Mechanical Load Test / PI Berlin AG

Potential Induced Degradation Effects and Tests for Crystalline Silicon Cells

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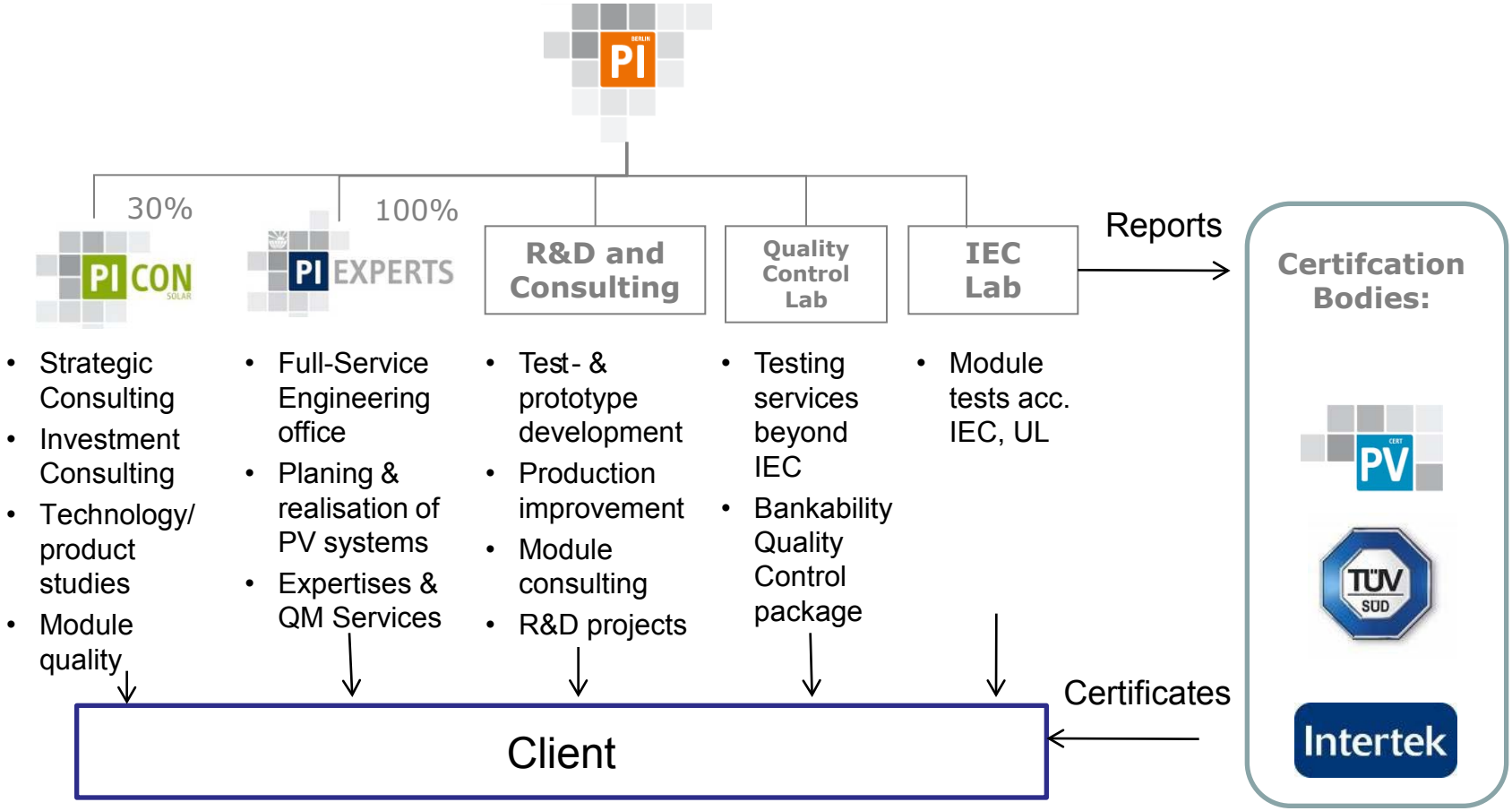
Overview

1. PI-Berlin AG
2. Introduction Potential induced degradation
3. PID influencing test parameters
4. The influence of the anti reflective coating
5. The influence of the encapsulant
6. Outlook
7. Summary

PI Berlin Business Units



PI Berlin Business Units

Clients	Service
• Manufacturers	Certificates, Re-Testing, Pre-testing, bench-marking, Test-to-Failure tests
• Turn-key Suppliers	see above
• Component Suppliers	Lamination service, screening, extended IEC tests (double, triple)
• Wholesalers, OEM-Clients	Factory Inspection, Bench Marking, Quality Control, Certification, Analysis of Field returns
• System developers, Owners	Incoming Module Quality Control, Systems engineering
• Banks, Investors	Expertise in module failure probability
• Assurances	Failure analysis, Module repair
• Universities, Institutes, Industrial R&D teams	Project partnering in industrial R&D projects

Introduction

1978, Hoffman and Ross (JPL), “Environmental Qualification Testing of Terrestrial Solar Cell Modules”

Polarization (Sunpower 2005)

	N-type silicon	P-type silicon	Amorphus/micro morphus Silicon	CIGS	CdTe
+ potential	x				
- potential		x	x		

PID (SOLON 2009)

TCO Corrossion (Mon 1985)

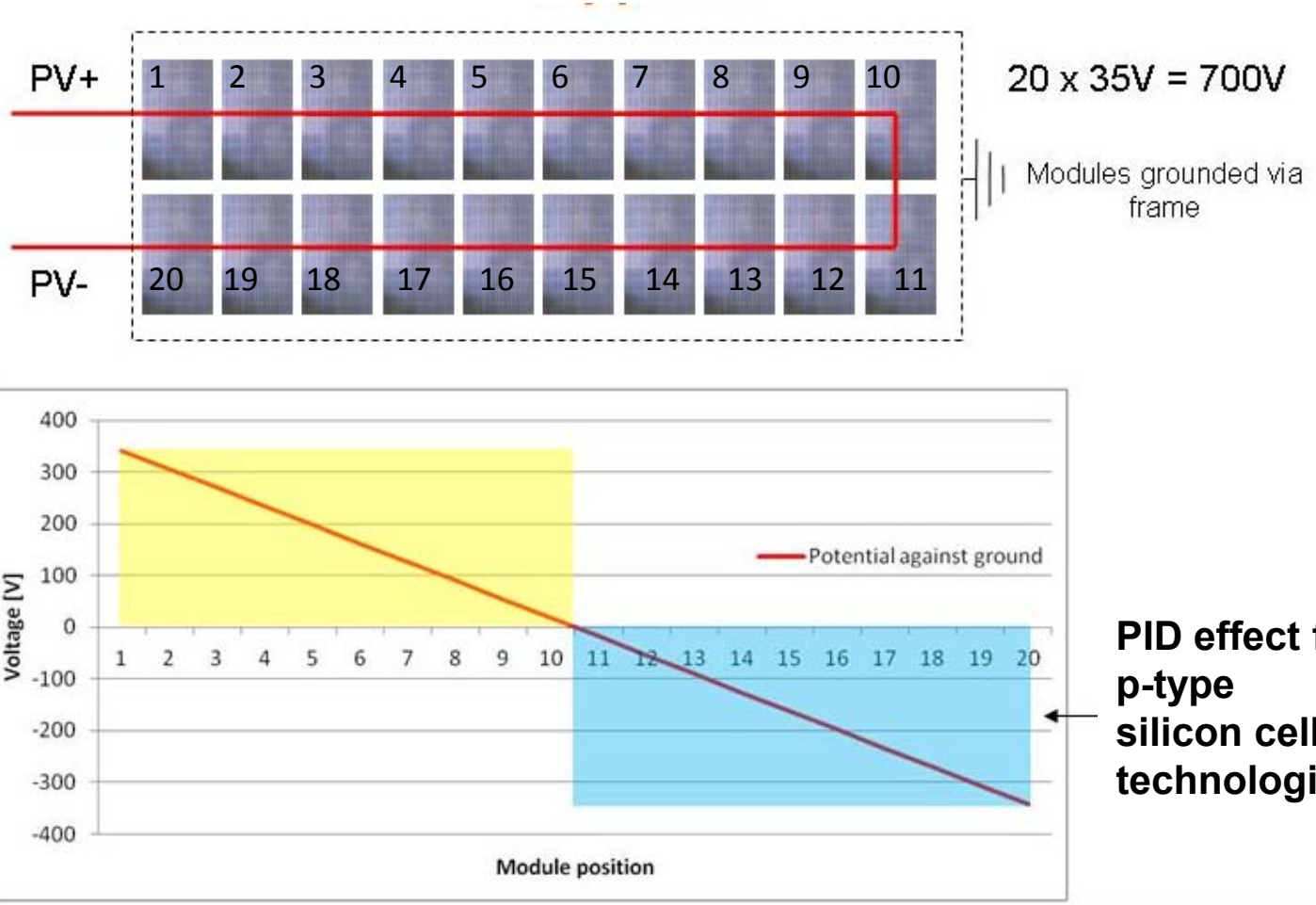
Potential induced degradation subsumption and definition

	N-type silicon	P-type silicon	Amorphus/micro morphus Silicon	CIGS	CdTe
+ potential	R&D	R&D	R&D	R&D	R&D
- potential	R&D	R&D	R&D	R&D	R&D

Potential induced degradation ≠ Module behaviour induced by voltage stress

- Used cell technology (p-type, n-type, thin film, etc.)
- Positive or negative potential relative to ground

Which modules have a risk of PID in the field?

