EBIC and IBIC imaging on polycrystalline CdTe

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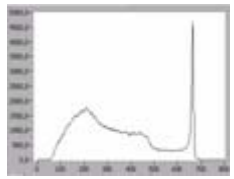
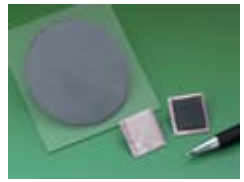
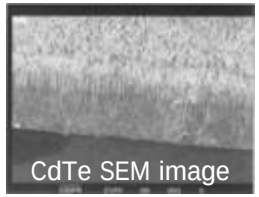
Introduction

- Polycrystalline CdTe: advantages and drawbacks



Monocrystalline: - very good charge transport properties
- suitable for spectrometry.
- high cost processes (THM, HPBM)
- limited dimensions (≈ 1 cm^3)





Polycrystalline: - low cost growth processes
- large detection surface
- poorer properties (but good resistivity)
- greater amount of defects: chemical and **structural**

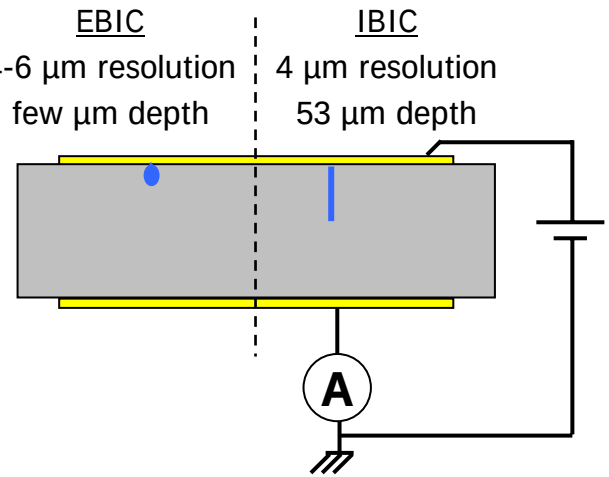
⇒ **structural defects** and **local properties** studies

Beam Induced Current principles

- Principle: high resolution mapping of current induced by a focused beam in a polarized detector.

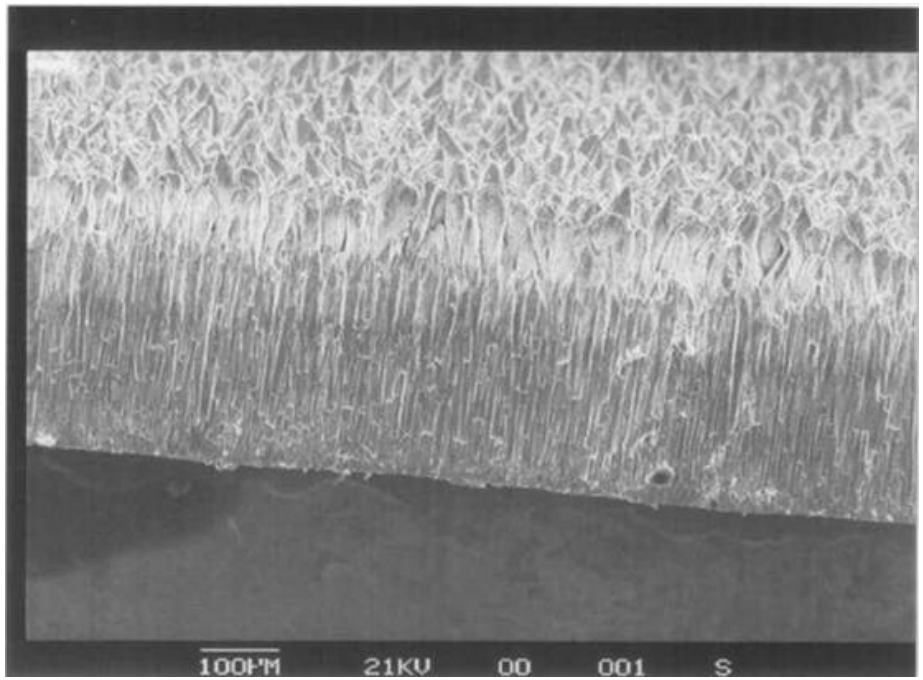
- The Electron-BIC experiment:
  - e^- beam of a SEM microscope
  - direct measurement of the induced current
  - measurement beneath the electrical contact

