ADVANCED MATERIAL AND DEVICE CHARACTERIZATION TECHNIQUES FOR SILICON AND THIN-FILM BASED PV

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MANY ADVANCED CHARACTERIZATION TECHNIQUES ARE AVAILABLE AT IMEC

Some examples:

- Auger Electron Spectroscopy (AES)
- Energy Dispersive Spectrometry (EDS)
- Conductive Atomic Force Microscopy (C-AFM)
- ERD (Elastic Recoil Detection)
- Focused Ion Beam (FIB)
- RAMAN spectroscopy
- Rutherford Backscattering Spectroscopy (RBS)
- Secondary Ion Mass Spectrometry (SIMS)
- Spreading Resistance Probe (SRP)
- Scanning Spreading Resistance Microscopy (SSRM)
- Transmission Electron Microscopy (TEM)
- Time-Of-Flight Secondary Ion Mass Spectrometry (TOFSIMS)
- X-ray Photoelectron Spectroscopy (XPS)
- Total reflectance X-Ray Fluorescence (TXRF)
- Photoluminescence and Time-resolved Photoluminescence (TR-PL)

OUTLINE

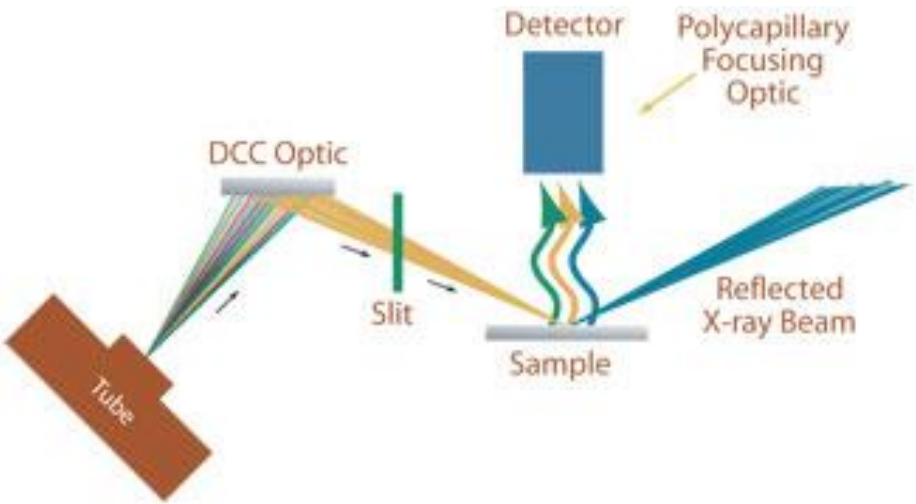
- Crystalline Si Solar Cells
  - TXRF for metal contamination control
  - SIMS and SSRM for junction formation optimization
- Thin-film solar cells
  - Time-resolved Photoluminescence of CZTS

TOTAL REFLECTION X-RAY FLUORESCENCE

TOTAL REFLECTANCE X-RAY FLUORESCENCE

Surface elemental analysis technique for particles, residues and impurities
Important tool for wafer surface contamination control in semiconductor chip manufacturing

TXRF is an energy dispersive XRF technique in a special geometry
TXRF shows an increased elemental measurement sensitivity compared to conventional XRF



An incident beam impinges upon a sample at angles below the critical angle of external total reflection for X-rays resulting in reflection of almost 100% of the excitation beam photons.