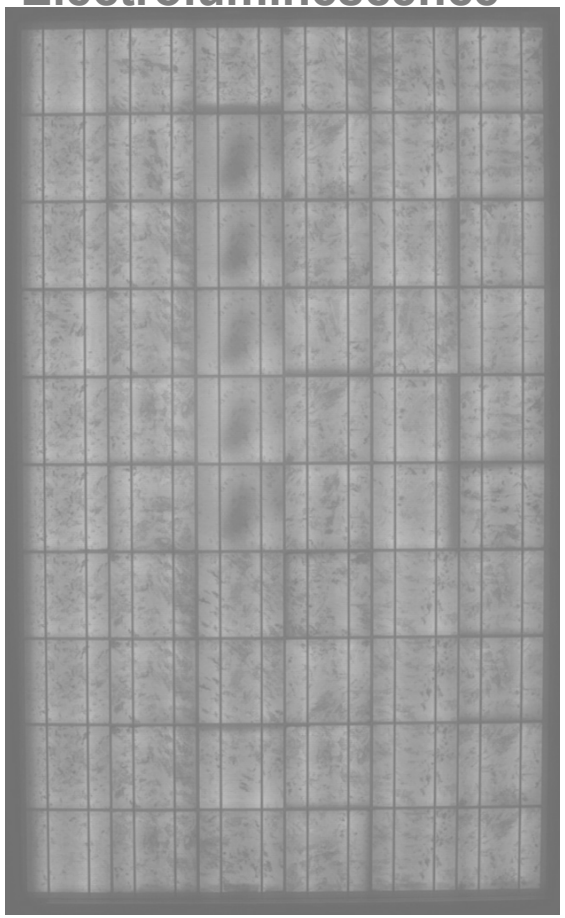


PID effect for p-type silicon cell technologies

Fig. 1: Potential against ground module string with floating potential

Damp heat 85 C/85% r.H. -1000V (PID Test)

Electroluminescence



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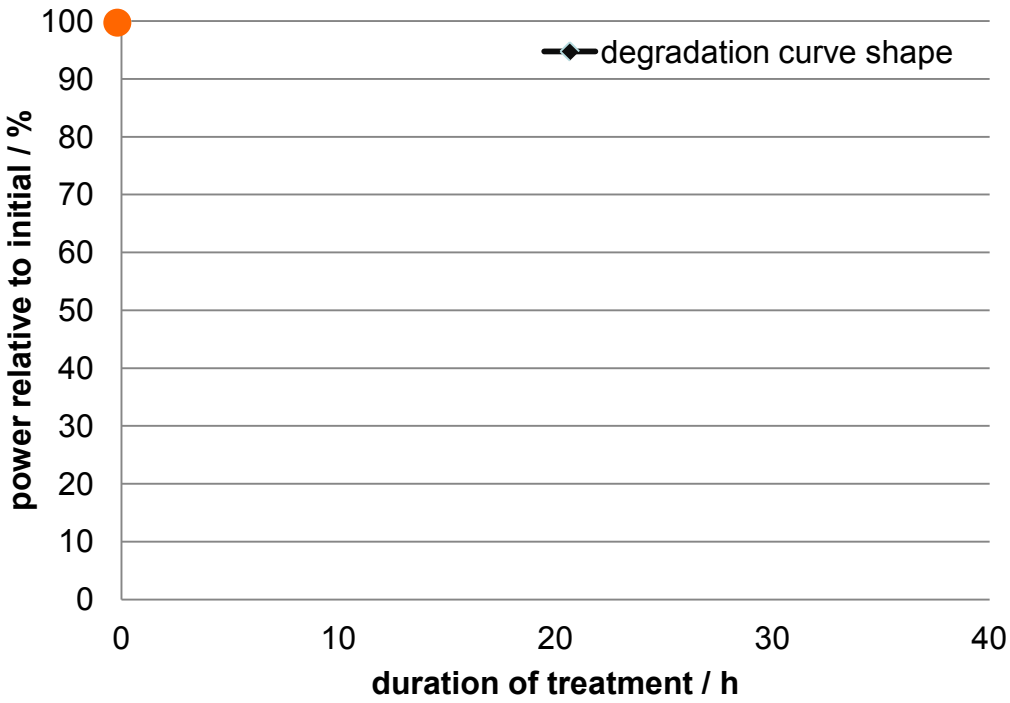

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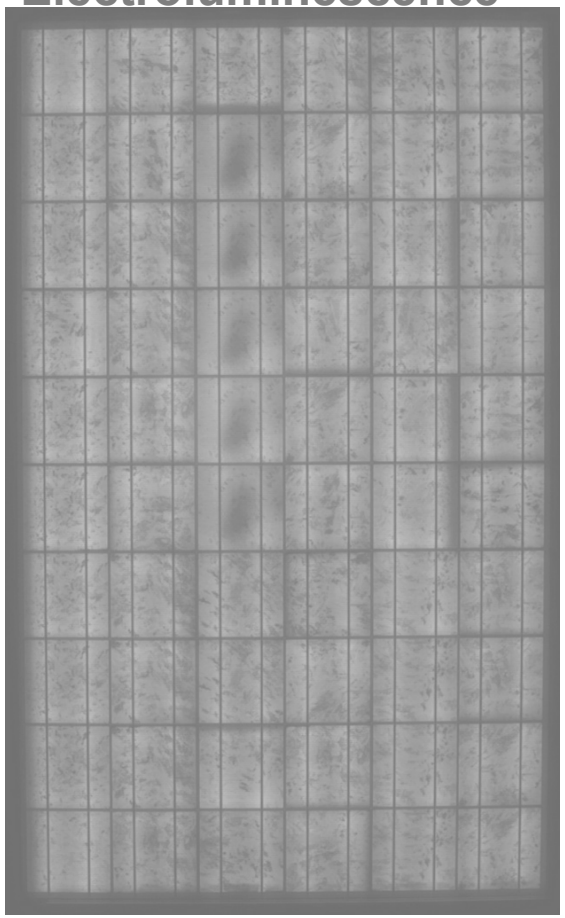

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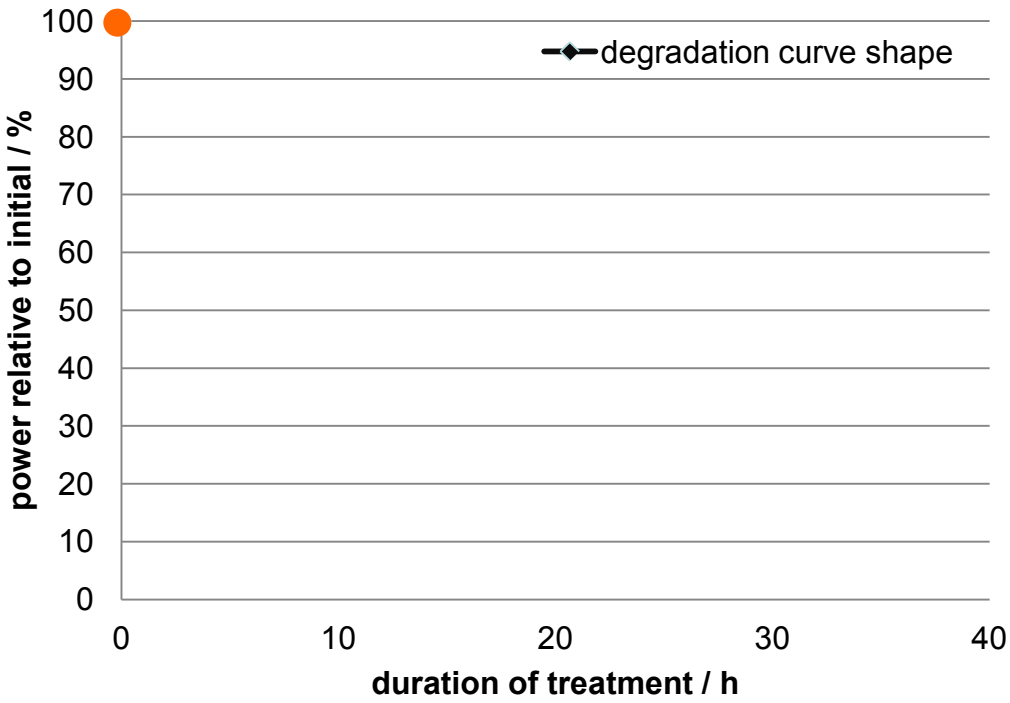

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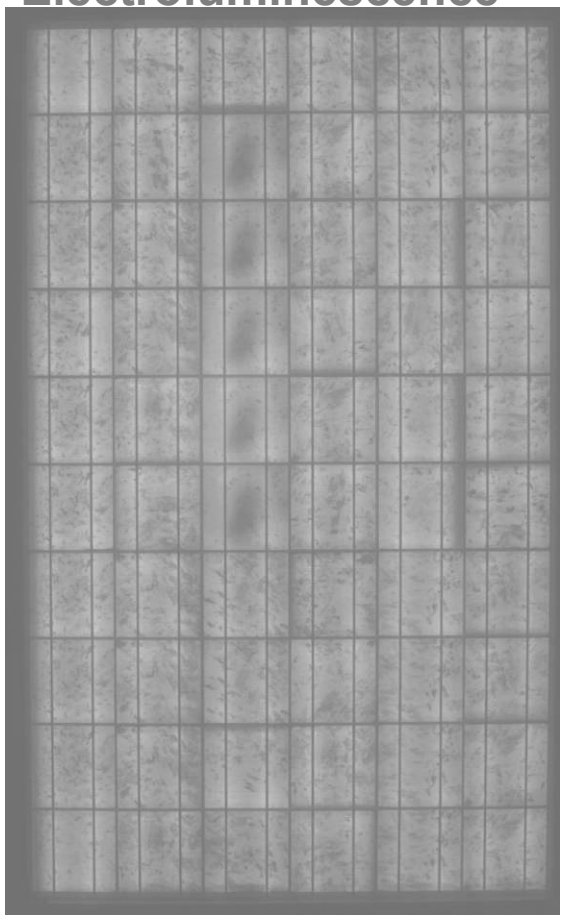

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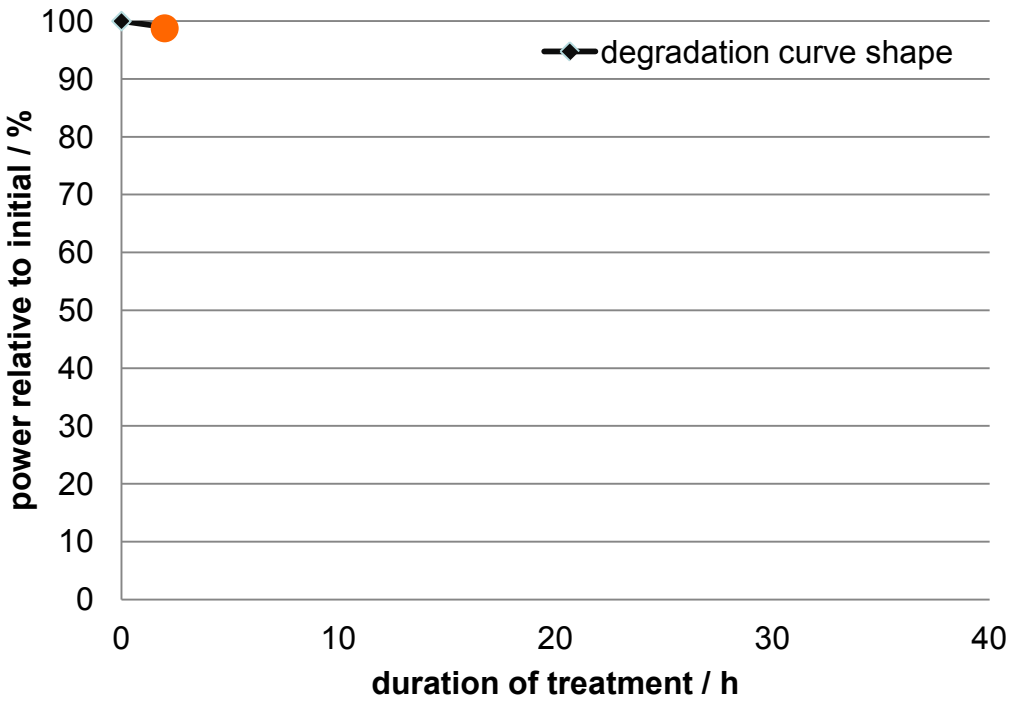

