Optoelectronic properties of High-Flux CdZnTe with optimized electrodes.

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Cadmium Zinc Telluride (CdZnTe or CZT) is a promising candidate for direct X-ray detection under high photon flux with energies in the range of 30keV to 100keV. In this collaboration work between IMEM-CNR and ESRF, the optoelectronic and transport properties of Redlen high-flux CdZnTe (HF-CZT) single crystals with electroless gold and sputtered platinum electrodes are studied. We report low leakage current under dark conditions (6nA/cm^2 at 5kV/cm), good linearity with moderate to high incident flux (10^7 to 10^{10} photons.mm^{-2}.s^{-1}), good stability up to 10^{+11}photons.mm^{-2}.s^{-1}, and reduced transient phenomena (stabilization time, afterglow and polarization effects) as compared to standard CdTe material.

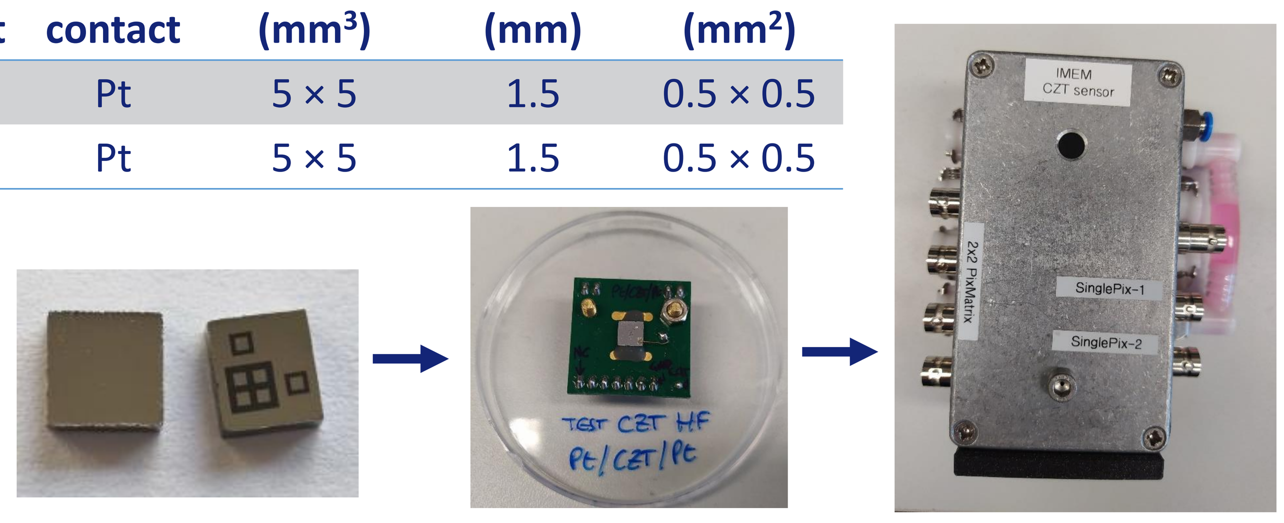
1 Introduction

4th Generation Synchrotron Light Sources such as the Extremely Brilliant Source (EBS) of the ESRF [1], have lead to an increased need for direct X-ray detection under high photon flux with energies ranging from 30keV to 100keV. For these applications, the high-flux CdZnTe (HF-CZT) material developed by Redlen is a promising candidate as it limits the polarizing phenomena observed in standard CZT under high photon flux [2-3]. However, the gold electroless blocking contacts commonly used to achieve low leakage current in standard CZT lead to much higher leakage current in HF-CZT [4]. This work results from a collaboration between IMEM-CNR and ESRF. The objectives of this joint work were, first, to develop optimized electrodes to reduce the leakage current of HF-CZT, and then, to evaluate the capabilities of the optimized samples under high photon fluxes.