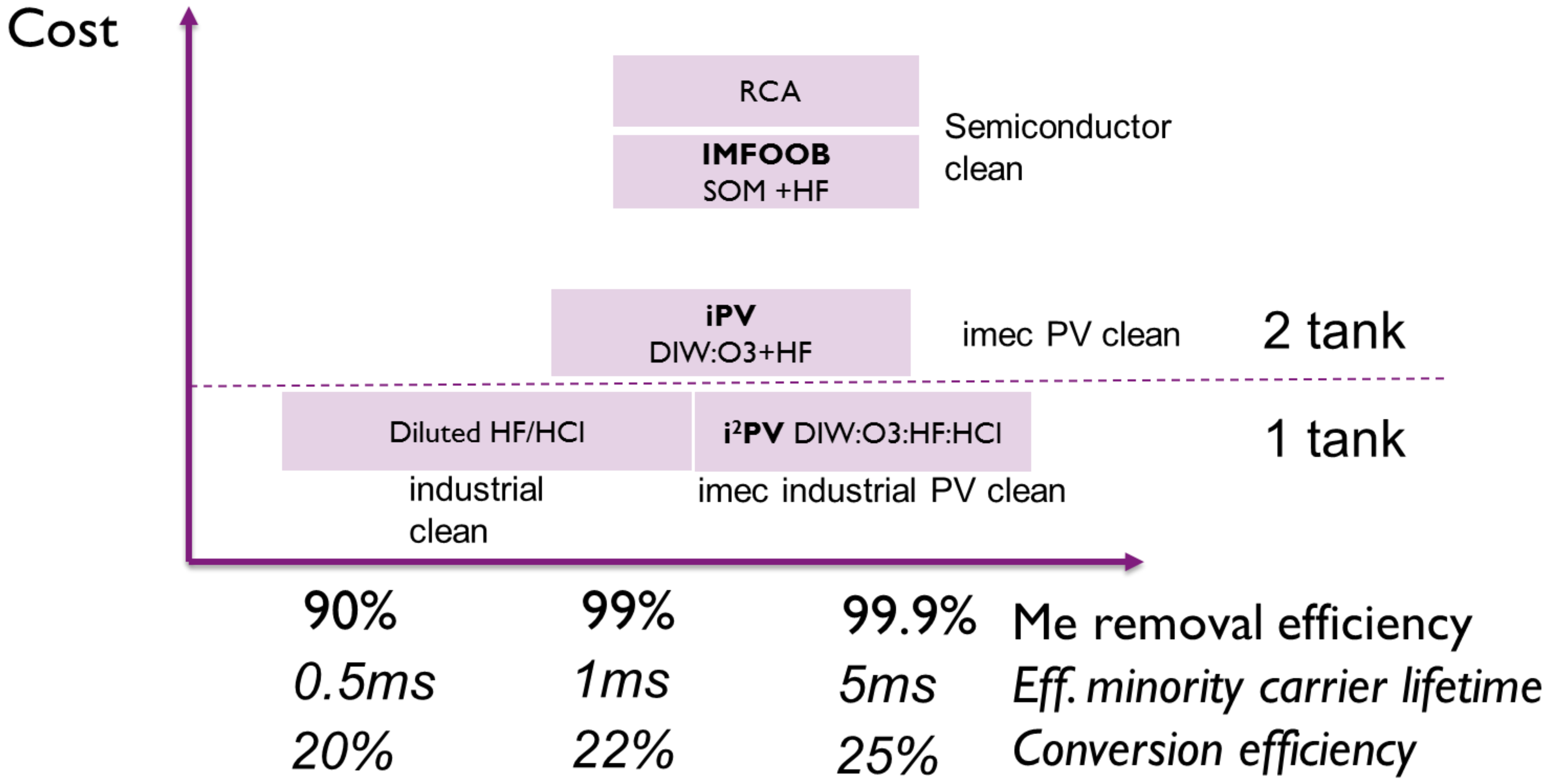
HIGH EFFICIENCY SILICON CELLS REQUIRE CLEAN AND HIGH LIFETIME PROCESSING

Cleaning of wafers needed at various stages of device processing
Requirements of cleaning solutions:

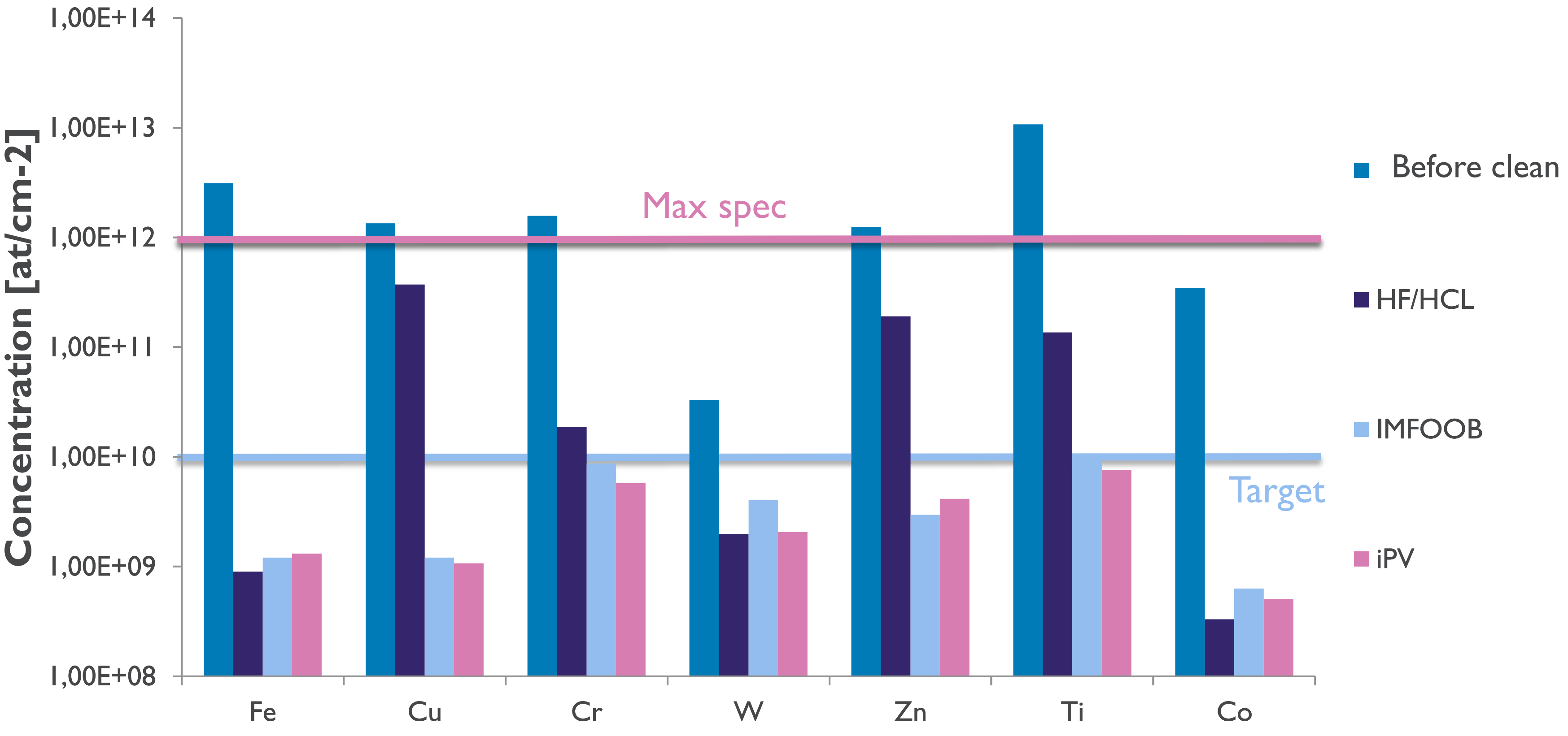
- Cost of Ownership
  - Lower chemical consumption (less steps or more diluted chemistries, or both)
  - Lower de-ionized water consumption (Rinsing)
  - Faster processing time (less tanks)