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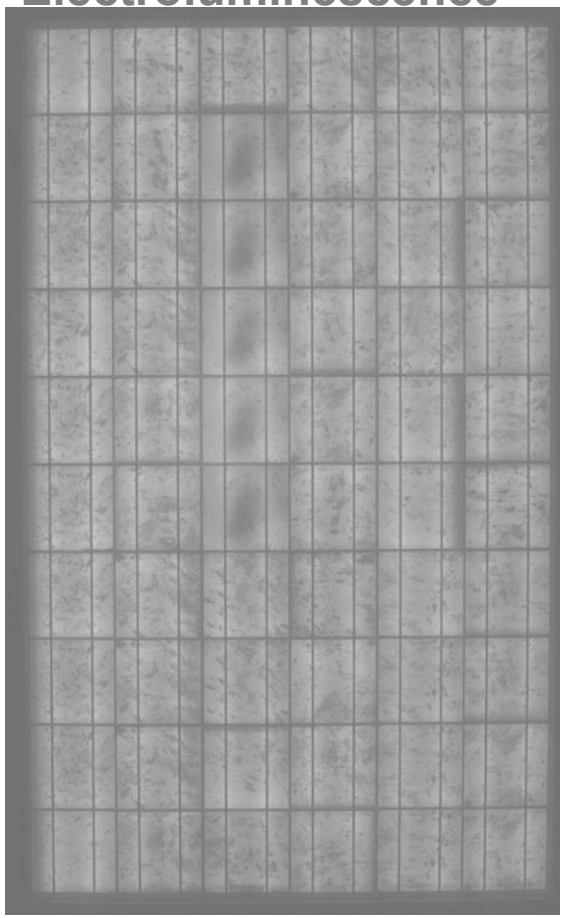

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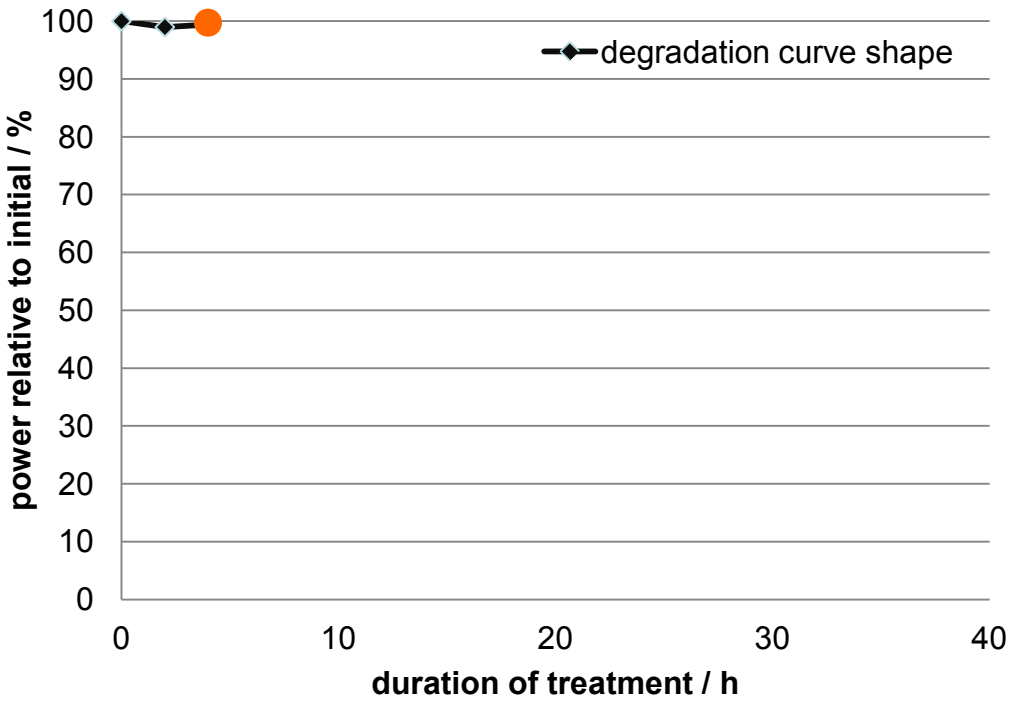

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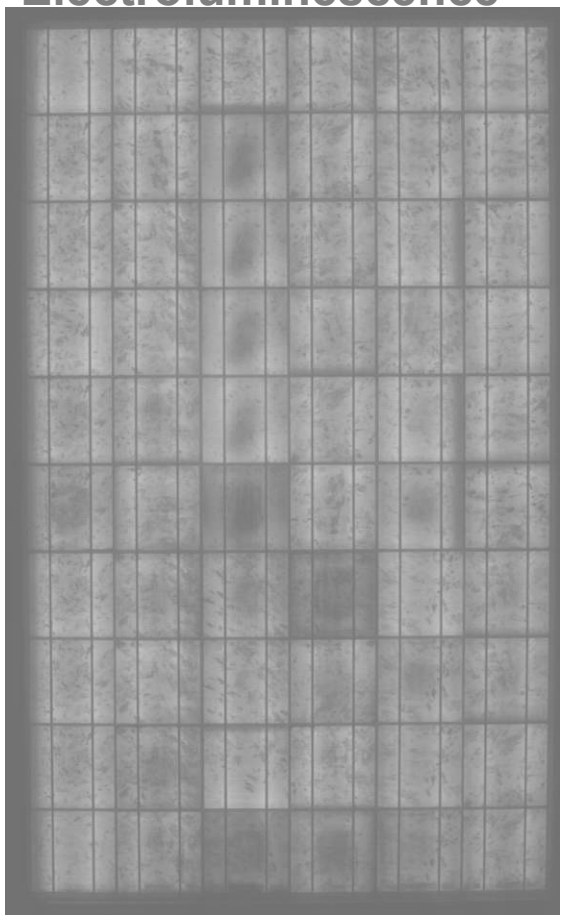

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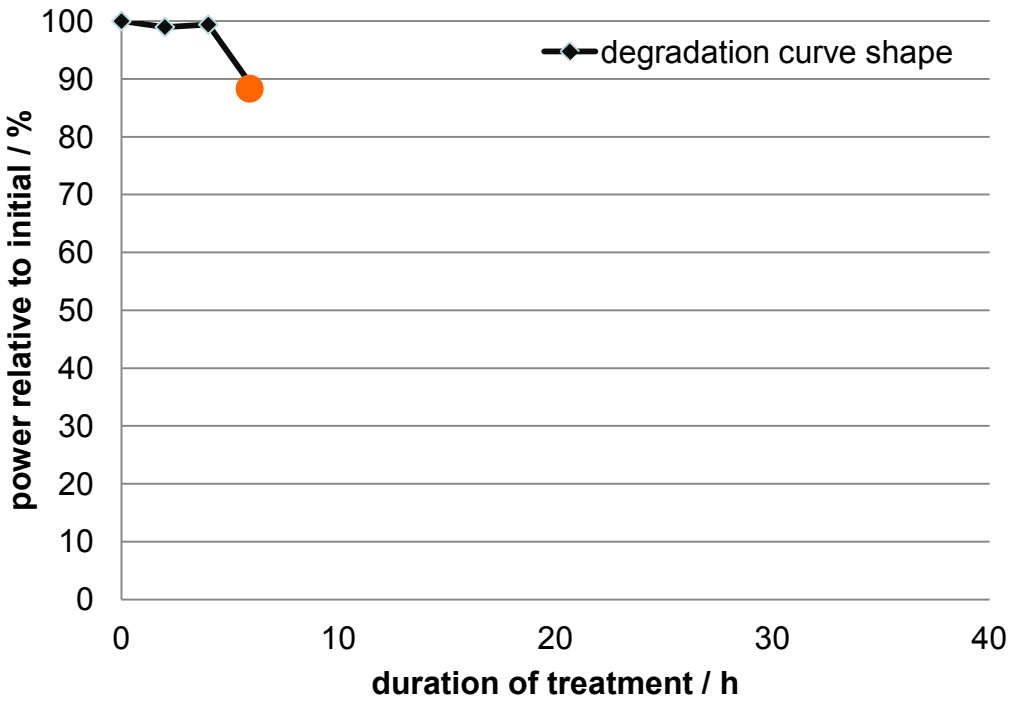

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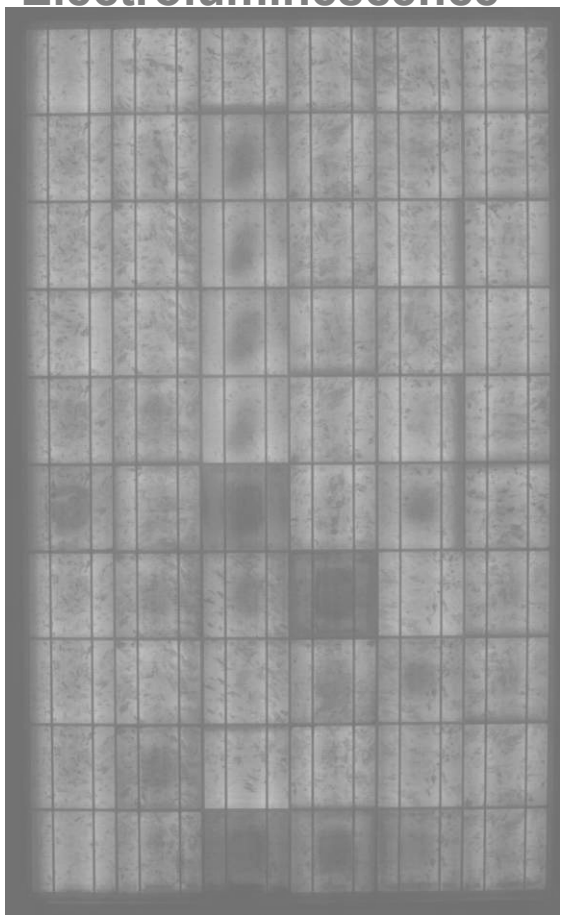

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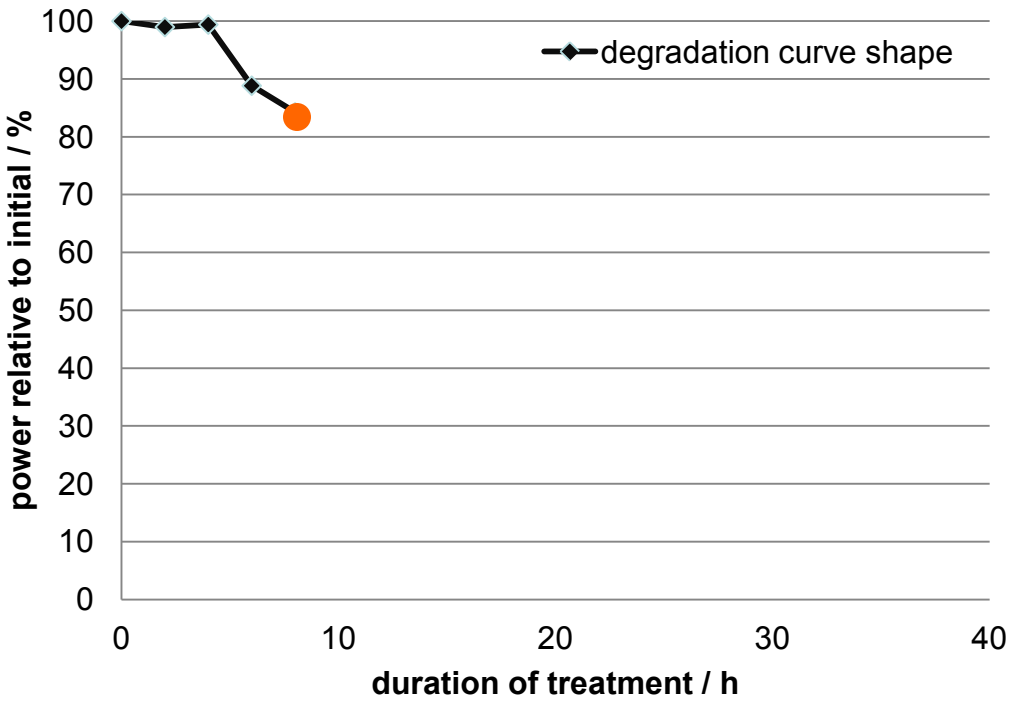