2 Methods: HF-CZT with optimized electrodes

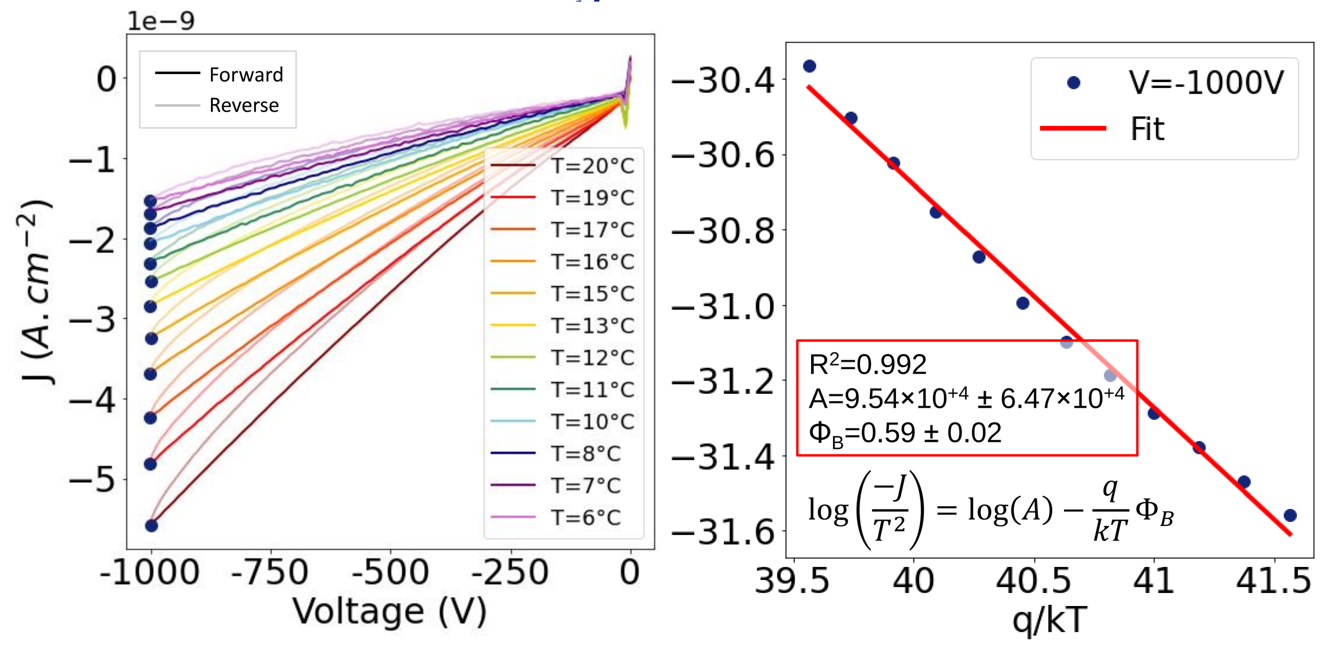
IMEM-CNR process: Au electroless and Pt sputtered electrodes deposited onto polished Redlen HF-CZT single crystals.

Sample	Cathode contact	Anode contact	Geometry (mm³)	Thickness (mm)	Pixel size (mm²)
1	Au	Pt	5 × 5	1.5	0.5 × 0.5
2	Pt	Pt	5 × 5	1.5	0.5 × 0.5



3 Dark conditions

For both samples, J_{dark}=6nA/cm^2 when V=-5kV/cm and T=20°C. This is a 4 orders of magnitude improvement as compared with other electrode configurations [4]. Both samples exhibited non-ideal Schottky characteristics: low reverse current lower and linear reverse characteristics. Using the thermionic model, the height of the Schottky barrier was estimated to be Φ_B=0.59eV regardless of the bias voltage.