- Performance
  - Effective removal of contaminants after the alkaline processing, more specifically for lifetime killers : **Fe** and **Cu**
  - High minority lifetime values after processing

IMEC DEVELOPS LOW-COST HIGH-PERFORMANCE CLEANS

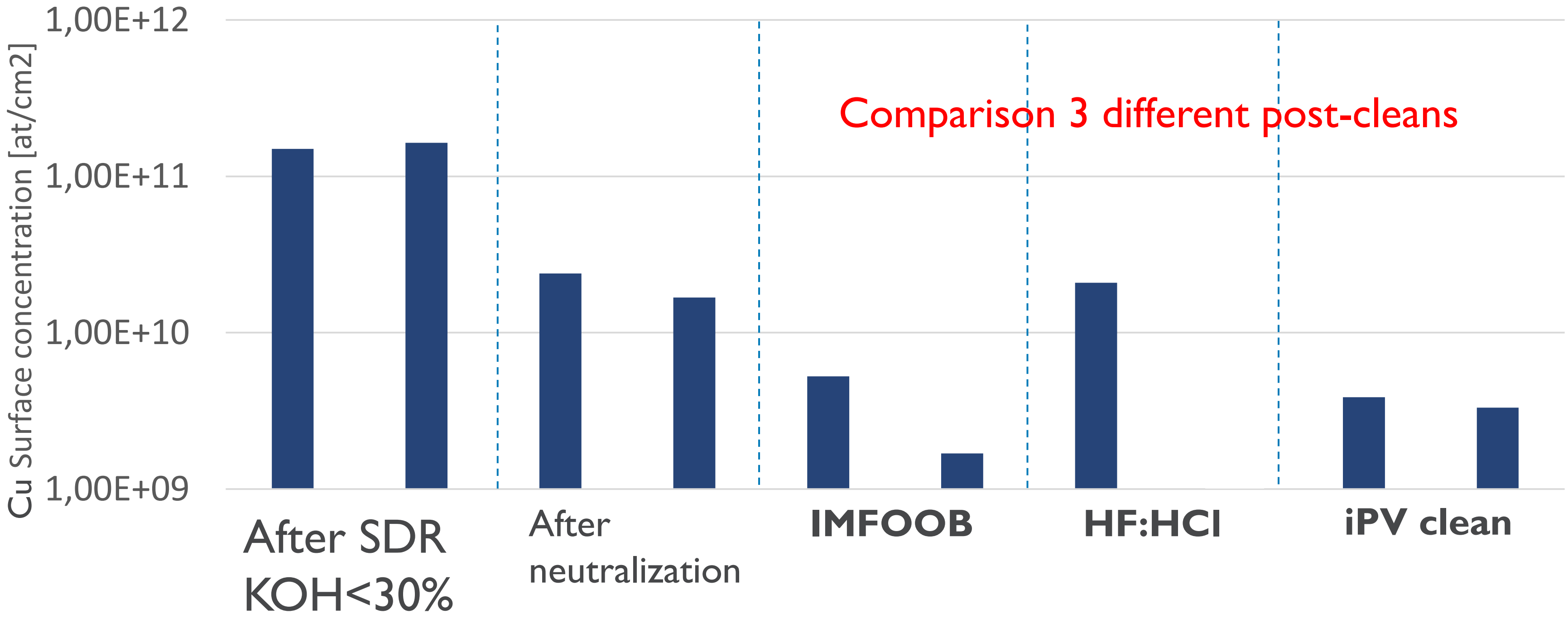


TXRF ALLOWS TO COMPARE THE EFFICACY OF DIFFERENT CLEANS FOR DIFFERENT METAL CONTAMINATION

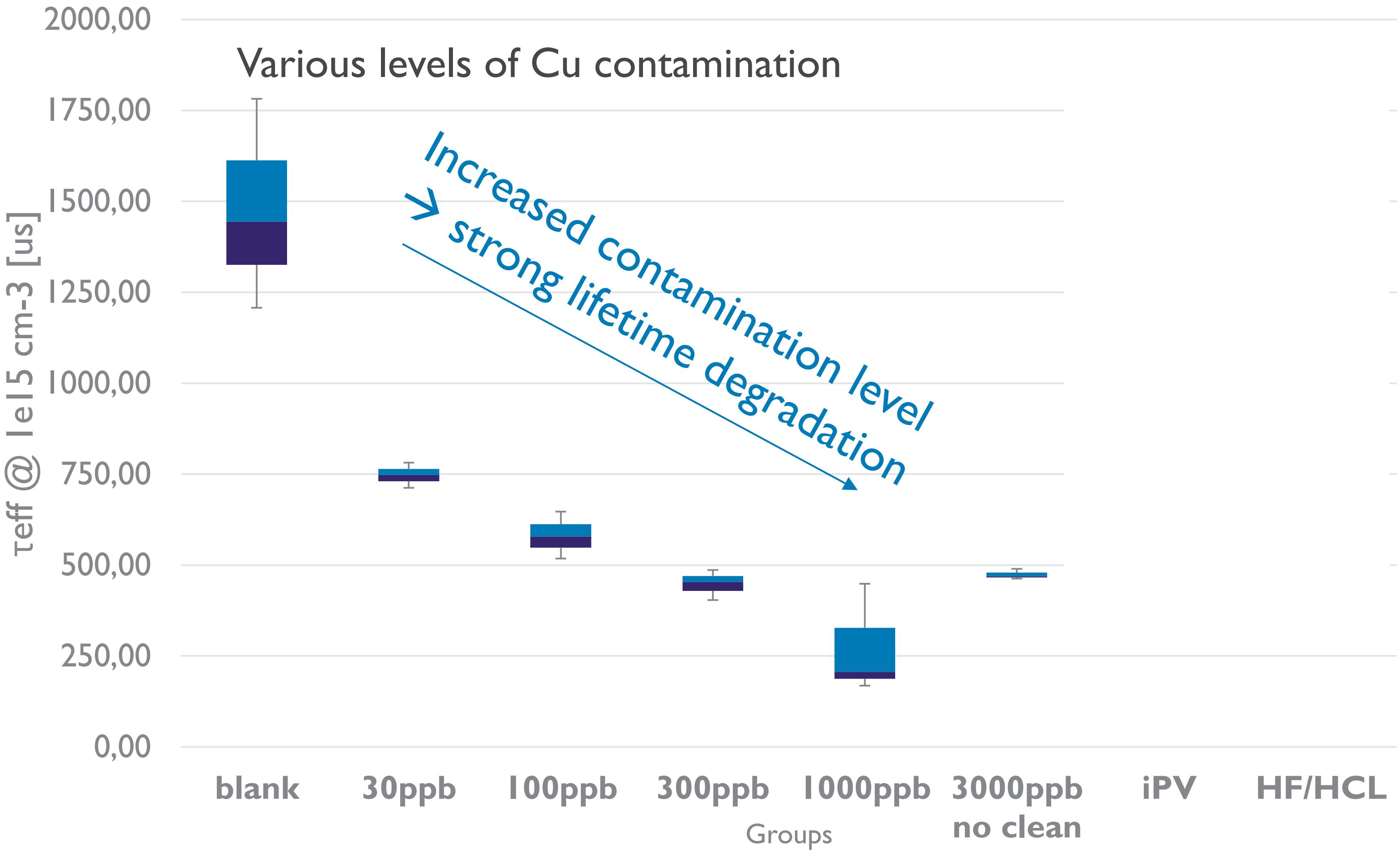


TXRF ALLOWS TO MONITOR THE CONTAMINATION PRESENCE AFTER EACH PROCESS STEP