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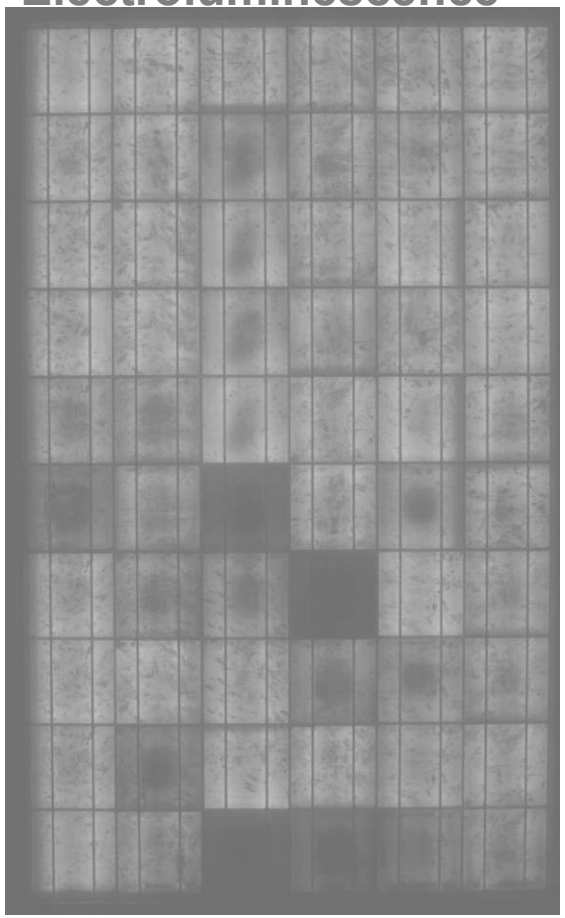

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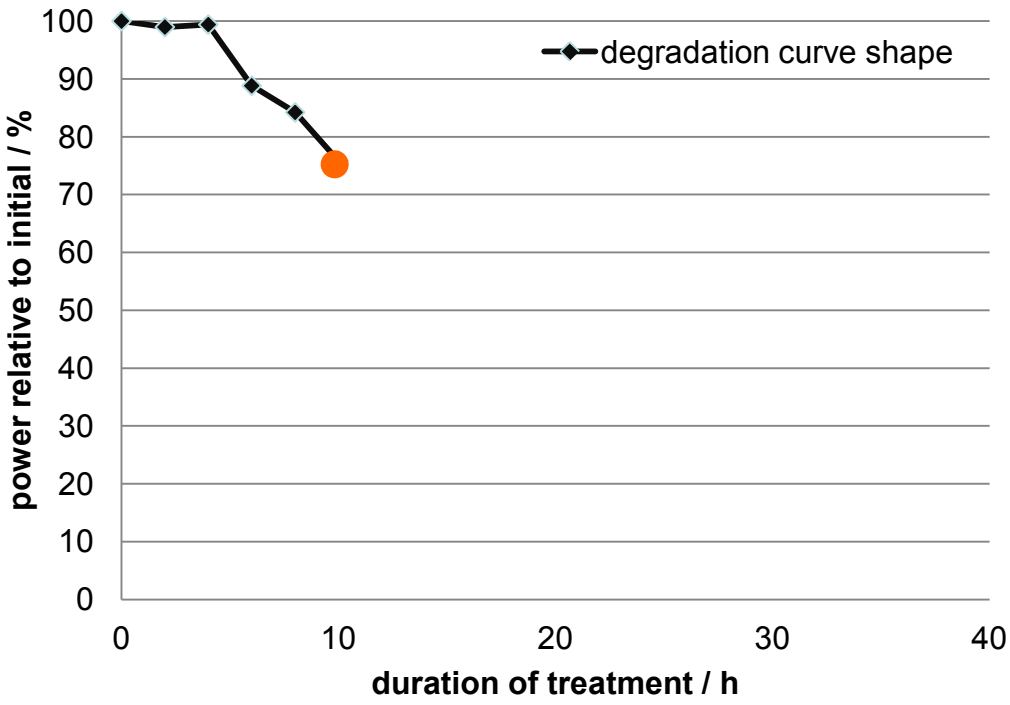

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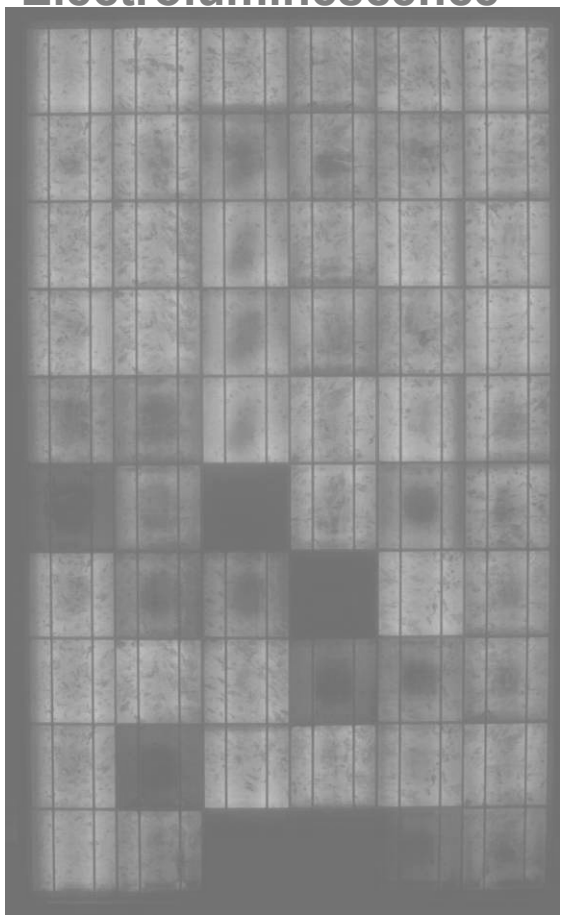

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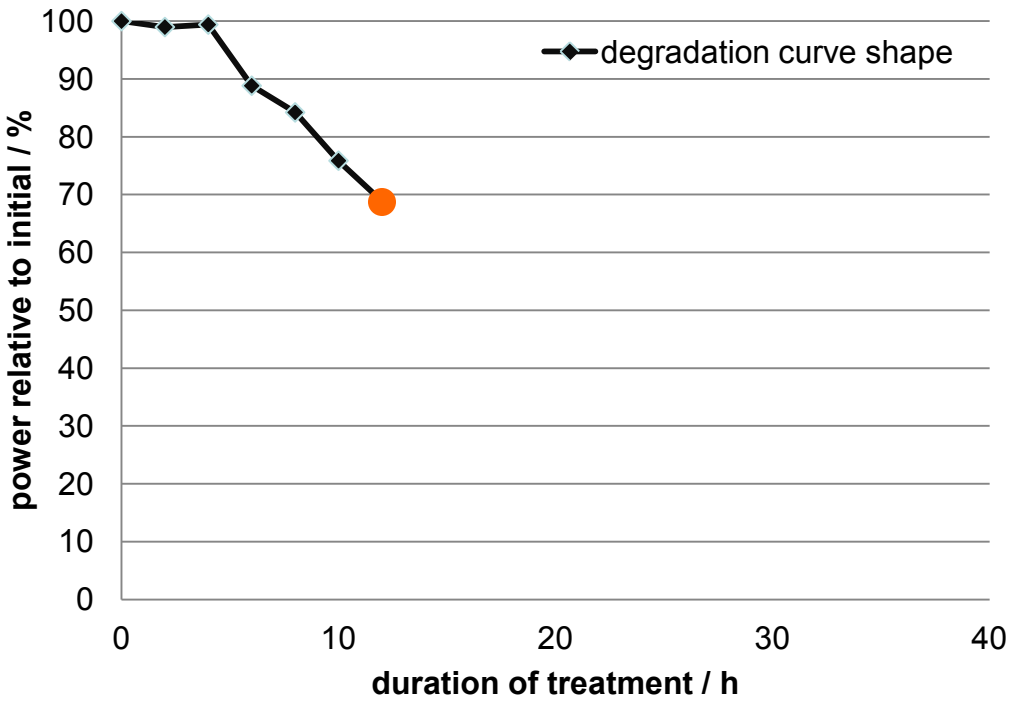

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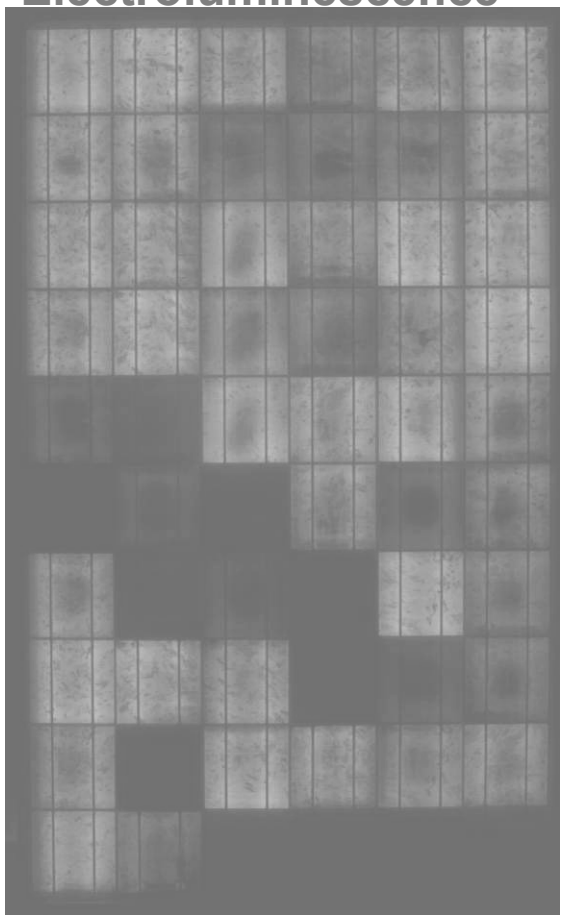

