Degradation and electric behavior in thin film photovoltaic devices

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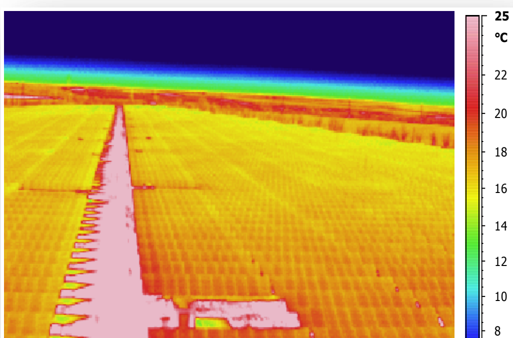
- Characterization on cell level
- Characterization on module level
- Characterization vs. Degradation

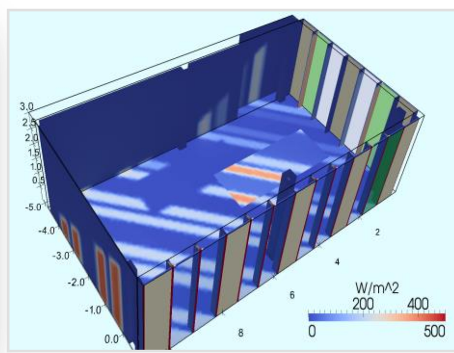
Photovoltaic Systems at AIT

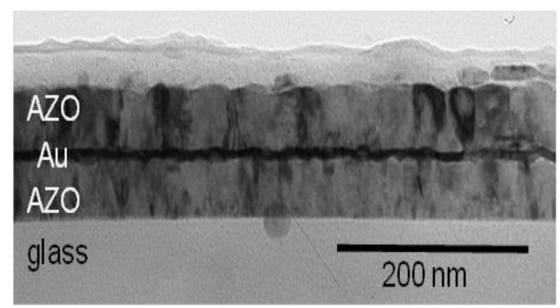
Assured quality for solar power systems and components

Building-integrated photovoltaics - BIPV

Technologies for next-generation solar cells







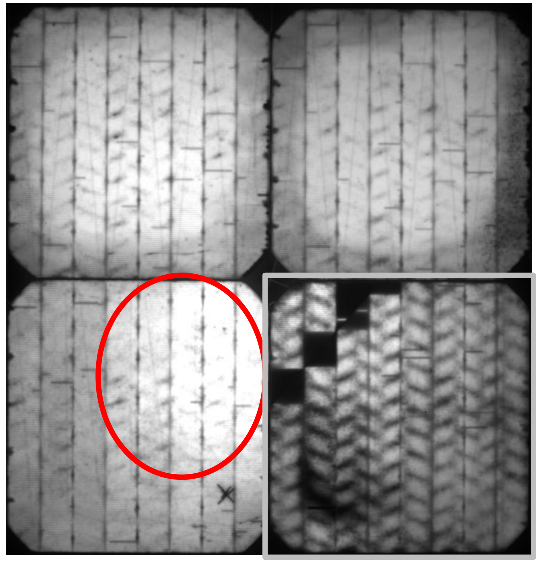
1. Electro-optical Characterization on Cell Level

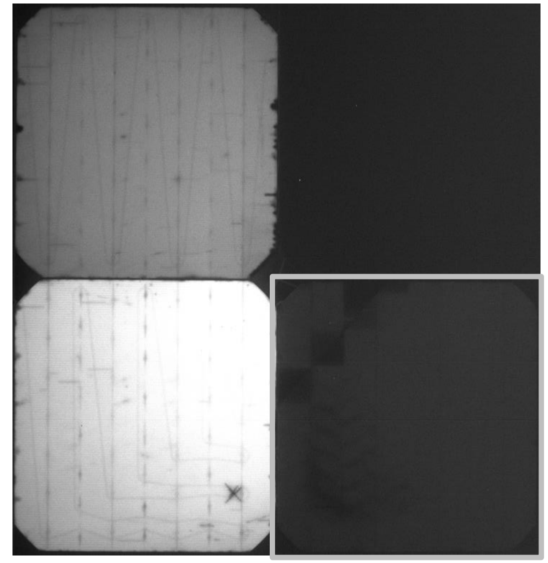
Comparison of different methods for optical characterisation of PV Cells and mini-modules within CHEETAH

- Electroluminescence (EL): 100% Isc and 10% Isc
- Photoluminescence (PL): NIR: 840 nm, 100W electrical power
- Photoluminescence (PL): VIS: 525 nm, 4,8 kW electrical power
- Dark lock-in infrared thermography (DLIT): 100% Isc, 5s period,