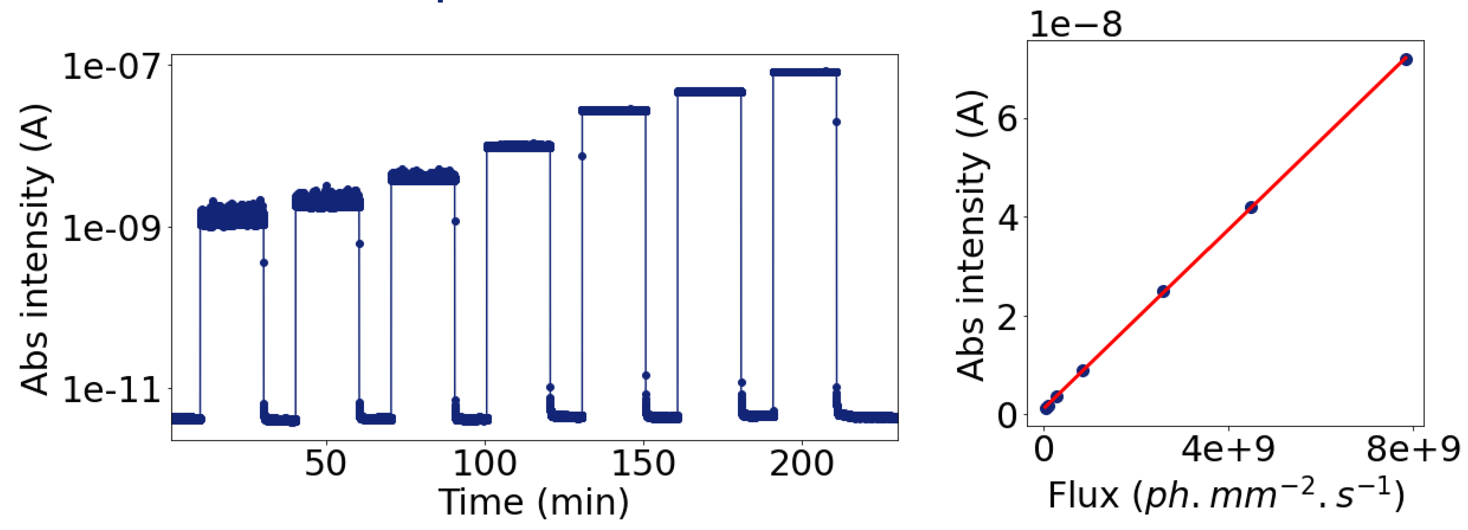


Left: J-V_{dark}(T) of sample 2. Right: Schottky barrier height estimation using the thermionic model.

4 Behavior under X-ray irradiation

A. Moderate to high flux: $3\times10^{+7}$-$8\times10^{+9}$ photons.mm^{-2}.s^{-1}

Measurements acquired on BM05, at 20keV, V=-1000V.

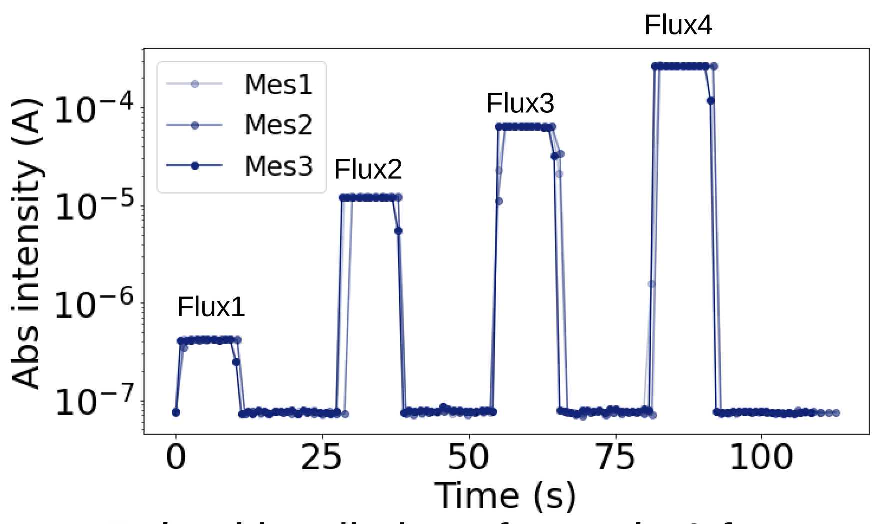


Left: pulsed irradiation of sample 2 for increasing fluxes. Right: average absolute intensity of sample 2 as a function of incident flux.

Good stability and linearity under moderate to high flux.

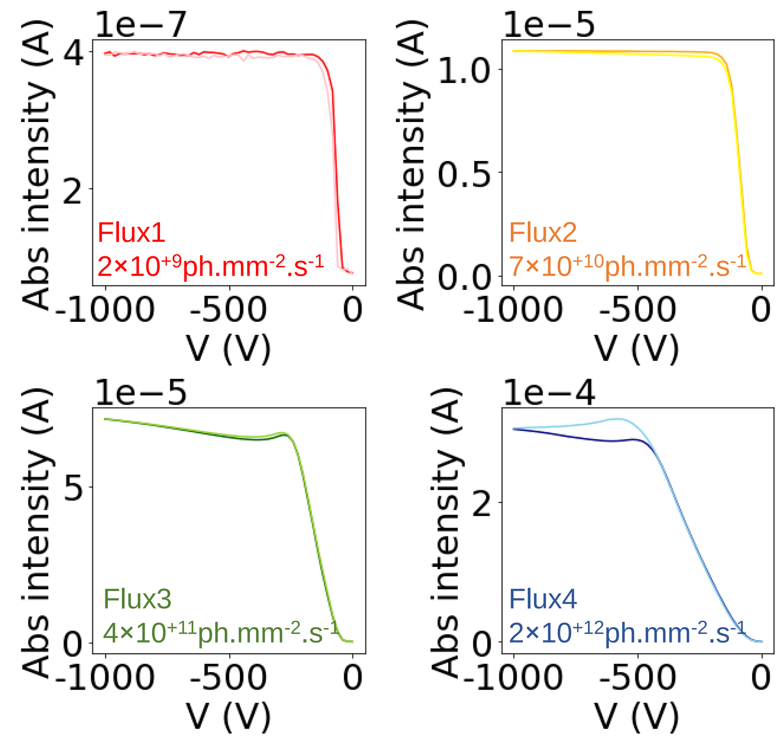
B. High to very high flux: $2\times10^{+9}$-$1\times10^{+12}$ photons.mm^{-2}.s^{-1}