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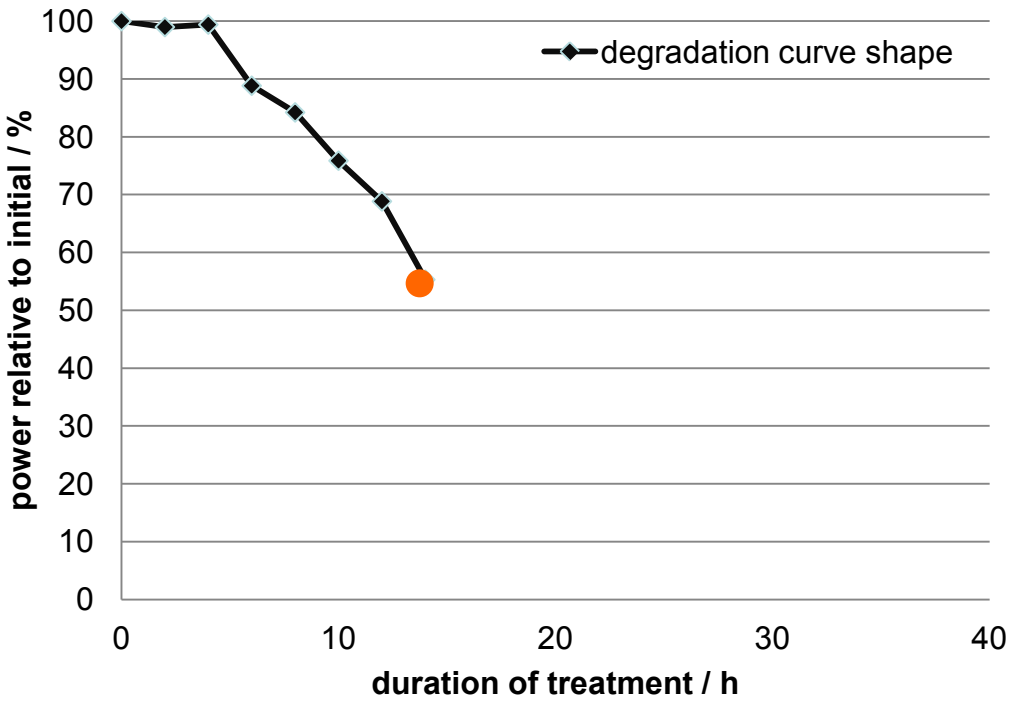

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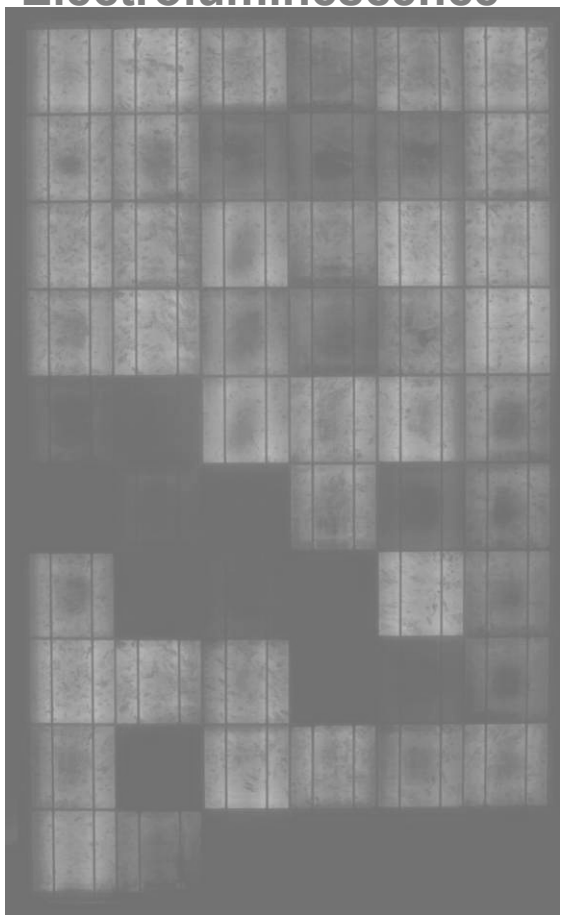

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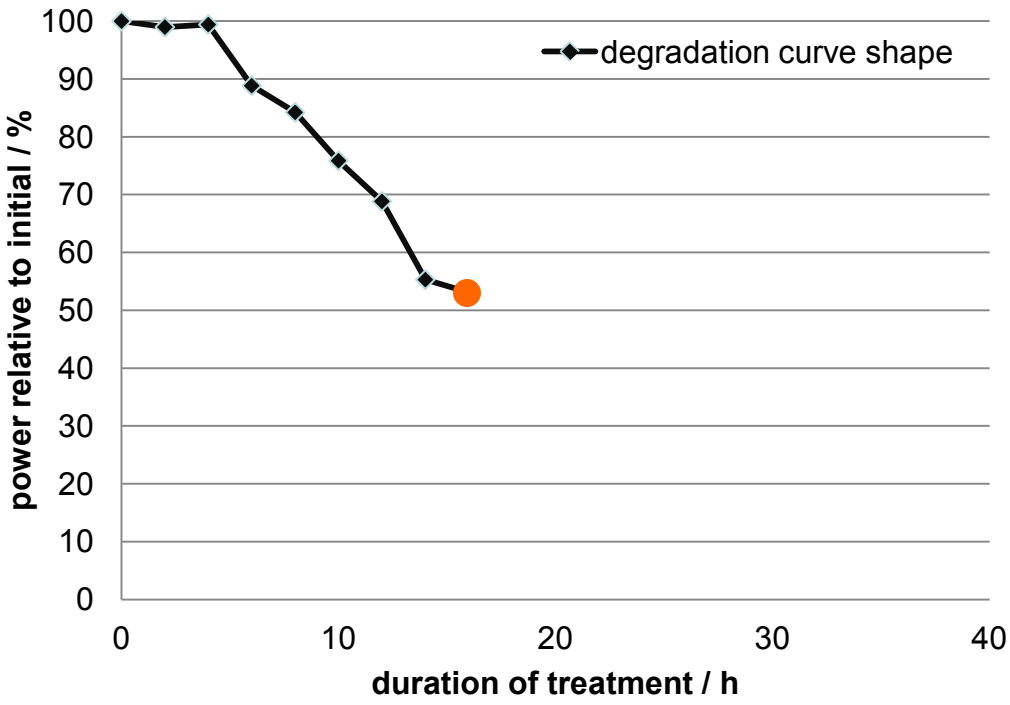

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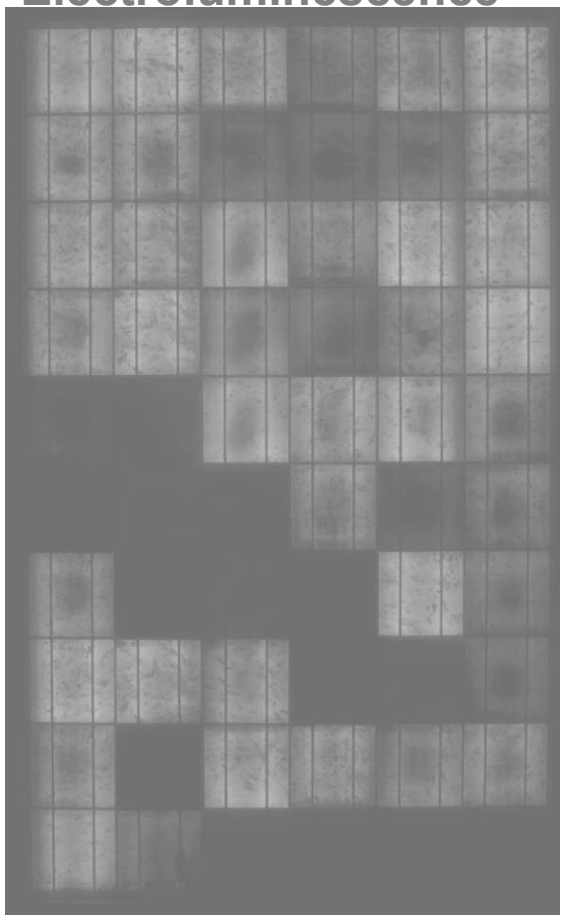

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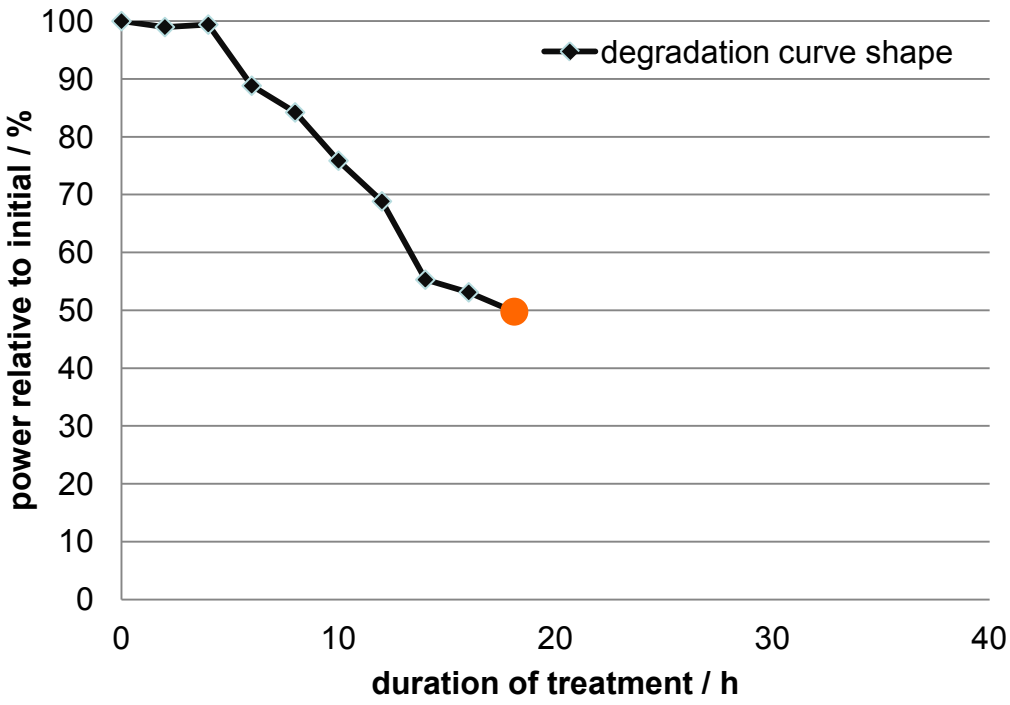

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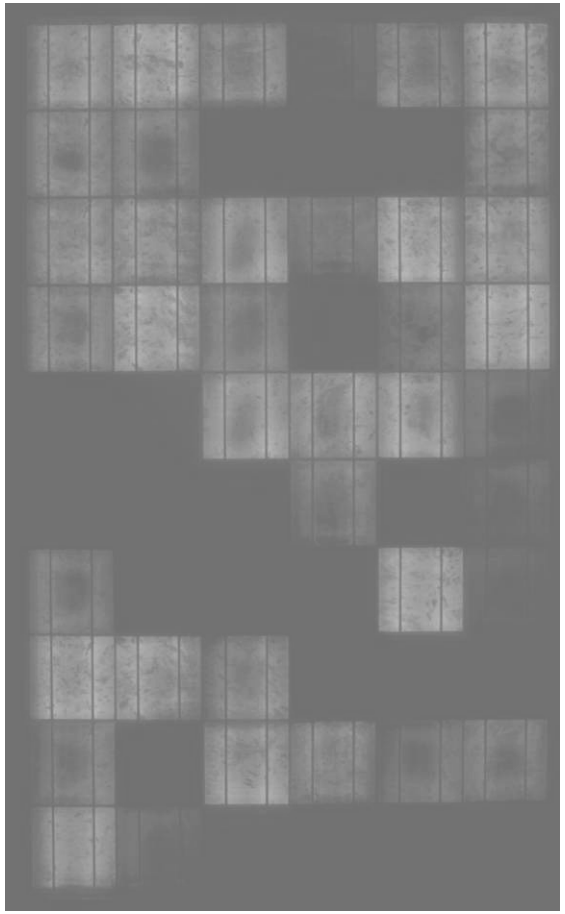