Electroluminescence 100% Isc, 10% Isc and DLIT

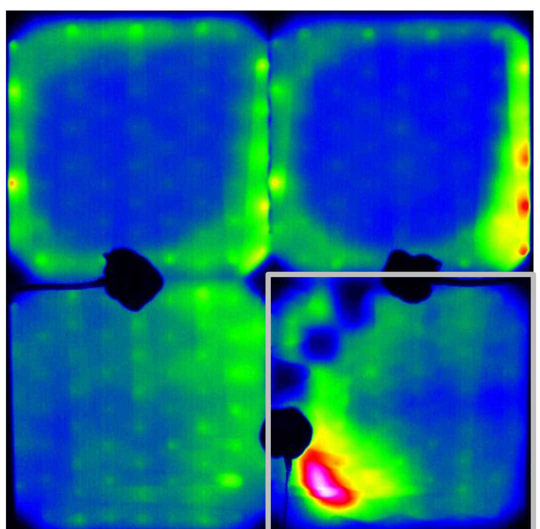
100% Isc

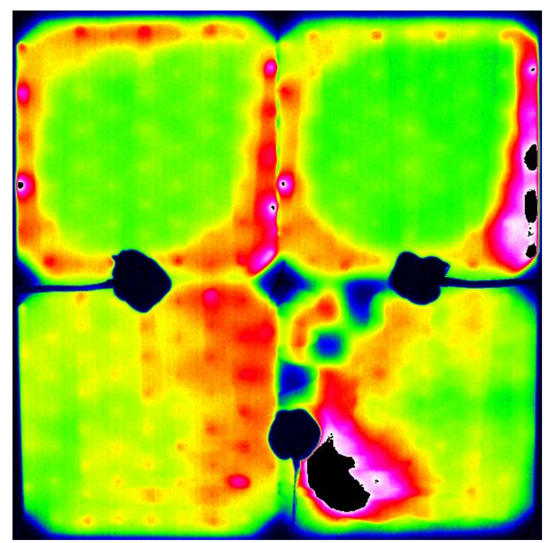




10 % Isc

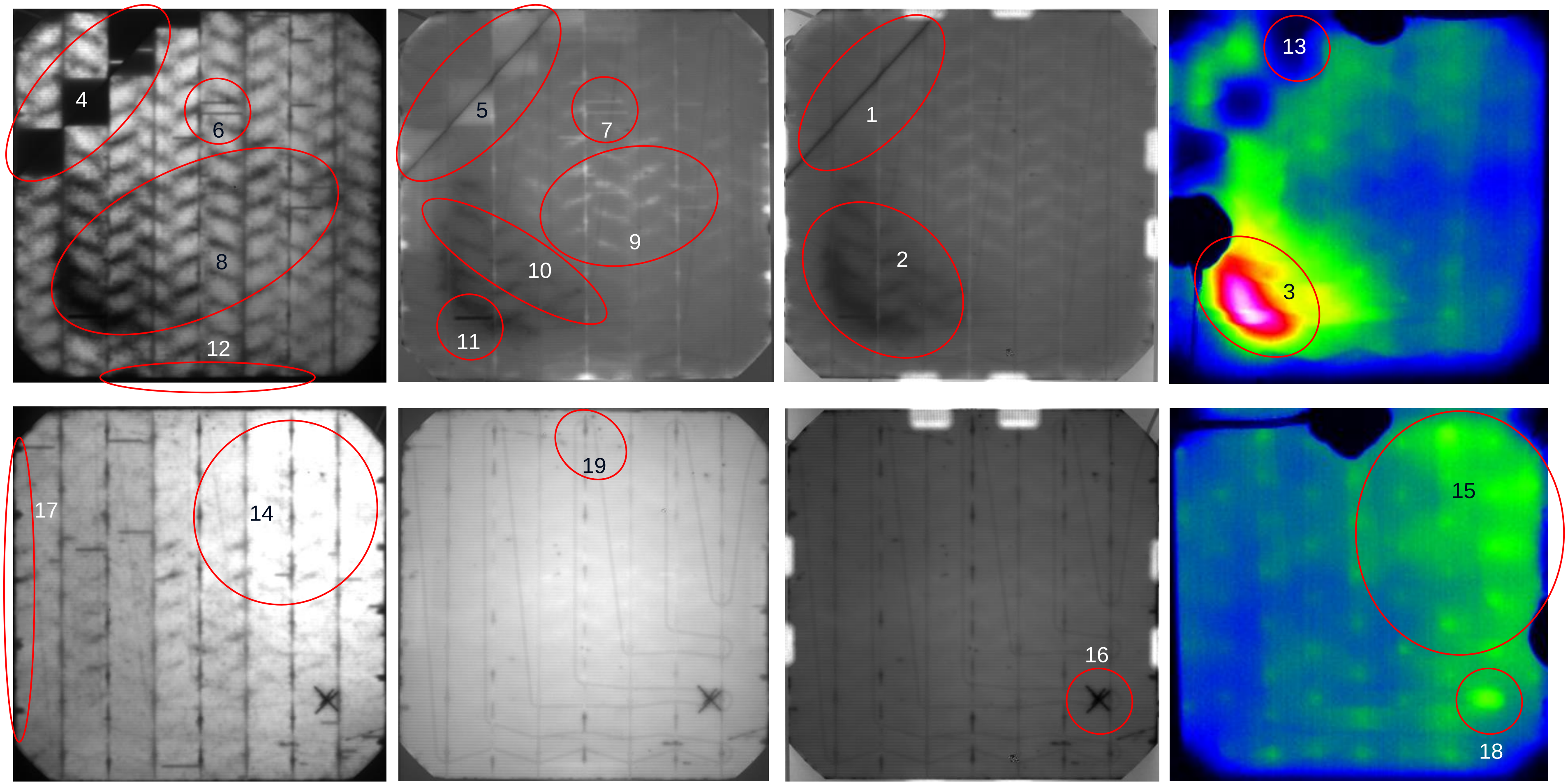
DLIT scale 0-100%





DLIT
scale 0-65%

EL100% Isc, PL NIR 840nm, PL VIS 525nm and DLIT



EL 100% Isc

PL 840nm

PL 525nm

DLIT 100% scale

Defects of cells

- 1 - **Microcrack**
- 2 - **Shunt**, low parallel resistance in the cell
- 3 - **Hot spot** due to shunt in the cell
- 4 - Electrically **separated regions** of the cell (no electrical contact)
- 5 - Electrically separated regions of the cell operate in open circuit mode
- 6 - **Fingers interrupted**
- 7 - Interrupted fingers **operate in open circuit mode**
- 8 - **Oven imprints**
- 9 - Oven imprints operate in open circuit mode
- 10 - Oven imprints **operate in short circuit mode**
- 11 – Interrupted finger operates in short circuit mode
- 12 – **Insulation problems** on the edge of the cell
- 13 – **Missing electrical contact**

Defects of cells

- 14 – **High current density** due to bad contacts someplace else
- 15 – **Hot contacts**
- 16 – Microcracks
- 17 - Insulation problems on the edge of the cell
- 18 – Hot spot due to soldering problem
- 19 – **Small shunts**

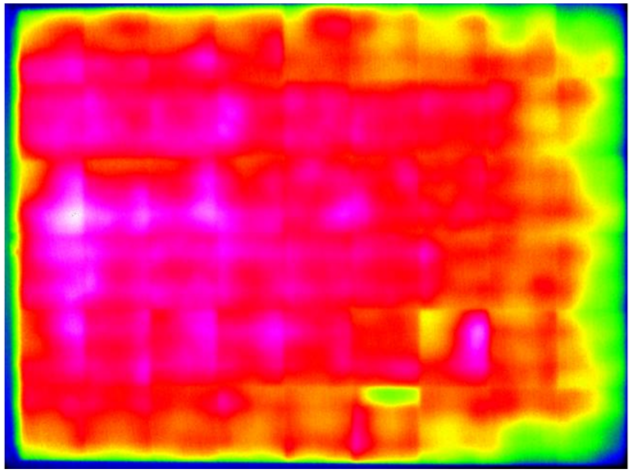
Methods: Advantages - Disadvantages

	+	-
▪ EL:	electrical contact defects, cracks, cell crystalline defects, short circuited cells	not all cracks detectable, electrical contacts needed, electrically not contacted regions often not measurable
▪ PHL:	no electrical contacts needed all type of cracks detectable, fast method, cell crystalline defects, bottom of the cell visible	can not differentiate between „hot“ and „cold“ electrical contacts, electrical contact defects between cell and busbar not detectable
▪ DLIT:	electrical contact defects, big crystalline defects, displays soldering faults, can differentiate between „hot“ and „cold“ contacts good resolution for shunts	can not detect cracks and small crystaline defects, slow method, reflection problems, electrical contact needed

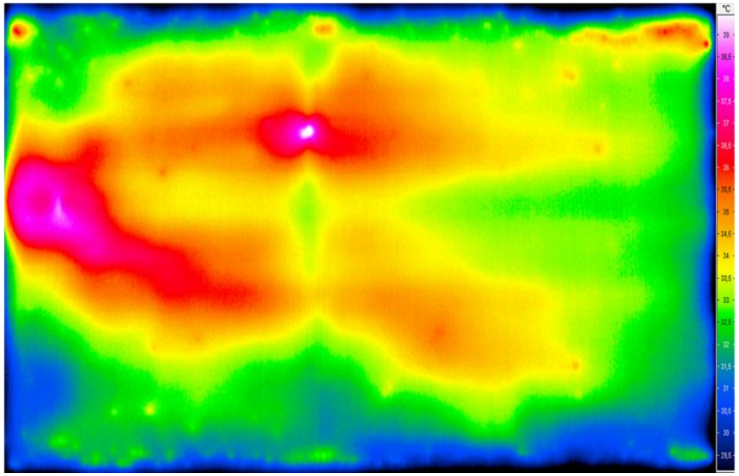
2. Electro-optical Characterization on Module