- The Ion-BIC experiment:
  - 2.58 MeV protons
  - penetration depth of protons ≈ 53 µm
  - Charge Collection Efficiency (CCE)



Polycrystalline CdTe sample

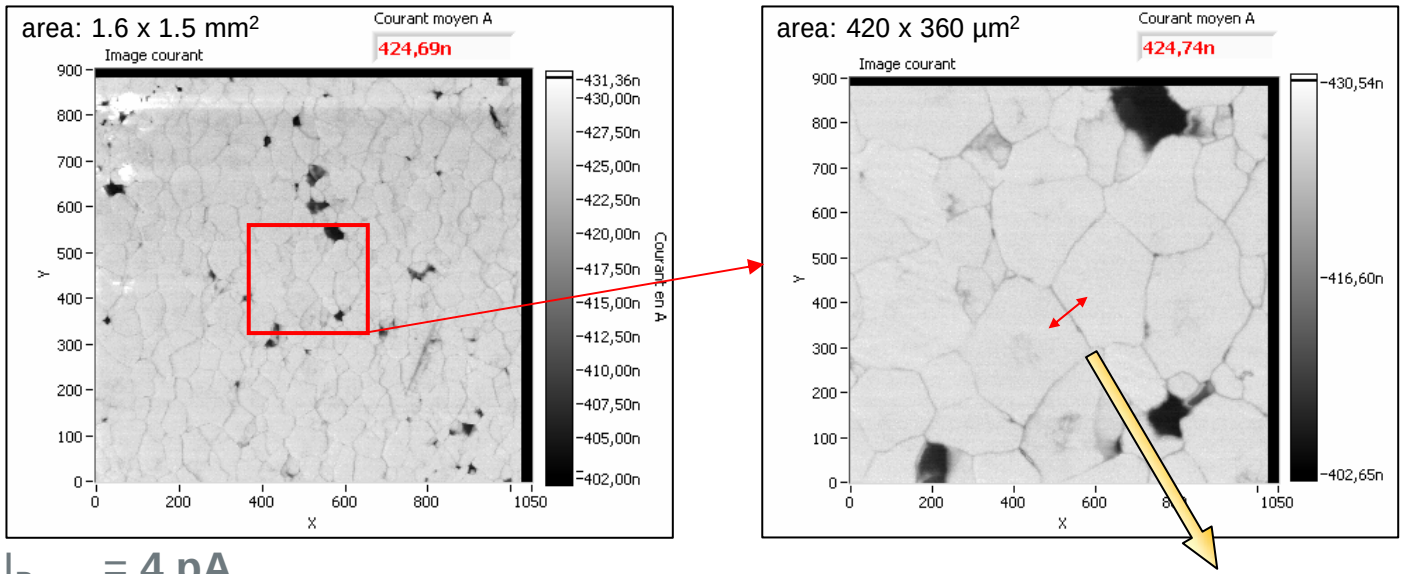
- Sample properties and measurement conditions:
  - thickness 350 µm
  - resistivity ρ = 4e10 Ω.cm
  - mobility $\mu_e \approx 500\ cm^2/V/s$
  - applied voltage HV_S = -100 V for EBIC
    = -150 V for IBIC



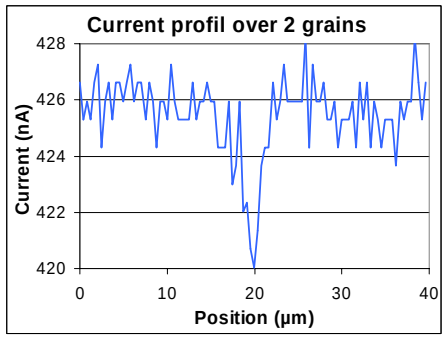
SEM image of a cleaved polycrystalline CdTe sample

EBIC results on poly-CdTe

- Beam: - HV_B = 30kV, current I_B = 4 pA to 53 nA
  - surface measurement, high charge creation density