Example: saw-damage removal using KOH etching:



CONTROLLED CONTAMINATION TESTS SHOW IMPACT OF CLEANING



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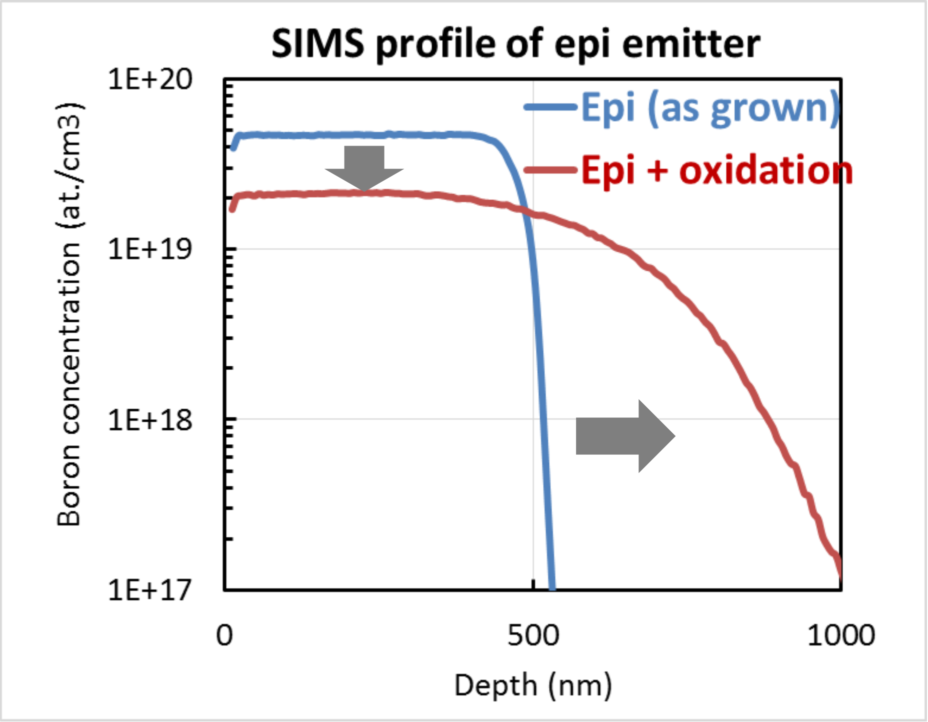
SCANNING SPREADING RESISTANCE MICROSCOPY

CONTROLLING JUNCTION PROPERTIES REQUIRES EXACT KNOWLEDGE OF THE JUNCTION PROFILE

Example of epitaxial emitter

- Doping profile formed by epi, is modified after following high temperature processes
- Doping profile needs to be optimized taking subsequent process steps into account