Thermographie

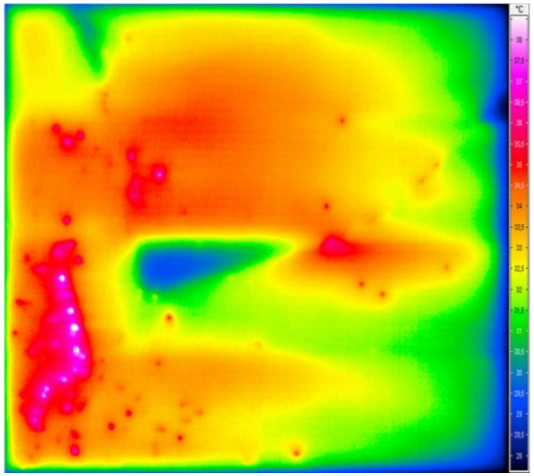
c-Si



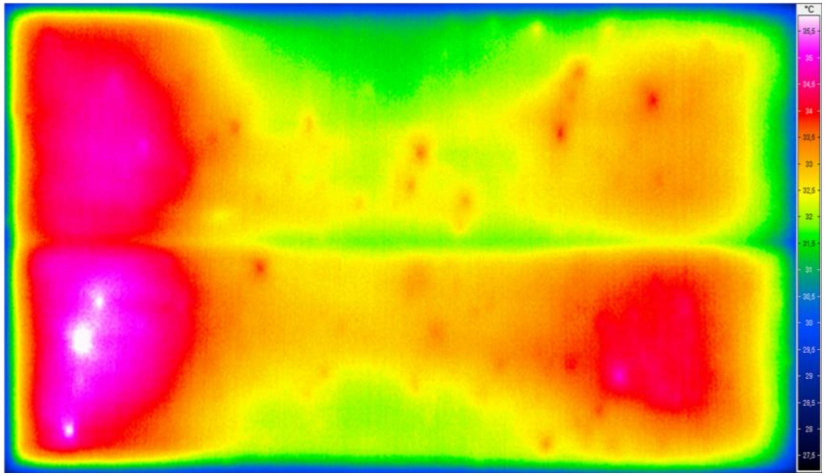
CdTe



a-Si

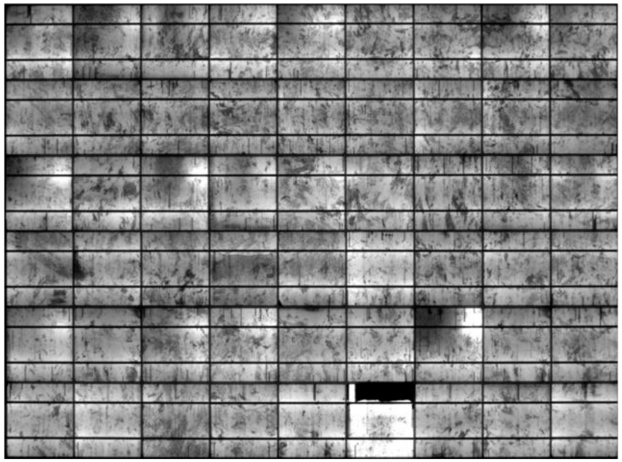


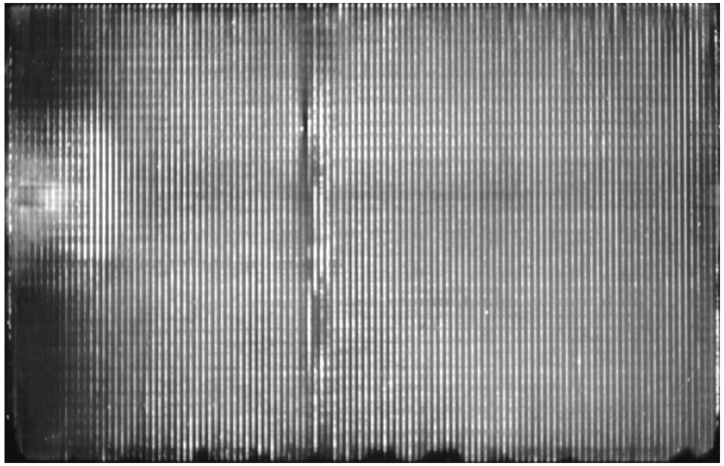
CIS

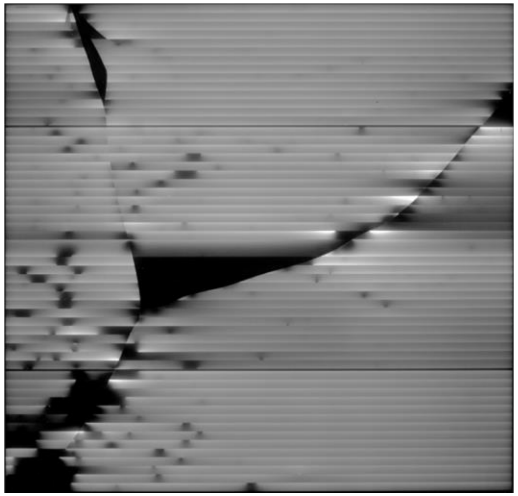


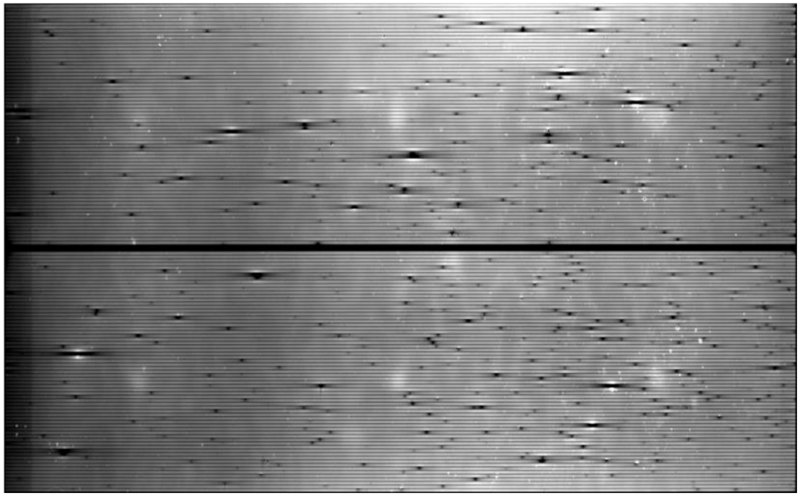
Module Level: Electroluminescence

EL



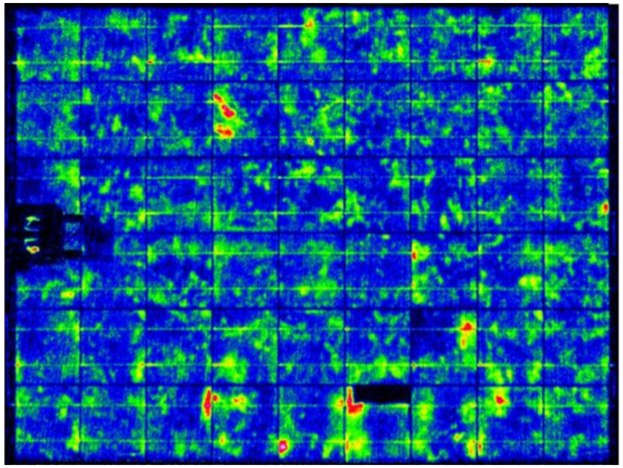


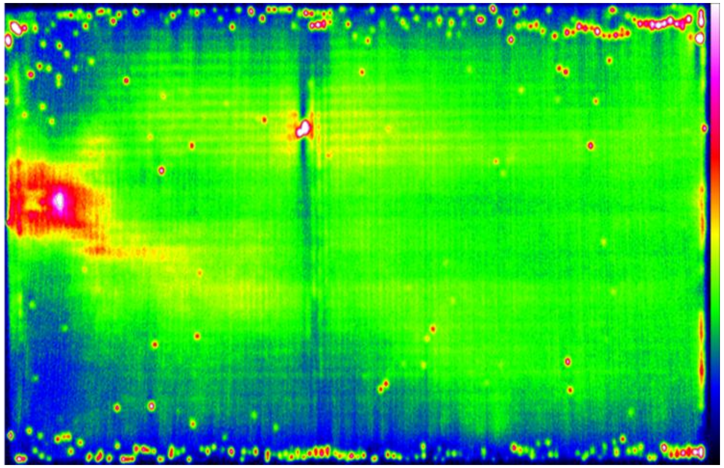


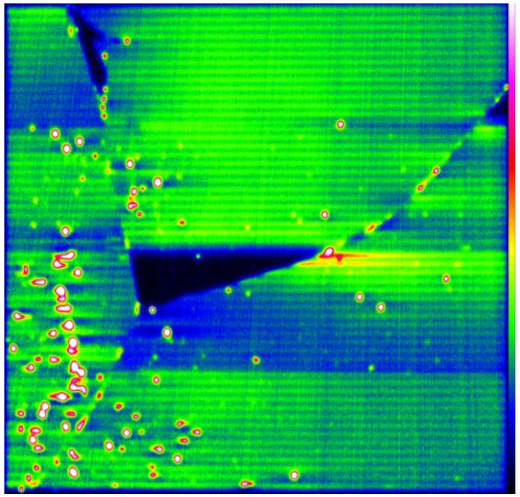


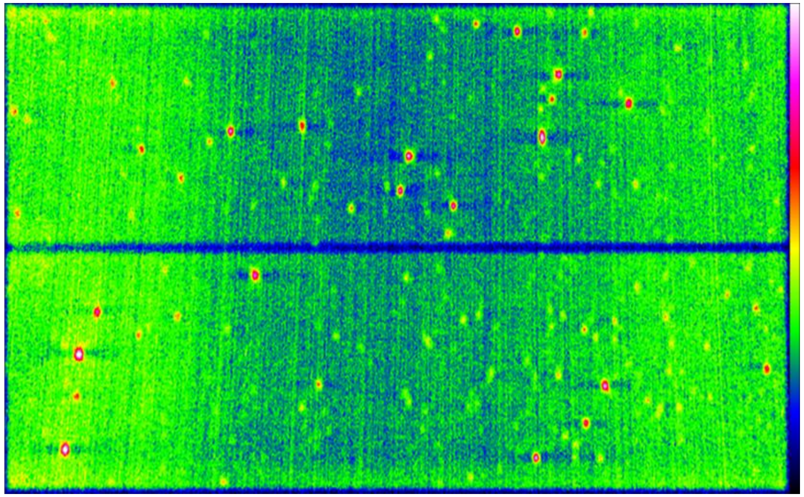
Module Level: DLIT-Amplitude

DLIT-Amp.