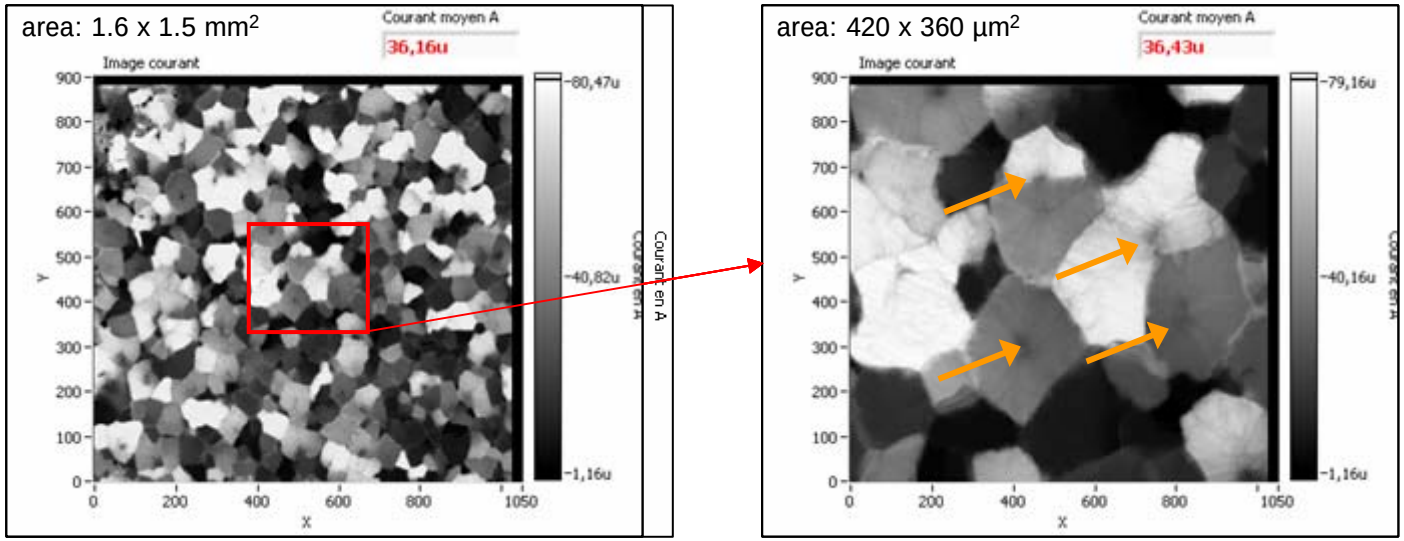
I_{Beam} = **4 pA**
Estimated created current ≈ **27 nA**



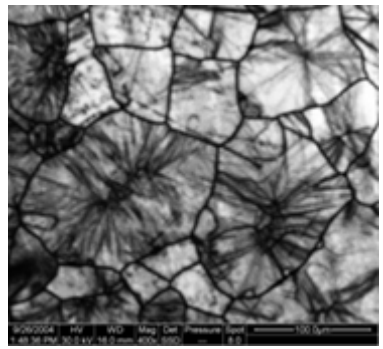
At low excitation:

- very good overall response homogeneity (dispersion < 10%)
- grain boundaries: 6 nA (≈ 22%) current decreasing

EBIC results on poly-CdTe



I_{Beam} = 42pA
Estimated created current ≈ 473pA


Cathodoluminescence

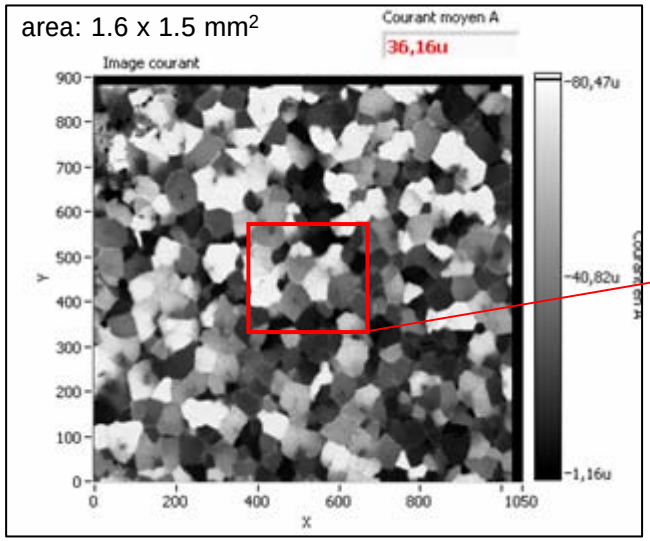
When increasing excitation:

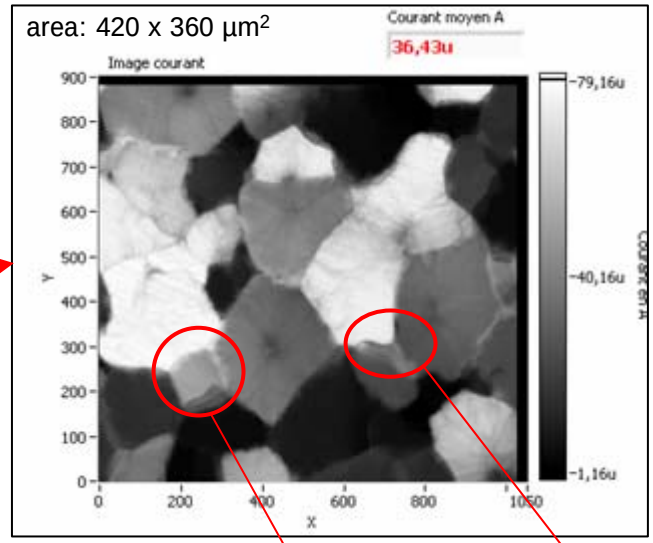
- appearance of in-grains structures
- confirmed with CL measurements

⇒ **correlation between low response and low luminescence**

Cathodoluminescence : crystal luminescence due to excitation by electrons. Measurement of the band to band recombination spectrum in semi-conductors.

EBIC results on poly-CdTe

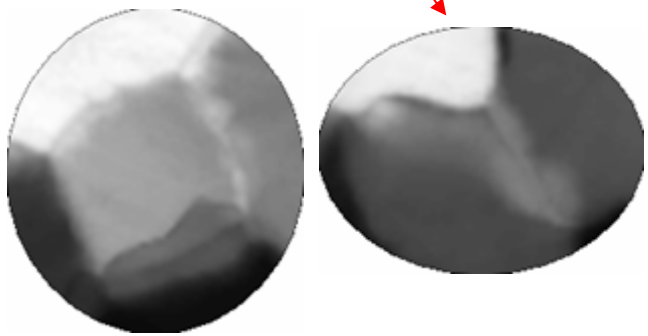




I_{Beam} = **14 nA**
Estimated created current ≈ **97 µA**

When increasing excitation:

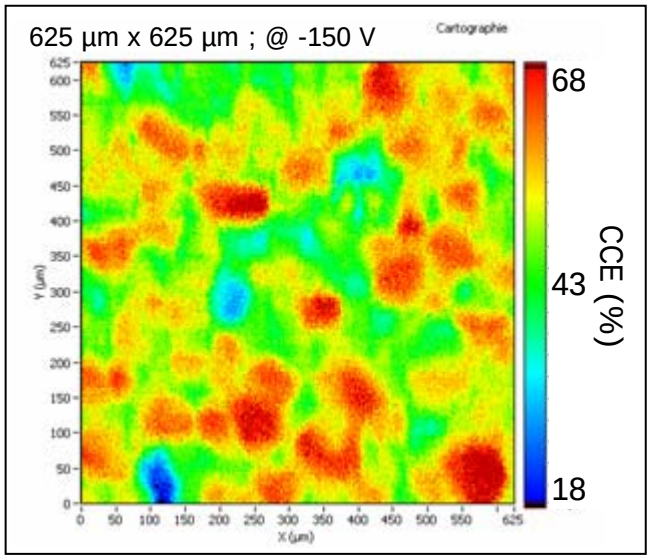
– grains influence each other near the boundaries