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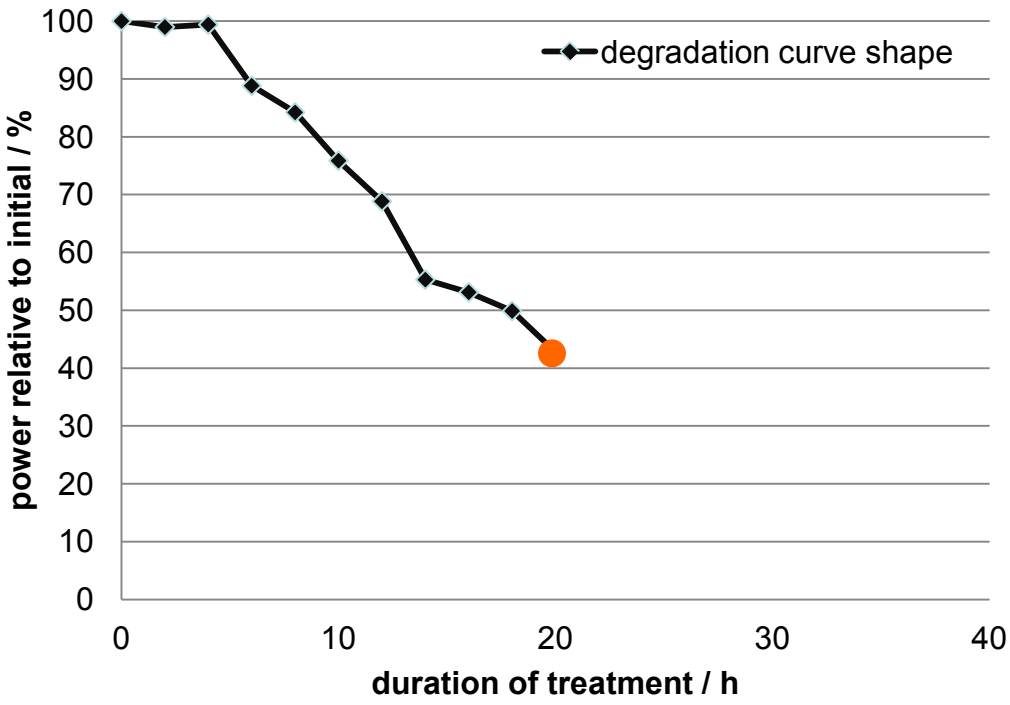

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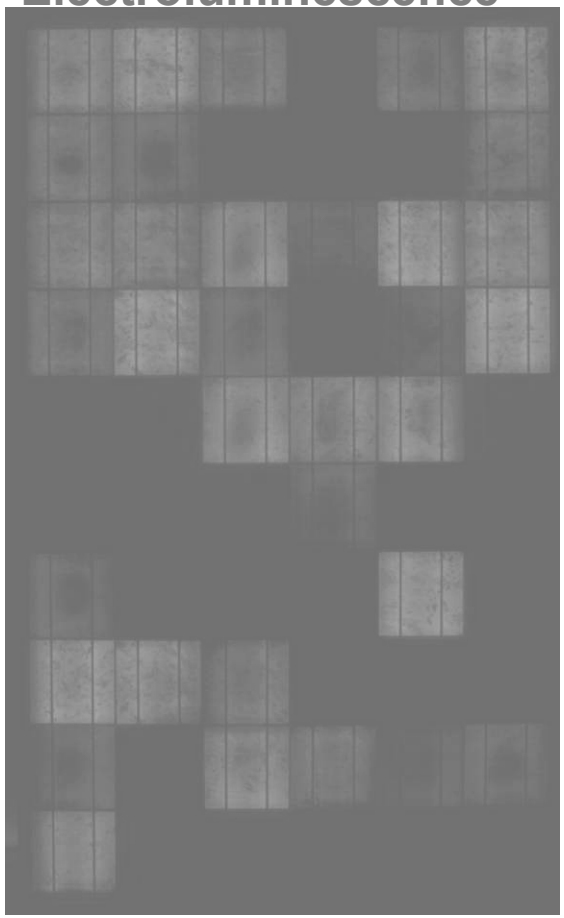

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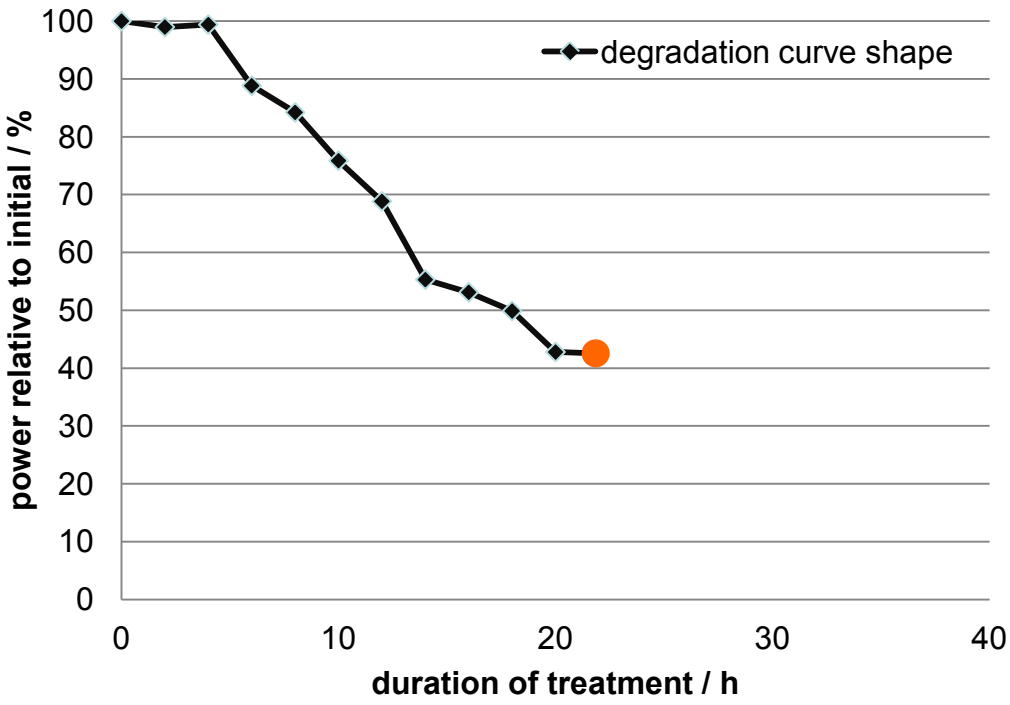

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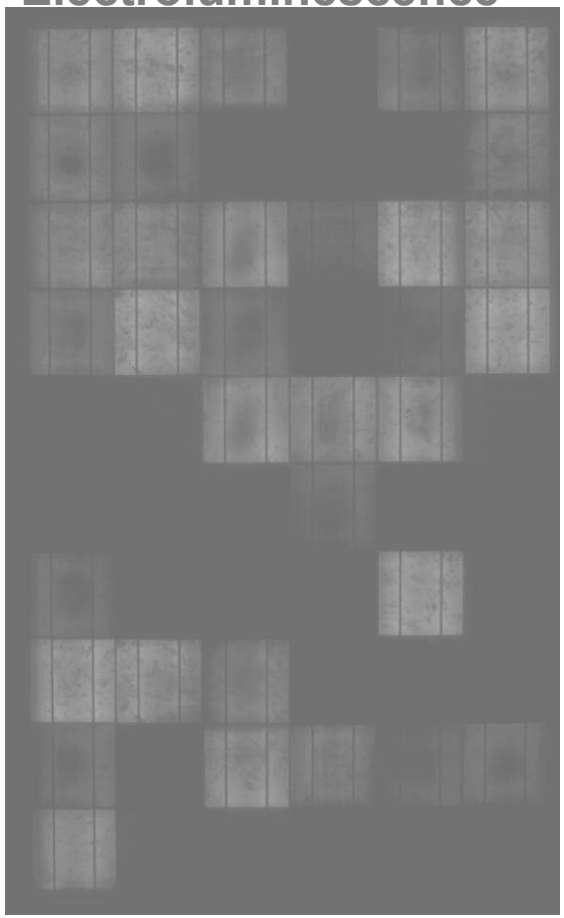

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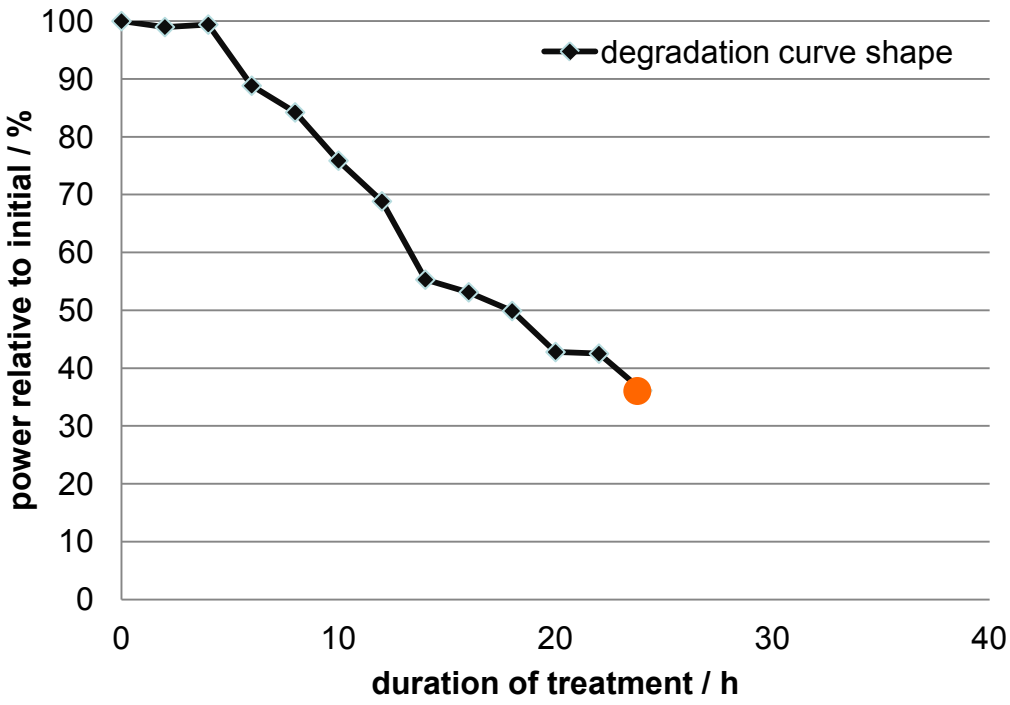