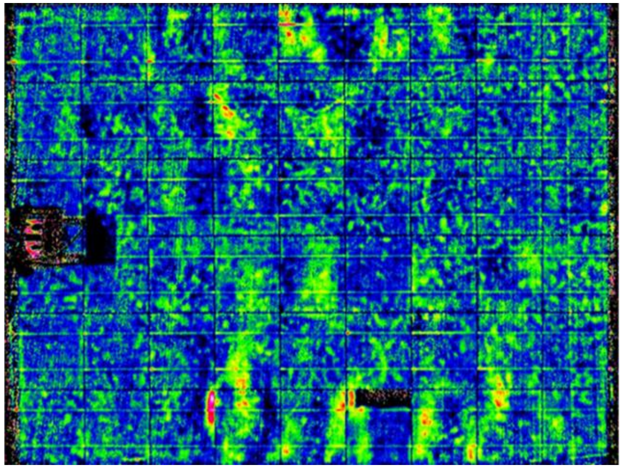


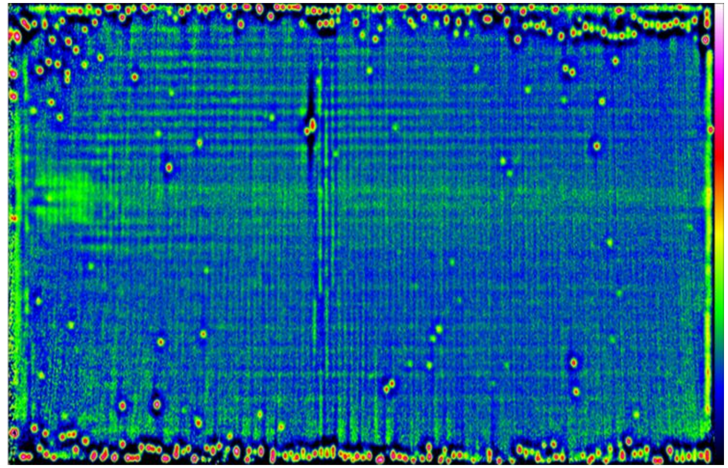


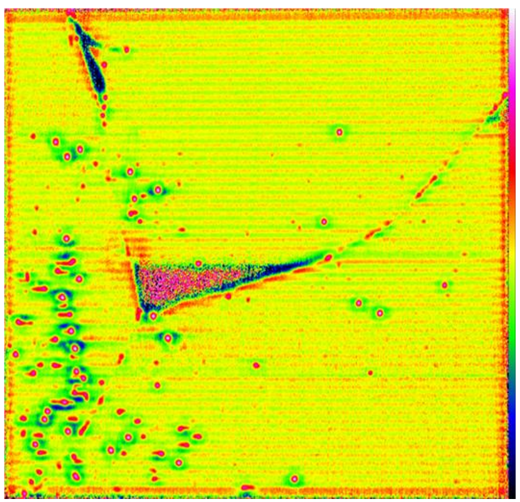


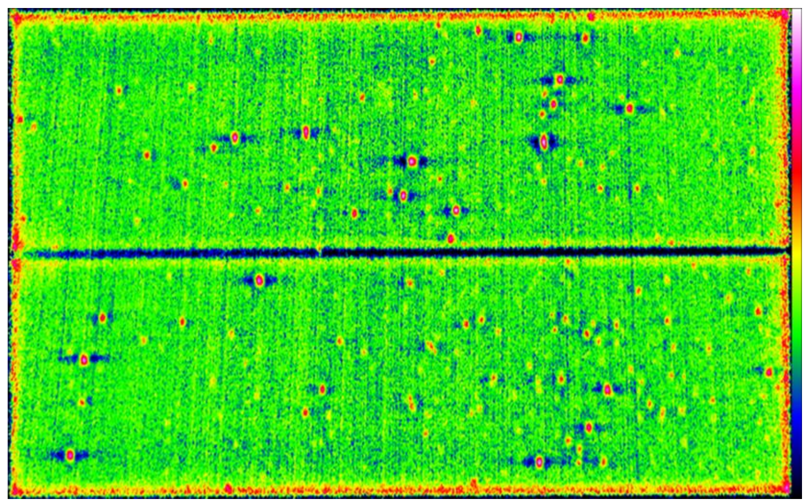
Module Level: DLIT: Phase

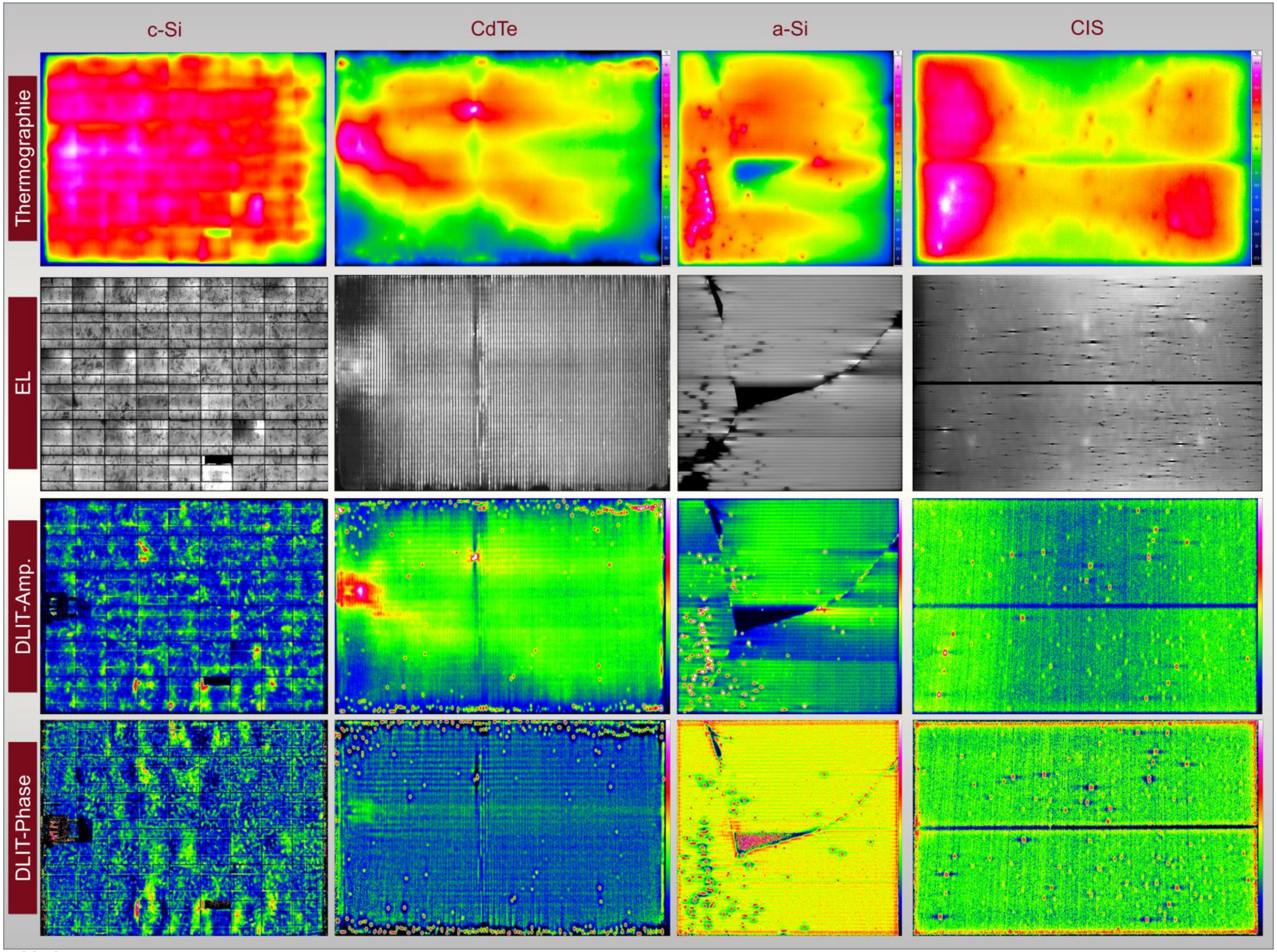
DLIT-Phase










c-Si
CdTe
a-Si
CIS
Thermographie
EL
DLIT-Amp.
DLIT-Phase

2. Electrical characterization vs. Degradation

Thin Film module affected by unstable bhavior under illumination

Why metastable behavior affects PV community?