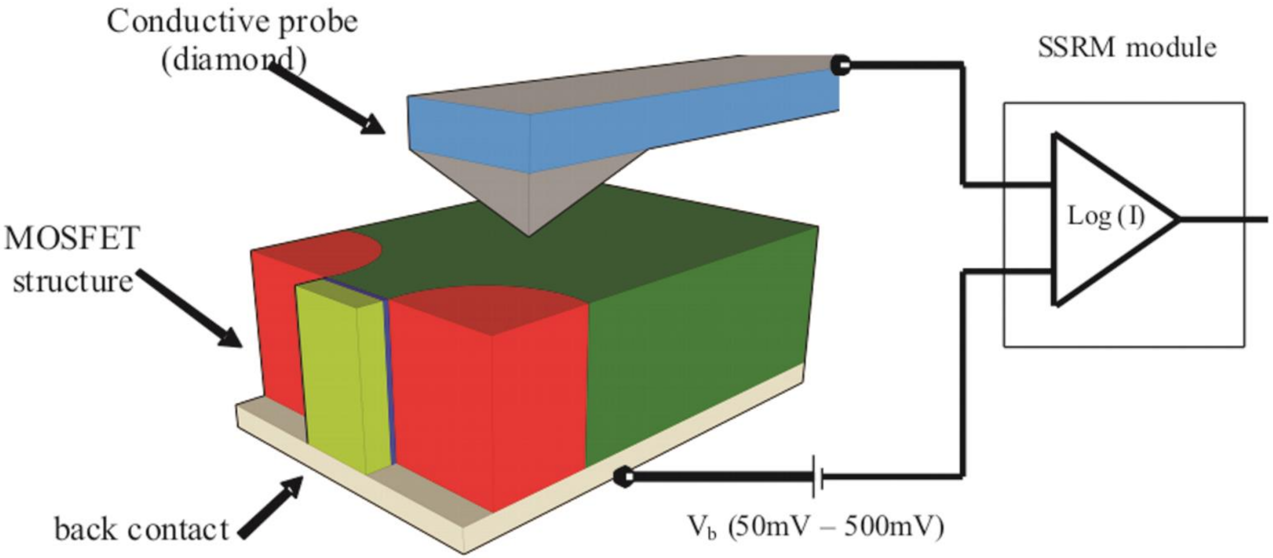


SIMS data is not always sufficient

- Spreading Resistance Probe (SRP)
- Scanning Spreading Resistance Microscopy (SSRP)
- ...

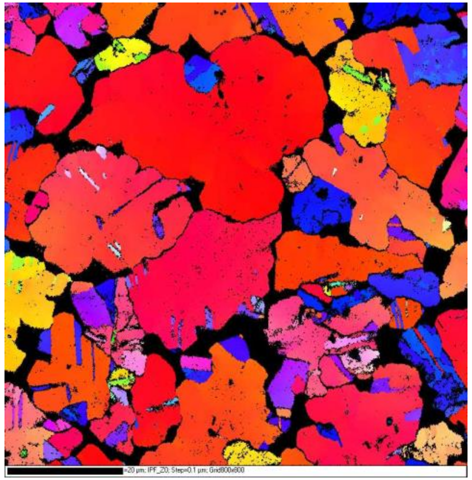
SCANNING SPREADING RESISTANCE MICROSCOPY

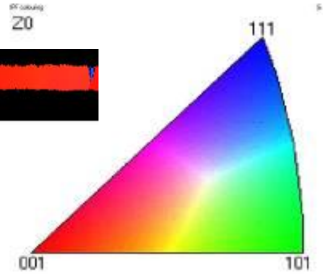
- Developed originally at IMEC
- Based on the measurement of the current flowing from a conducting AFM probe to a semiconductor sample, i.e. probing the point contact resistance
- 2D-map of point contact resistance provides an image of the 2D-carrier distribution

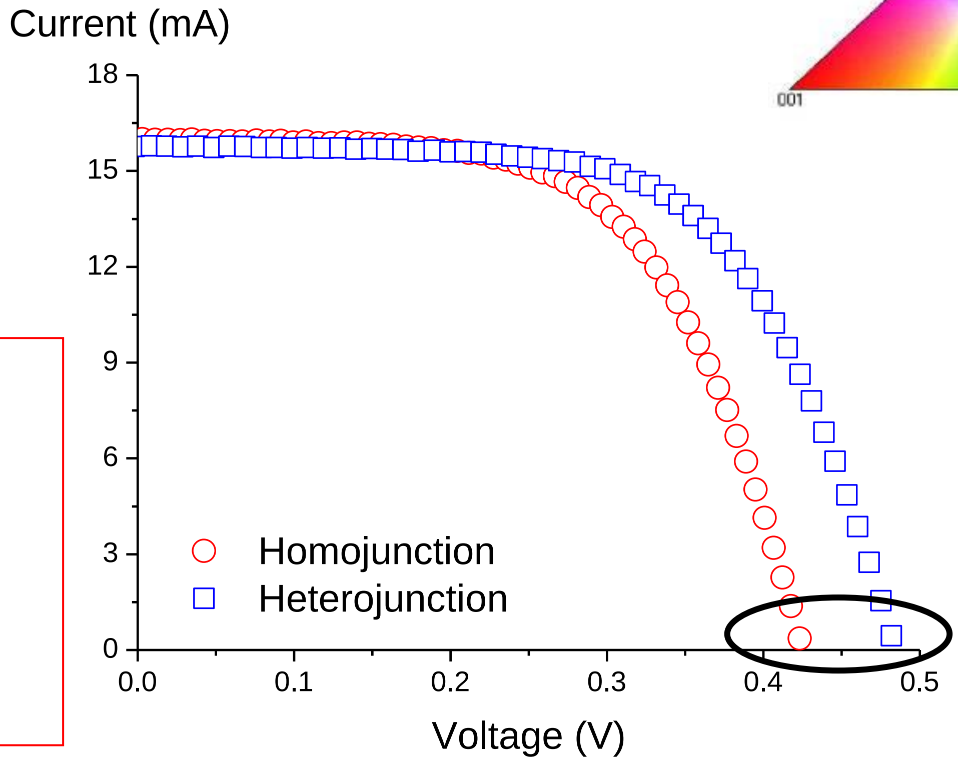


SCANNING SPREADING RESISTANCE MICROSCOPY APPLIED TO POLYCRYSTALLINE SILICON

Thin-film polycrystalline-silicon material, made by e.g. liquid phase or solid phase crystallization







2 types of devices made from this material:

Heterojunction formed by deposition of a-Si:P at low T

Homojunction formed by P diffusion at high T

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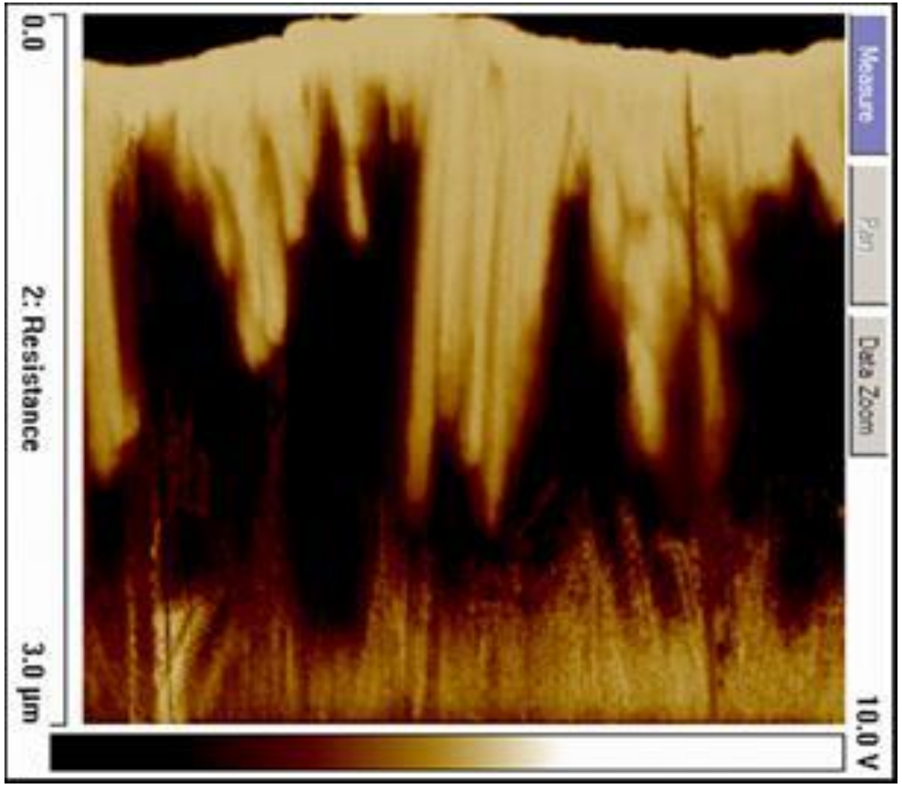
SSRM GIVES EXPERIMENTAL PROOF OF PREFERENTIAL P-DIFFUSION ALONG GRAIN BOUNDARIES LEADING TO LOWER VOC VALUES

Scanning Spreading Resistance Microscopy image:



n^+ emitter

p-type layer + P- spikes

p^+ BSF

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L. Carnel, I. Gordon *et al.*, IEEE Electron Device Letters **28**, 899-901 (2007)

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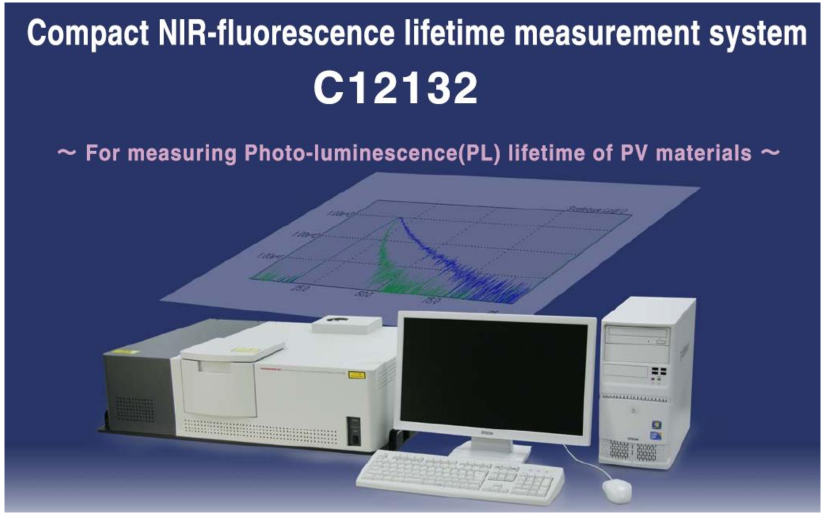
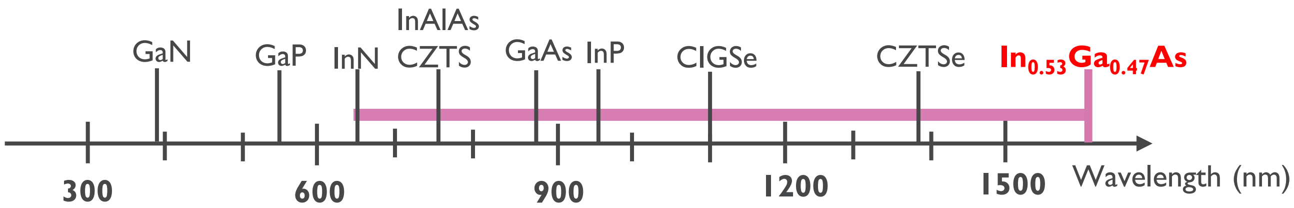
TIME-RESOLVED PL IS AN IDEAL TOOL FOR FAST SCREENING OF THIN-FILM COMPOUNDS FOR PV OVER A WIDE ENERGY RANGE