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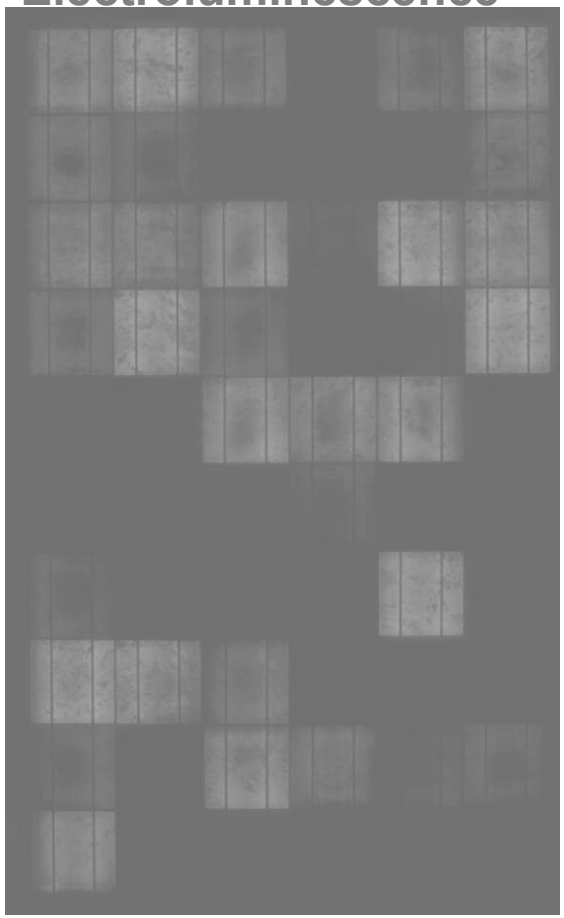

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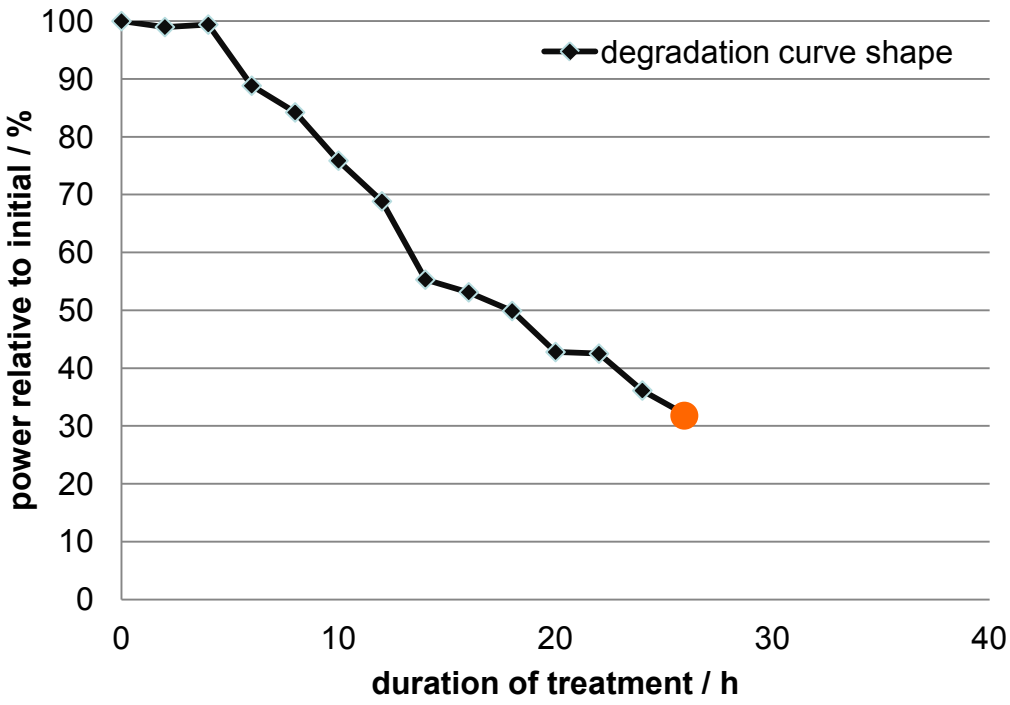

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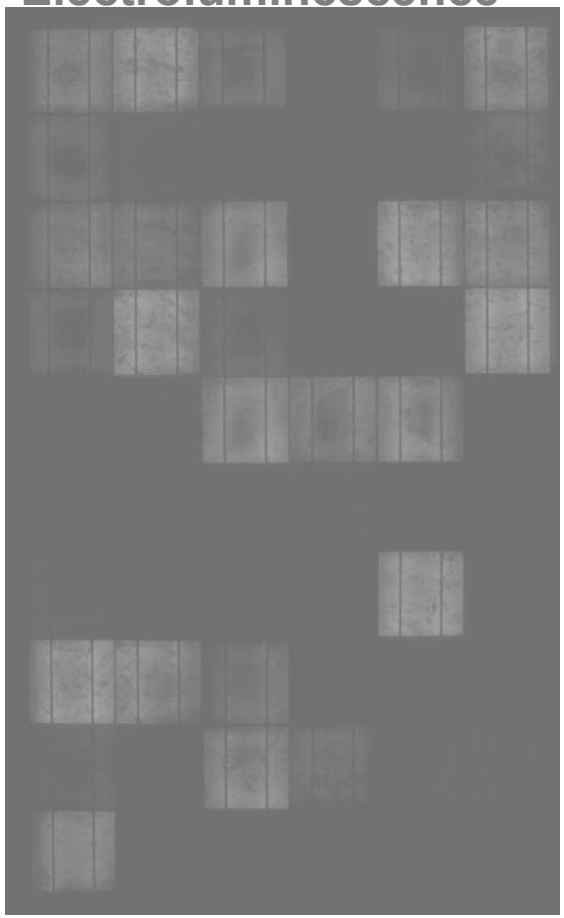

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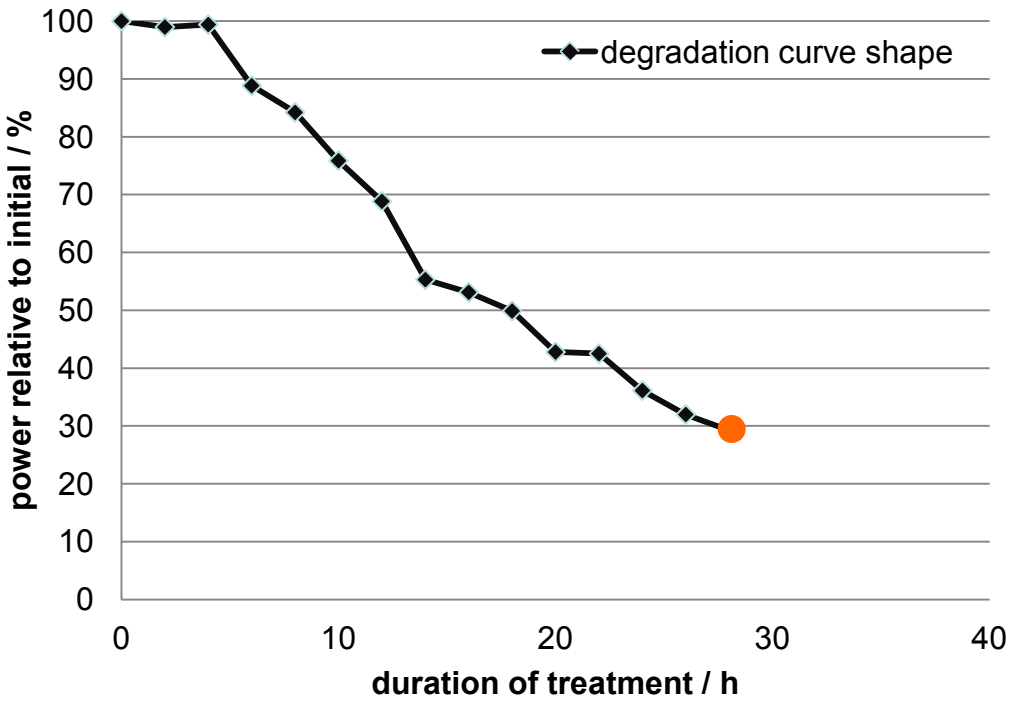

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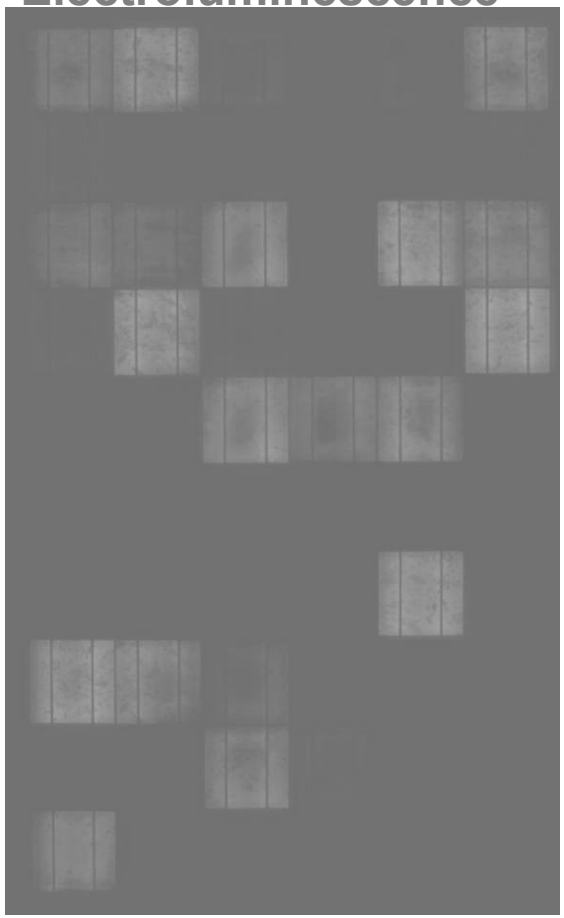