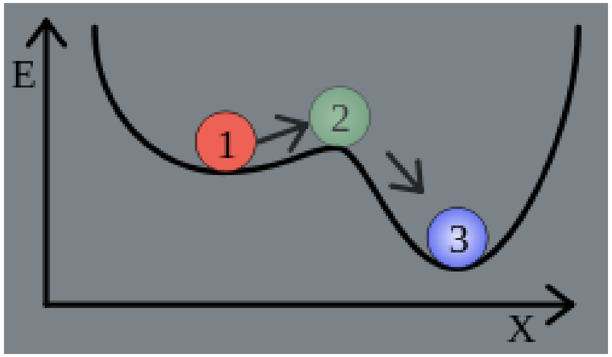
Instability of power when illuminated

Measurement methods not reliable for power rating

Unpredictibility in energy yield and field reliability

Metastabilities in Thin-Film Technologies

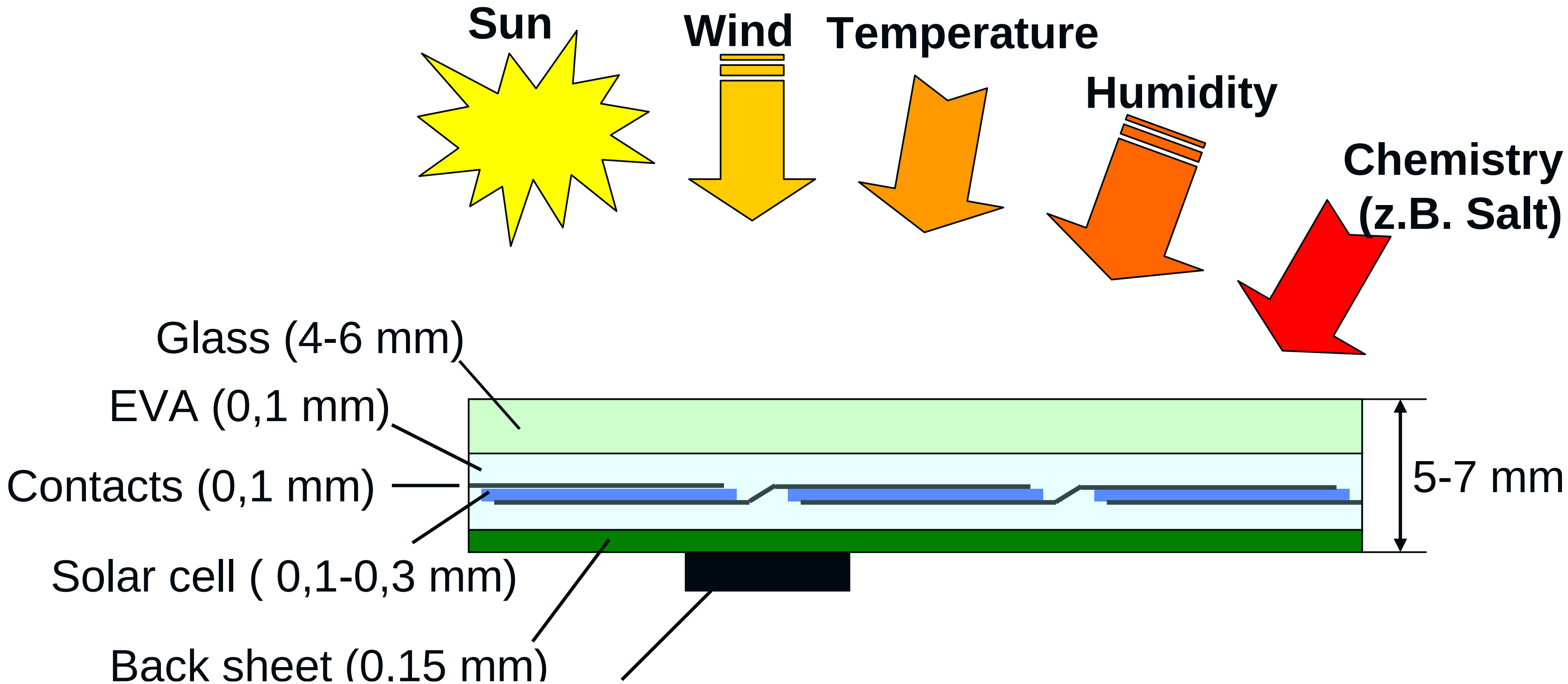
- A non-ground state (e.g. triggered by light)
- Metastable states may relax, e.g. thermally driven
- Origins from defect structure in the device
- Study on device level