⇒ **electrical field effects (space charge, …) ?**

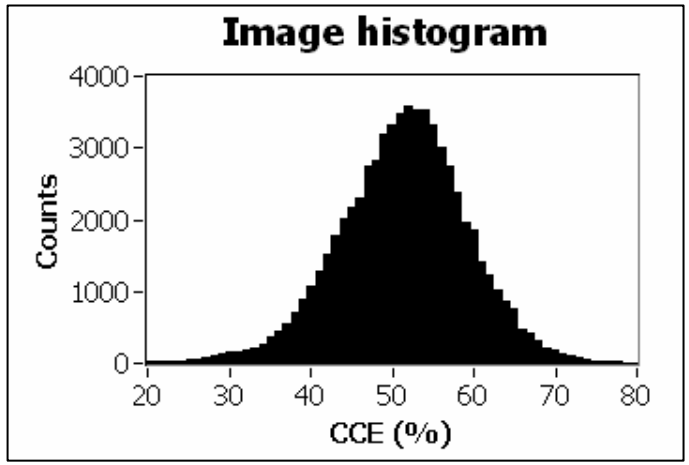
IBIC results on poly-CdTe

- Beam: E_p = 2.58 MeV ; ≈ 2 kHz events rate
- Output: Charge Collection Efficiency (CCE) = Q_{mes} / Q_{dep} (for each event)



Proton penetration range in CdTe: 53 µm
≈ 10 events / pixel

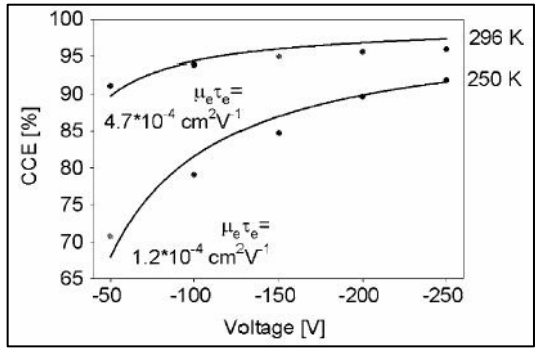
– very few dark areas
  - 1% for CCE < 30%
  - 7% for CCE < 40%
– good overall CCE response



⇒ **mean = 52% ; σ = 5.2**

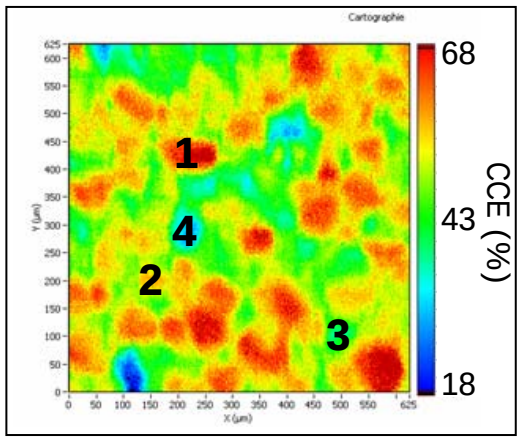
IBIC results on poly-CdTe

- $\mu\tau$ product:
  - using Hecht model, possibility to calculate $\mu\tau$
    (example with monocrystalline CZT material)

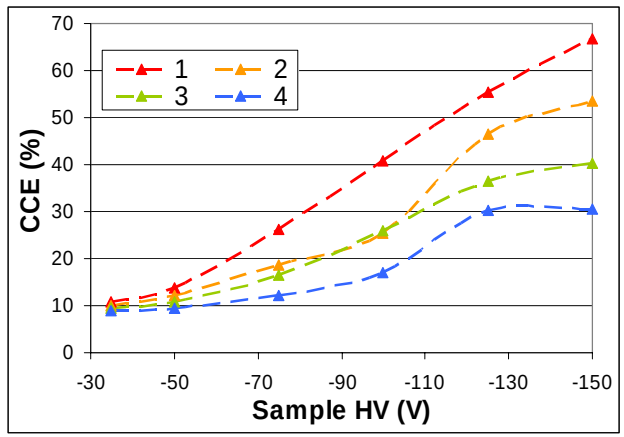


CCE vs. Voltage sample in monocrystalline CZT [1]

- For poly-CdTe
  - still in linear part of the model:
    - MFP < sample thickness
    - no measure at higher voltage
  - validity of the model:
    - electric field distribution ?