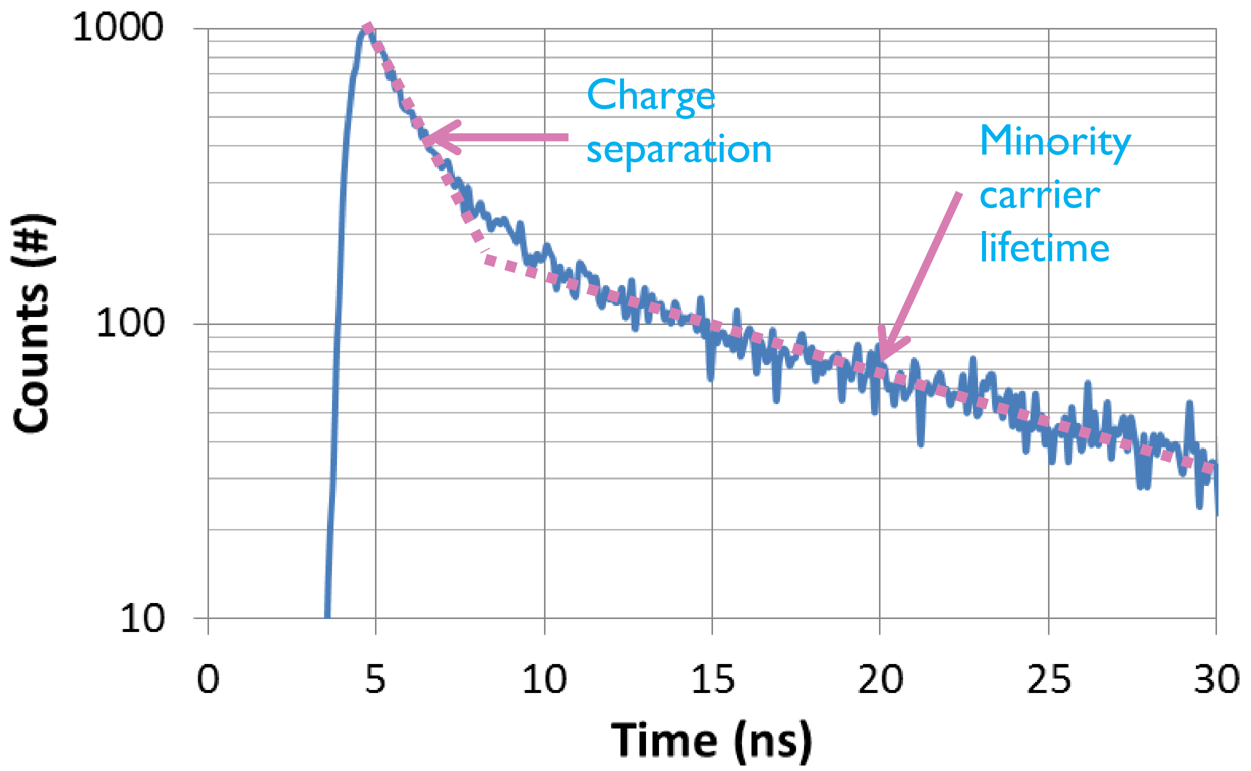
At IMEC we use a Hamamatsu C12132 system

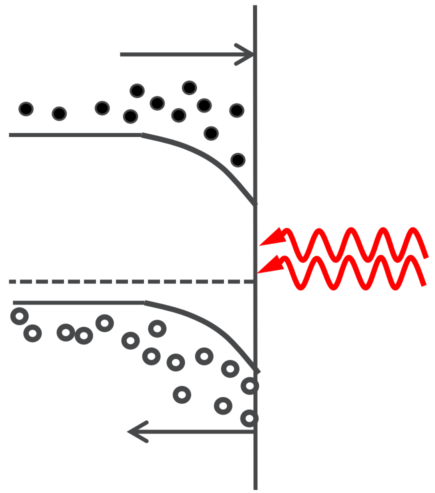
	C12132
Laser energy	532 nm
Laser power	42 mW
Repetition rate	15 kHz
Detector range	650-1600 nm
Lifetime range	200 ps – 50 μs