Metastabilities found in all thin-film devices:

a-Si, a-Si/µSi, CdTe, CIS, CIGS, CZTS, OPV, Perovskite

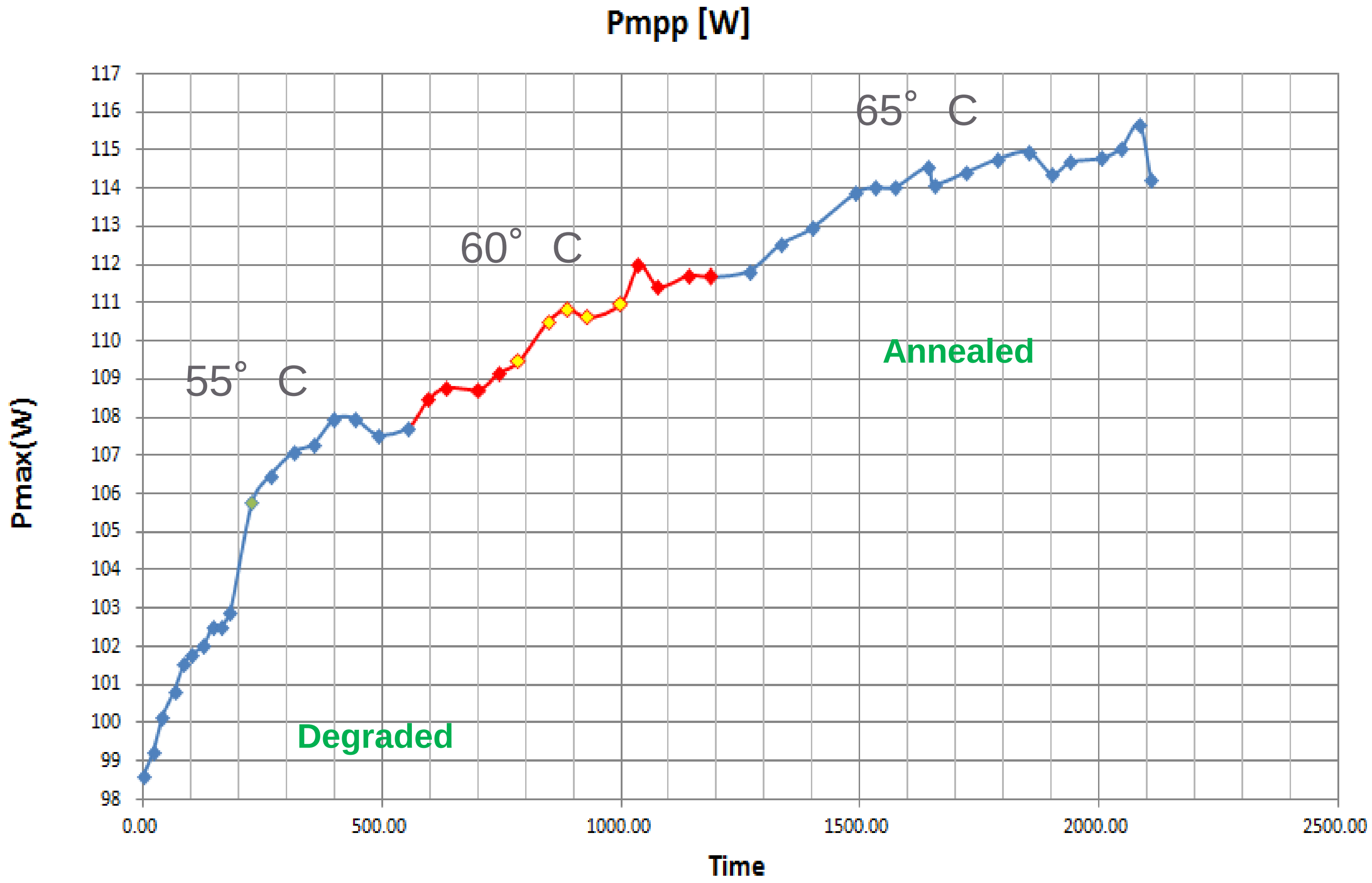
Degradation influences metastable bahavior



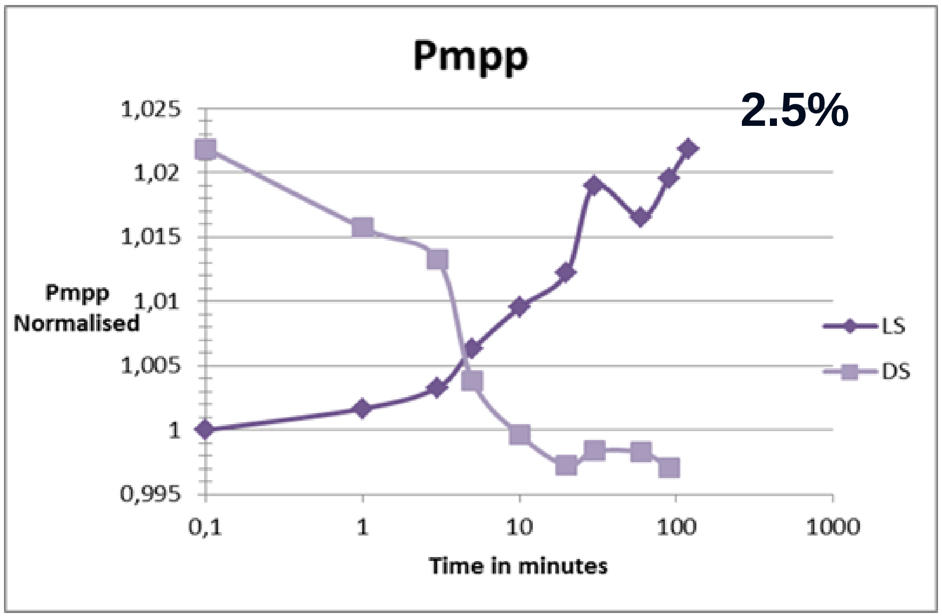
Pre-Treatment Procedure a-Si

Degraded modules → **Pretreatment (Light- and Dark-soaking)** → **Annealing till stabilized power** → **Pretreatment repeated after annealing**