CCE mapping



Mean CCE of homogeneous areas (grains)

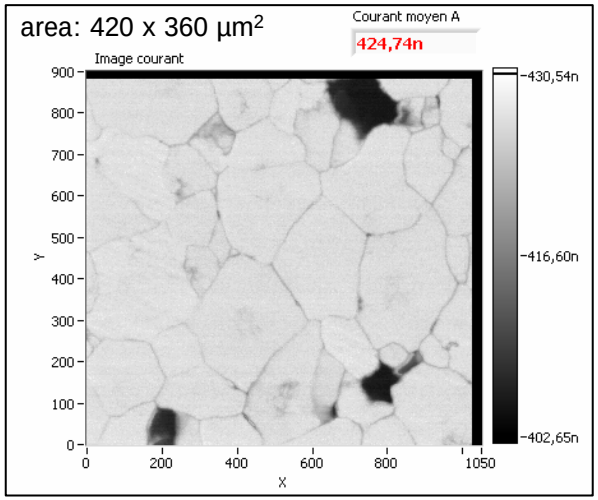
[1] A. Lohstroh *et al.*, High-resolution mapping of the mobility-lifetime product in CdZnTe using a nuclear microprobe, *J. Phys: Condens Matter* **16** (2004) 67

Summary

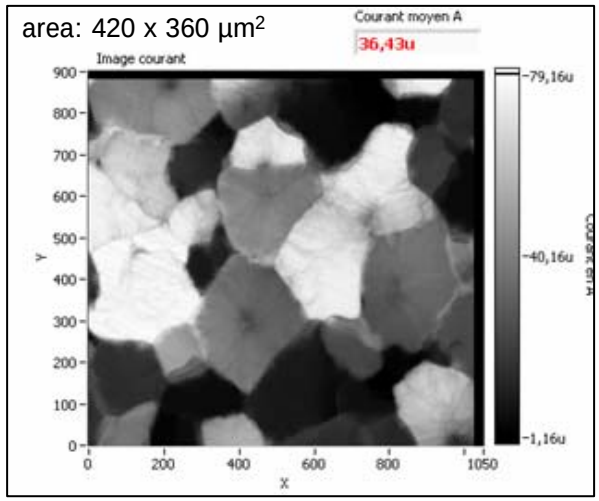
- Principal usefulness of poly-CdTe: X and γ detection

⇒ high charge density excitation to explore its particularities

Electron-BIC

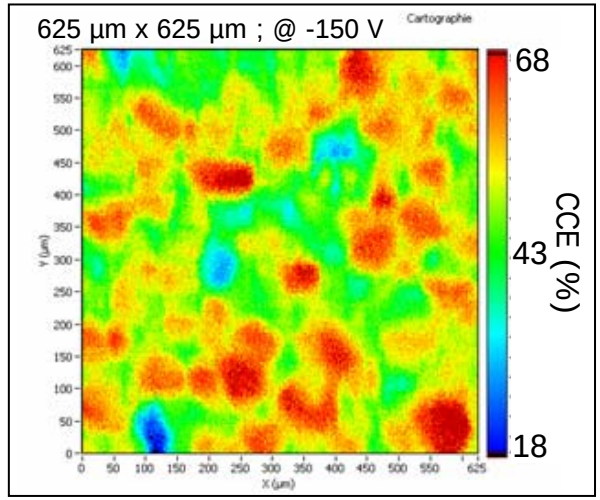


(low EBIC beam current)
- response homogeneity
- very few dark areas



(high EBIC beam current)
- inner structures
- electrical field effects

Ion-BIC



- very few dark areas
- good CCE response

Conclusion and prospects

- Beam Induced Current mappings reveal:
  - at high charge creation density
    - in-grains structures with poor luminescence
    - local space charge effects near the boundaries
  - at low charge creation density
    - homogeneous response
    - slightly visible grain boundaries effects
- Complementary measurements:
  - lateral EBIC and IBIC studies to see
    - "bulk" structures and properties
    - electrical field distribution in the detector

Thank you for your attention