Measurements acquired on ID19, at 19keV, V=-500V.



Pulsed irradiation of sample 2 for increasing fluxes.

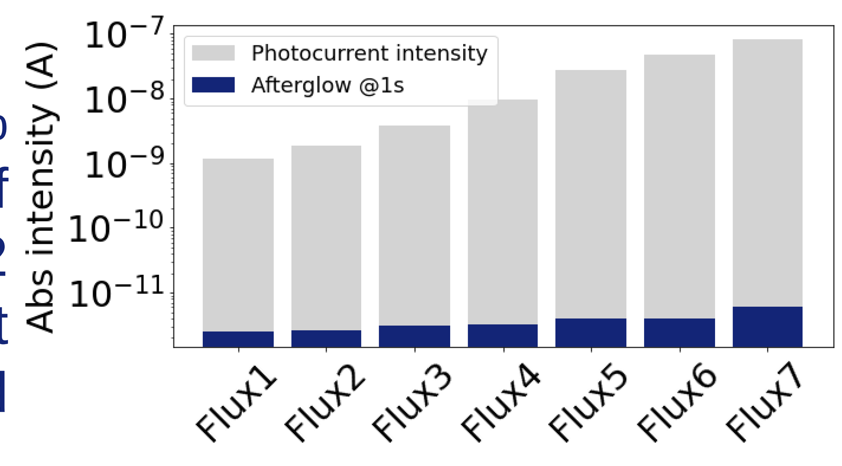
Stable (10s) and reproducible behavior up to 10^{+12} ph.mm^{-2}.s^{-1}. Above 10^{+11} ph.mm^{-2}.s^{-1} the I-V shape is deformed and an hysteresis appears.



I-V characteristics as a function of incident flux.

5 Afterglow

At 1s, the afterglow is below 0.5% of the photocurrent regardless of the incident flux. This is at least a 2 orders of magnitude improvement compared with standard CZT and GaAs.



Afterglow 1s after irradiation compared with photocurrent.

6 Conclusion

- Characterization of Redlen HF-CZT with optimized electrodes
- Low leakage current achieved with Au/CZT/Pt and Pt/CZT/Pt configurations (6nA/cm^2 @ -5kV/cm and 20°C)
- Good stability for fluxes up to 10^{+11} ph.mm^{-2}.s^{-1} and good linearity for 10^{+7}-10^{+10} ph.mm^{-2}.s^{-1} flux range.
- Low afterglow compared with CdTe and GaAs.

[1] P. Raimondi, 'ESRF-EBS: The Extremely Brilliant Source Project', *Synchrotron Radiat. News*, vol. 29, no. 6, pp. 8–15, Nov. 2016, doi: 10.1080/08940886.2016.1244462.
[2] B. Thomas *et al.*, 'Characterisation of Redlen high-flux CdZnTe', *J. Inst.*, vol. 12, no. 12, pp. C12045–C12045, Dec. 2017, doi: 10.1088/1748-0221/12/12/C12045.
[3] S. Tsigaridas *et al.*, 'Characterisation of pixelated CdZnTe sensors using MAXIPIX', *J. Inst.*, vol. 14, no. 12, pp. C12009–C12009, Dec. 2019, doi: 10.1088/1748-0221/14/12/C12009.
[4] M. Bettelli *et al.*, 'Low leakage currents contacts for High-Flux CdZnTe', presented at the IEEE-RTSD-2021, Oct. 2021.

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