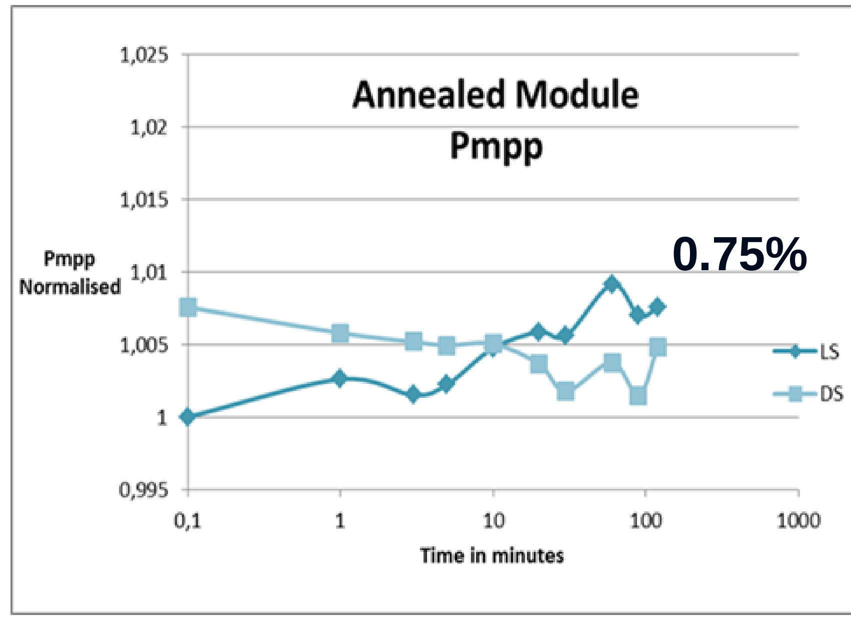
Annealing of a-Si



Metastable Behavior a-Si before and after annealing

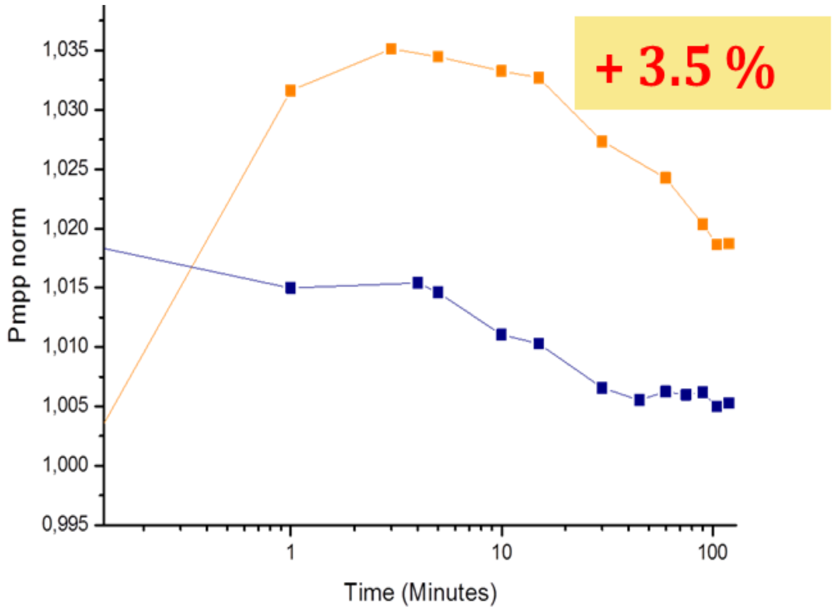


Degraded

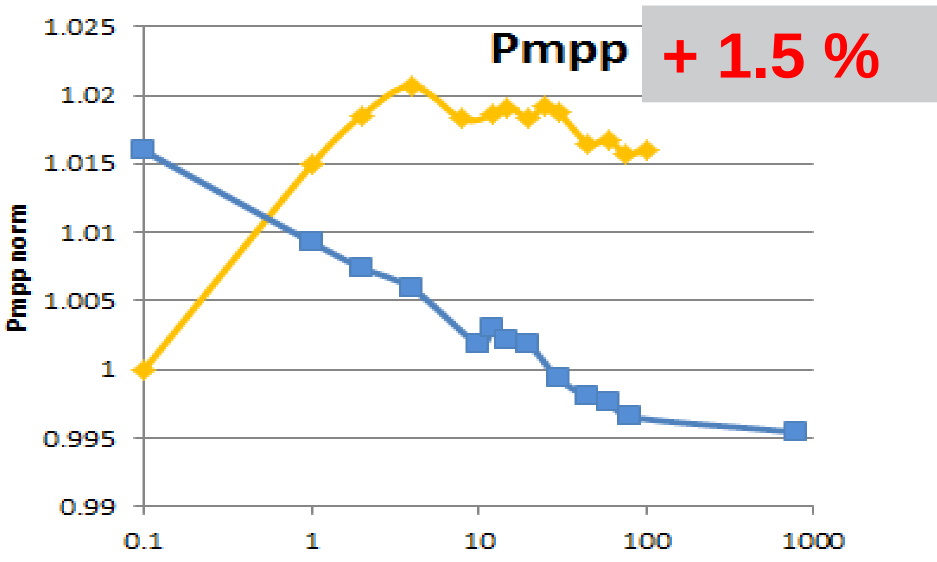


Annealed

Metastable Behavior CdTe before and after degradation

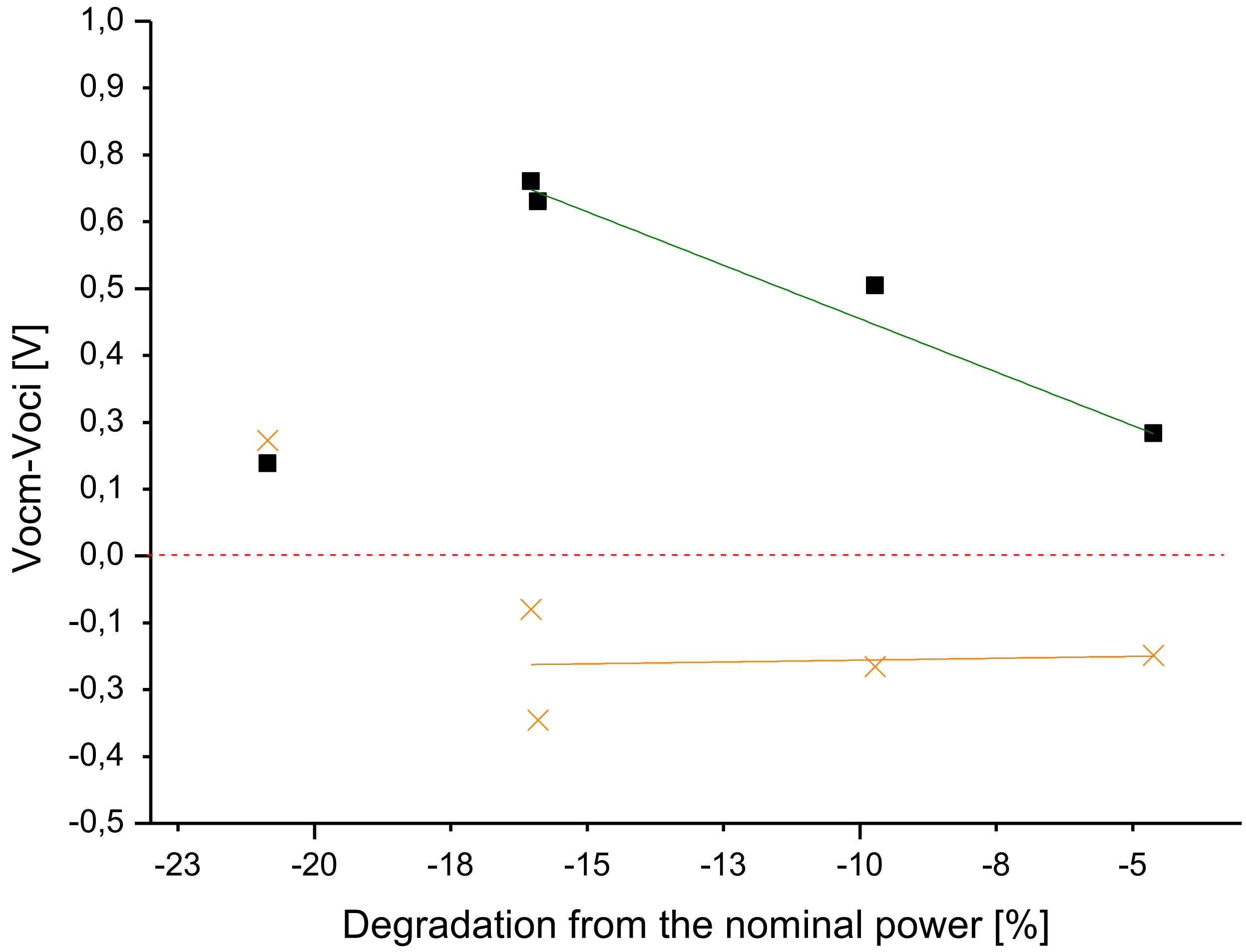


Degraded

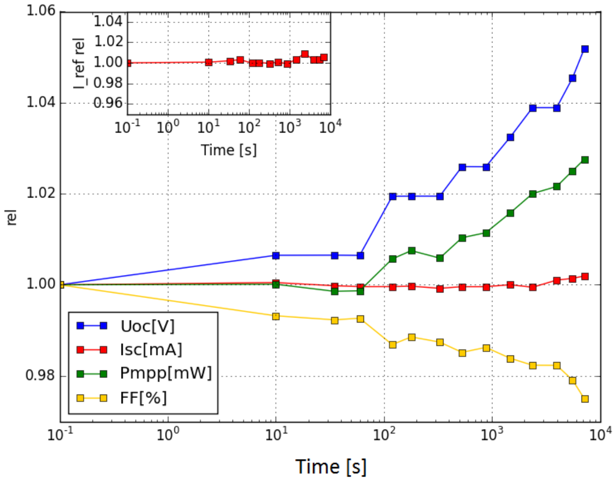


Not degraded

