analysis performed with:

- TEM-EDX
- High-Angle Annular Dark Field (HAADF)
- HRTEM

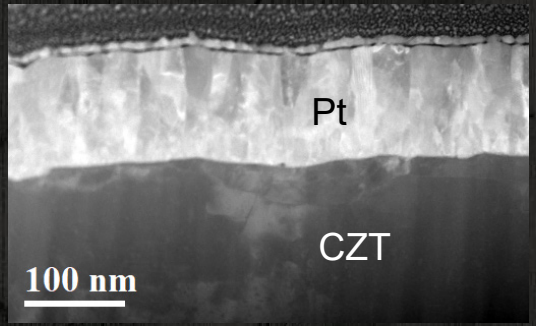


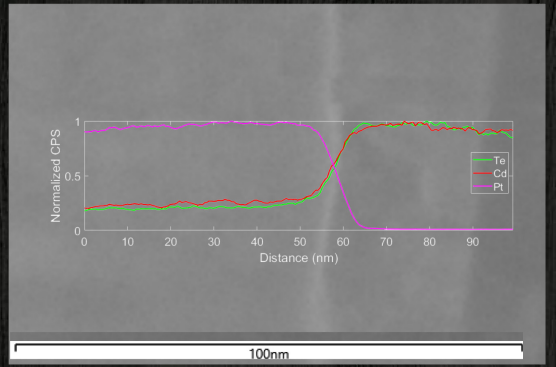
FESEM-FIB and TEM facilities at IMEM-CNR

Structural and Compositional analysis of Pt contact



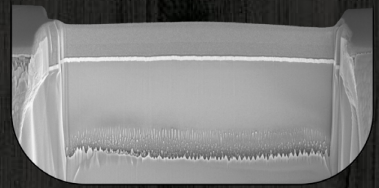
- 100nm thick platinum layer
- Stochiometric ratio of Cd(Zn) and Te is constant until the interface

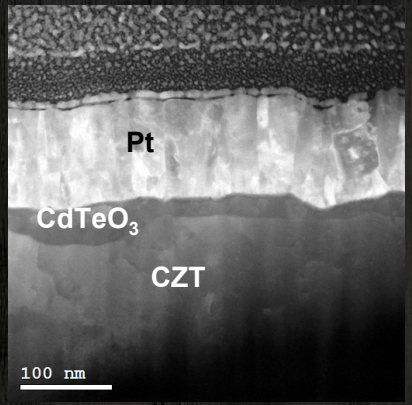


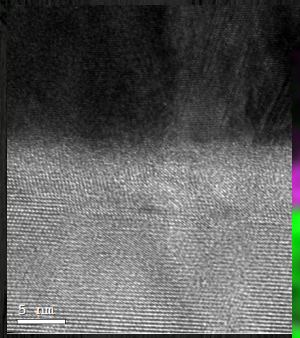


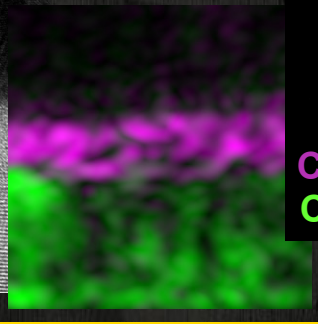
Structural and Compositional analysis of Pt contact

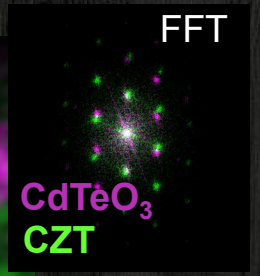
- 100nm thick platinum layer
- Stochiometric ratio of Cd(Zn) and Te is constant until the interface
- Presence of a thick layer of $CdTeO_3$: from 5 to 50 nm
- Oxide is monocrystalline and oriented minimizing the lattices mismatch