A TYPICAL MEASUREMENT OF A CZTSe SOLAR CELL

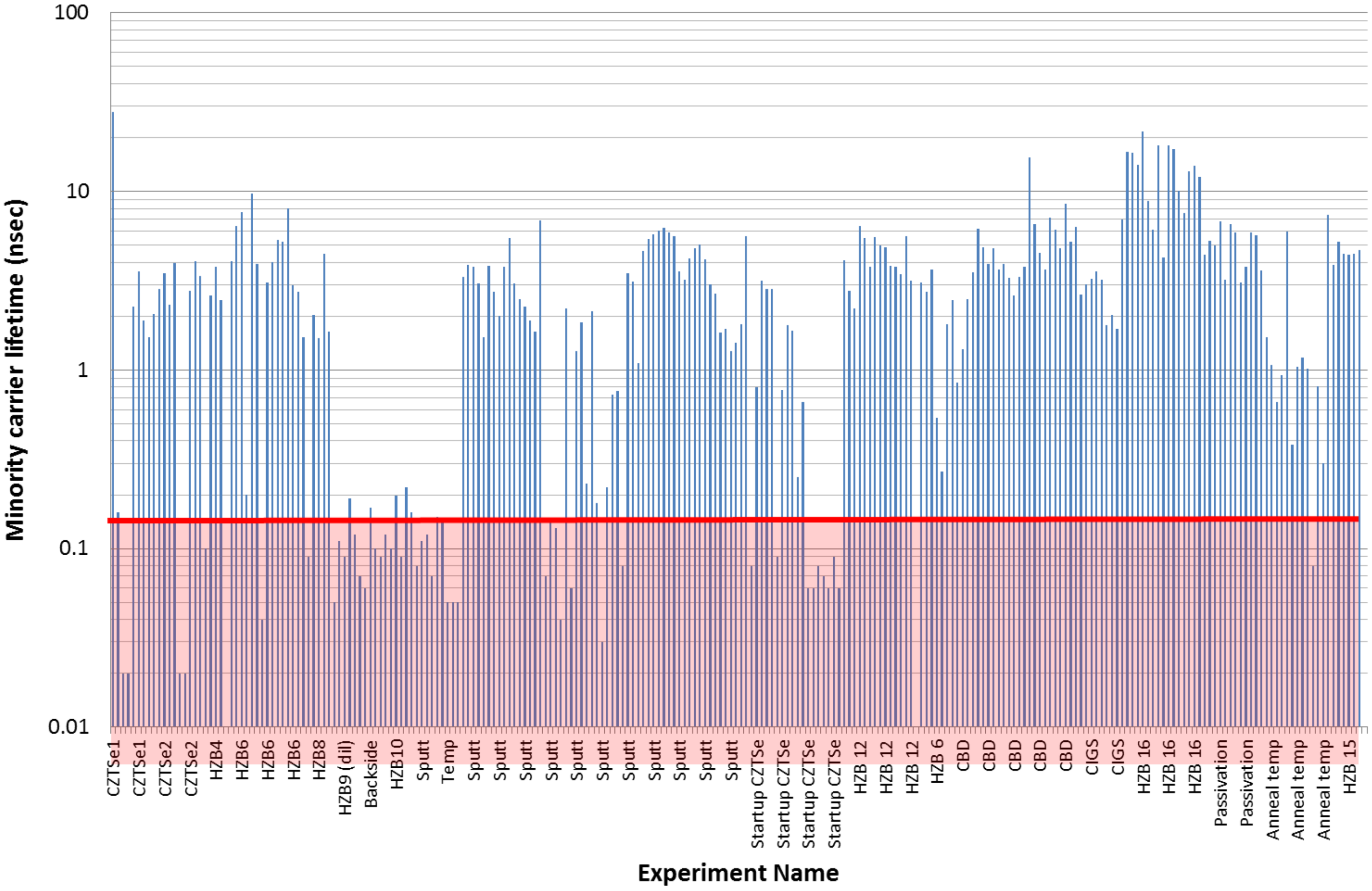




Combination of **two different exponential decays** is observed:

- First fast decay is linked to the **separation of charges** due to the built-in field of the device or layer.
- Slower decay linked to the **minority carrier lifetime** in the bulk of the absorber layer due to the different radiative and non-radiative recombination channels.

THIS VERY FAST MEASUREMENT METHOD IS IDEALLY SUITED FOR SCREENING OF MATERIALS



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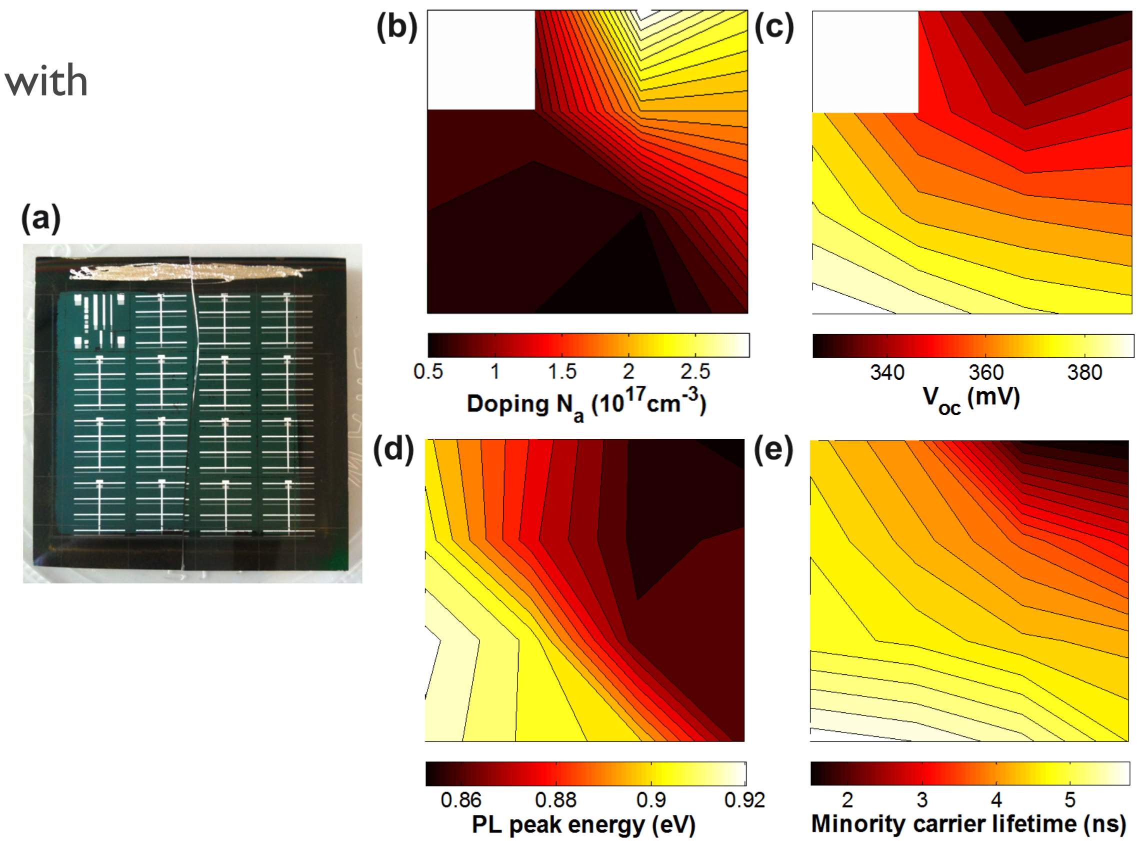
HOMOGENEITY OF SAMPLES CAN ALSO BE CHECKED

Up to 30 x 30 cm² and down to 20 x 20 µm² can be measured.

Correlations of local minority carrier lifetime with doping, V_{oc} and PL peak energy can be made



CONCLUSIONS

- TXRF is a very useful tool to monitor contamination during device processing and very helpful when developing new cleans

- SSRM can be used to visualize doping profiles in 2D

- TR-PL can be used for fast screening of thin-film PV compounds

THANK YOU VERY MUCH !

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