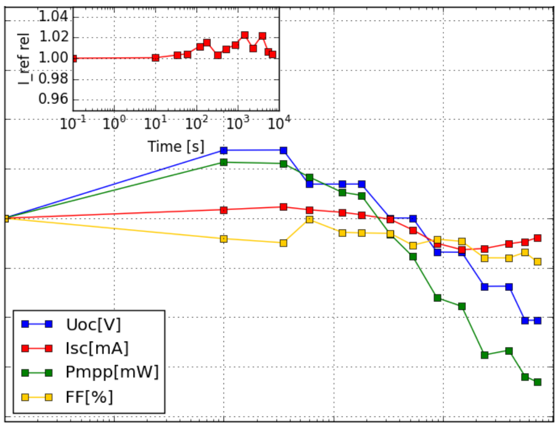
Dependency on degradation CdTe



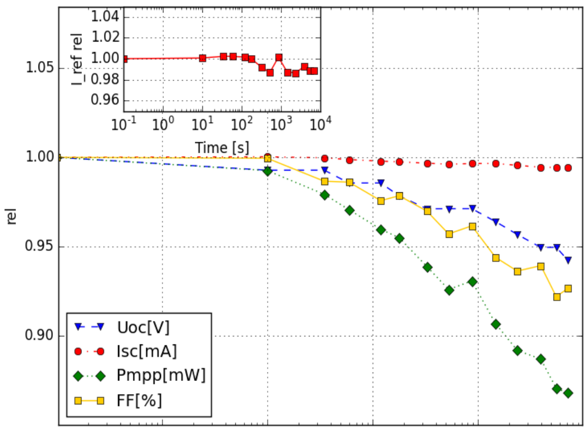
Metastable Behavior CIGS dependent on cell quality



worst

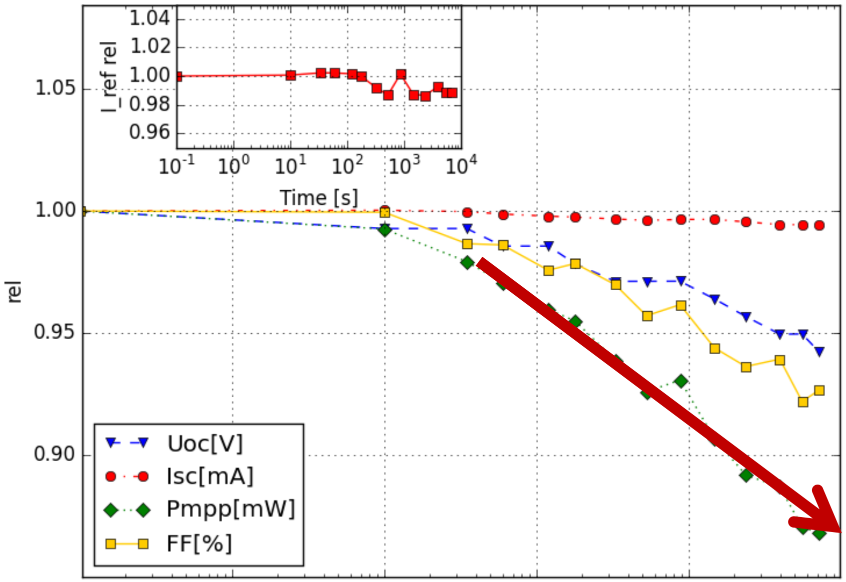


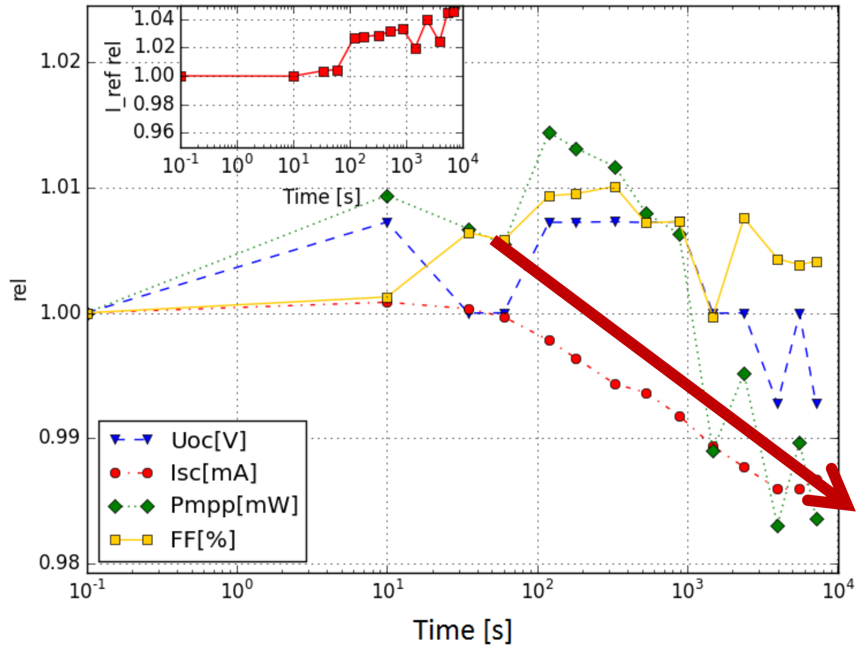
medium



best

CdS vs. ZnO buffer: CIGS





CdS: best

ZnO: best

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