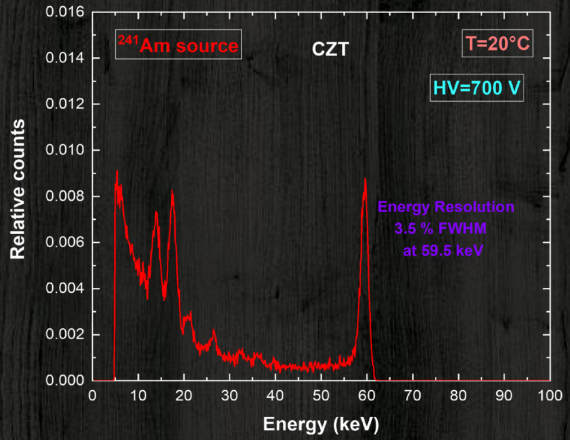


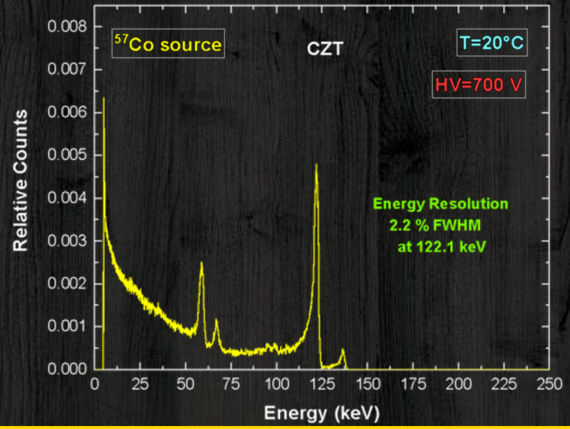
Spectroscopic performances

Spectroscopic performances were evaluated at UNIPA

Since both samples behaves similar,
only AP results are shown

Good spectroscopic resolution considering the large interpixel gap





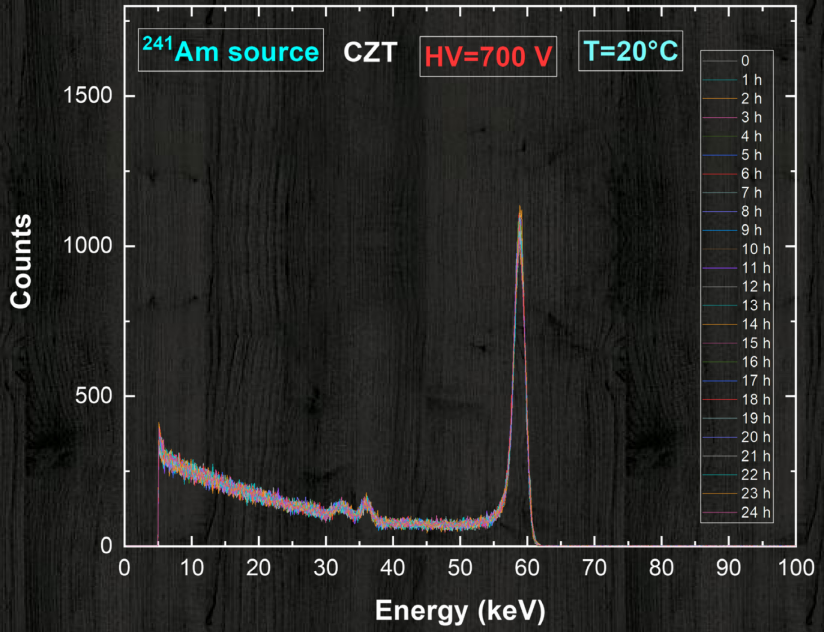
Spectroscopic performances

Spectroscopic performances were evaluated at UNIPA

Since both samples behaves similar,
only AP results are shown

Good spectroscopic resolution considering the large interpixel gap

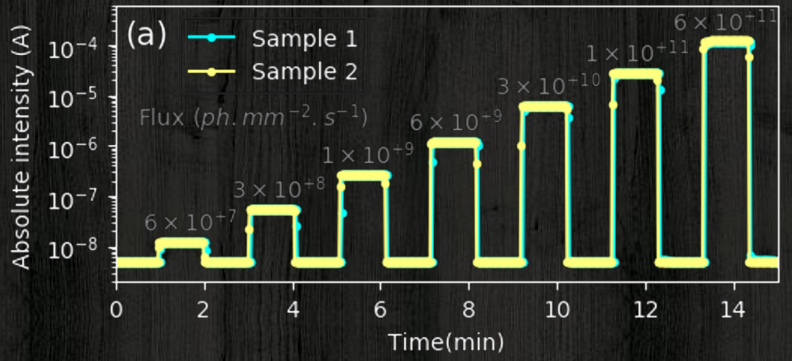
Excellent time-stability verified over a 24h monitoring

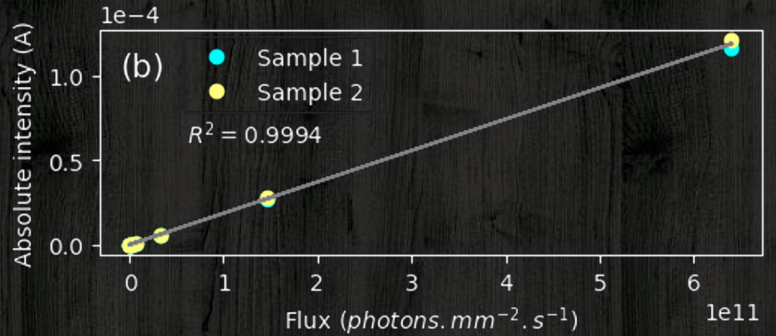


High-Flux performances

PP and AP samples were analyzed under high flux radiation at ESRF in Grenoble

Response linearity was verified up to $6 \cdot 10^{11}$ ph/mm^2/s
Good time stability





Summary

High performance contacts for HF CZT were developed

- Extremely low leakage current up to 15kV/cm
- Great electrical and spectroscopic time stability
- Very good linearity response up to $6 \cdot 10^{11}$ ph/mm^2/s

Platinum contact was studied:

- Holes barrier height is about 780 meV
- Thick interfacial layer of $CdTeO_3$ is present under platinum contact

Thanks!

Any questions?

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