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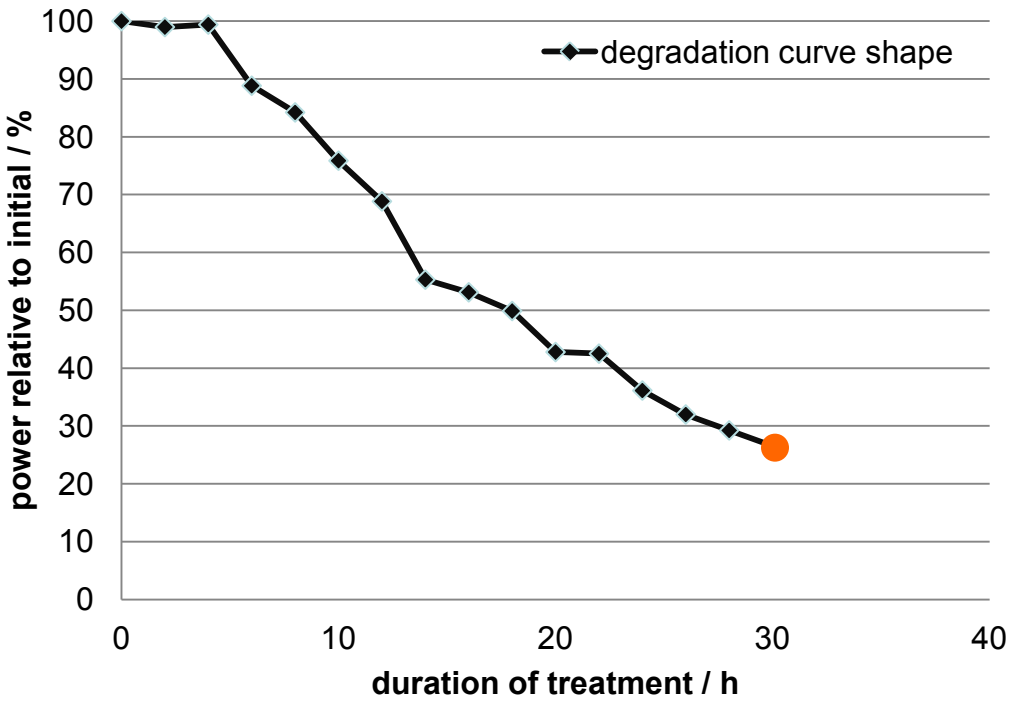

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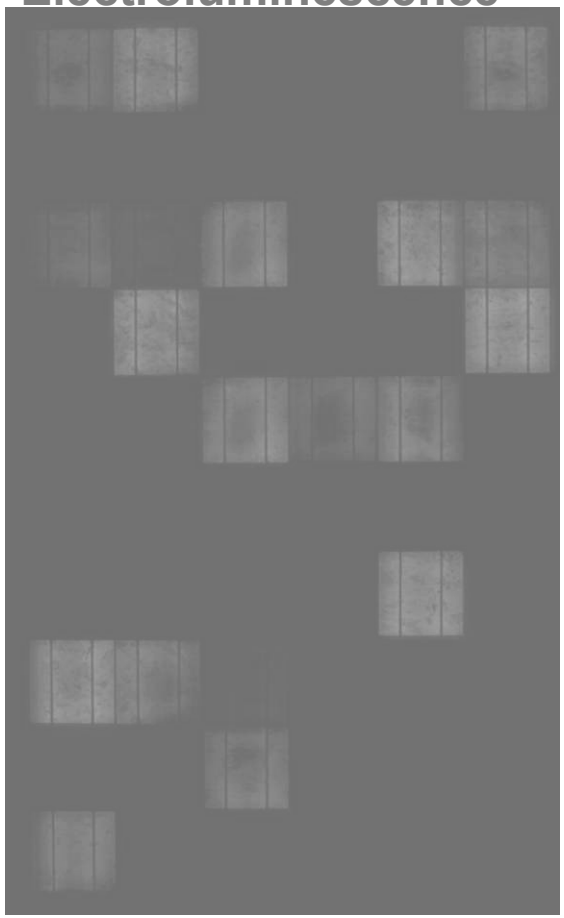

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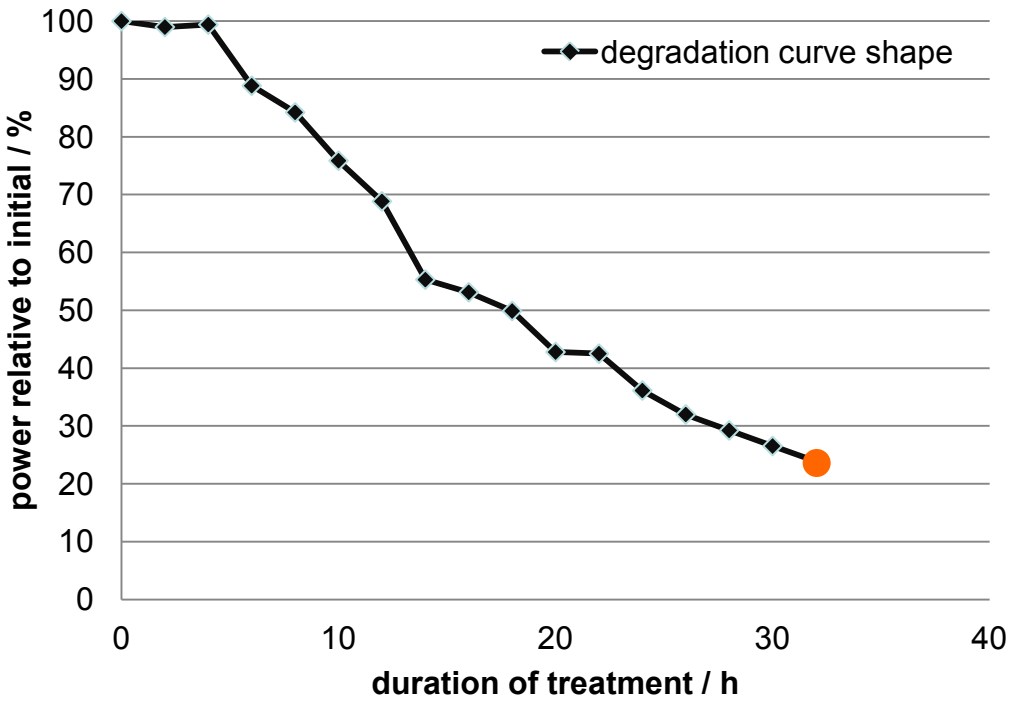

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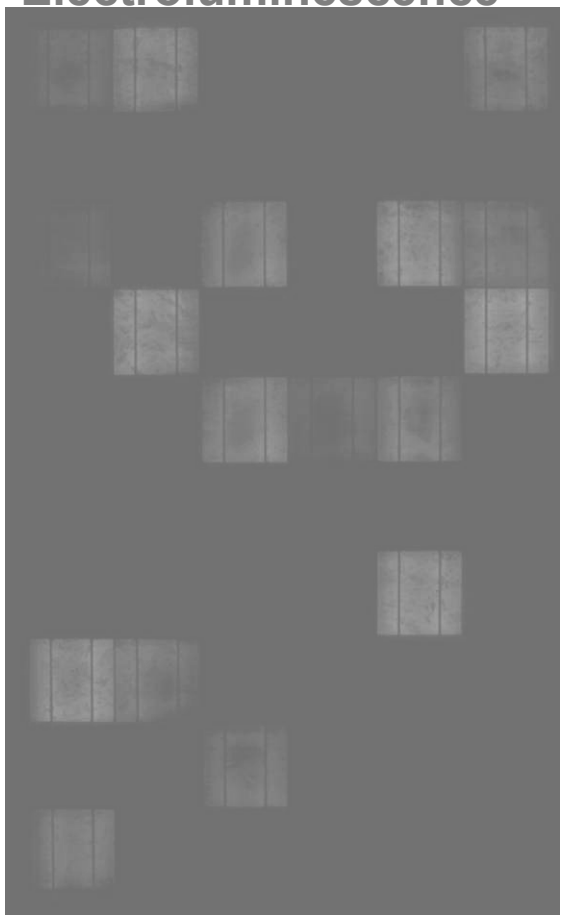

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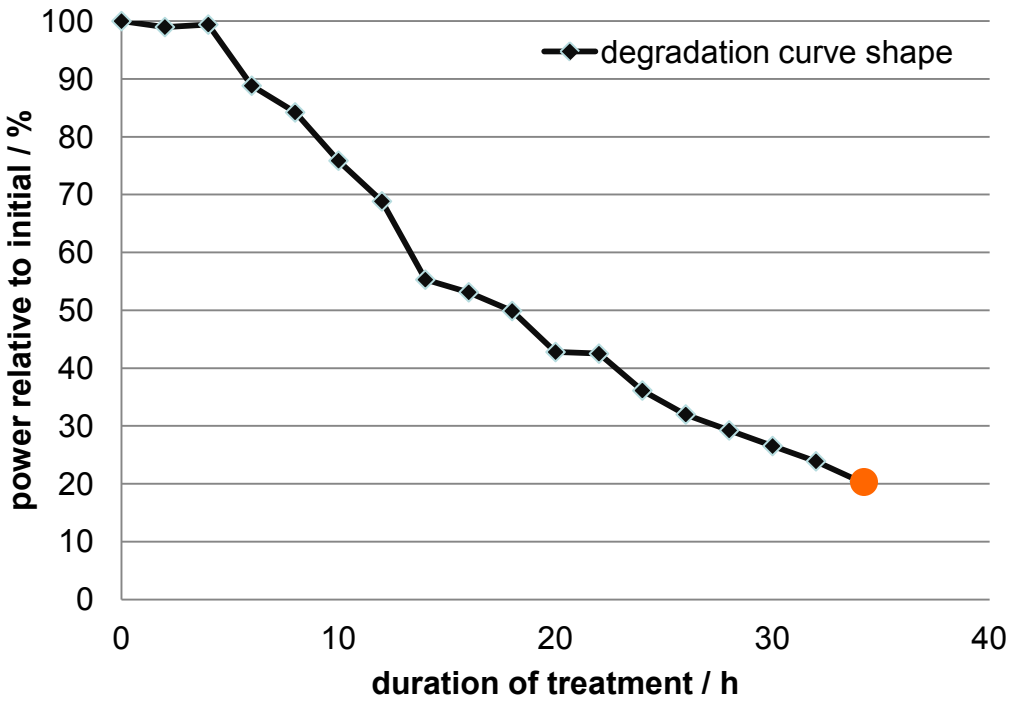

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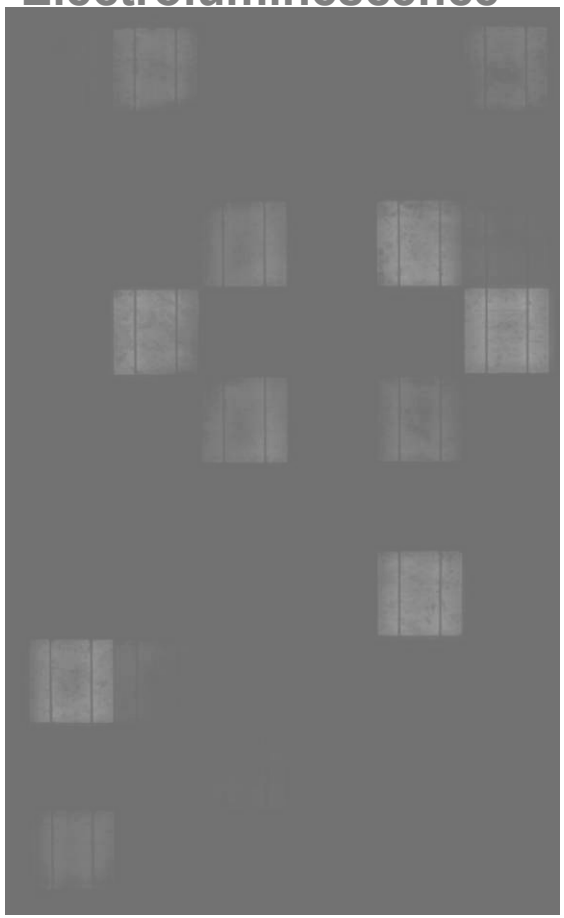

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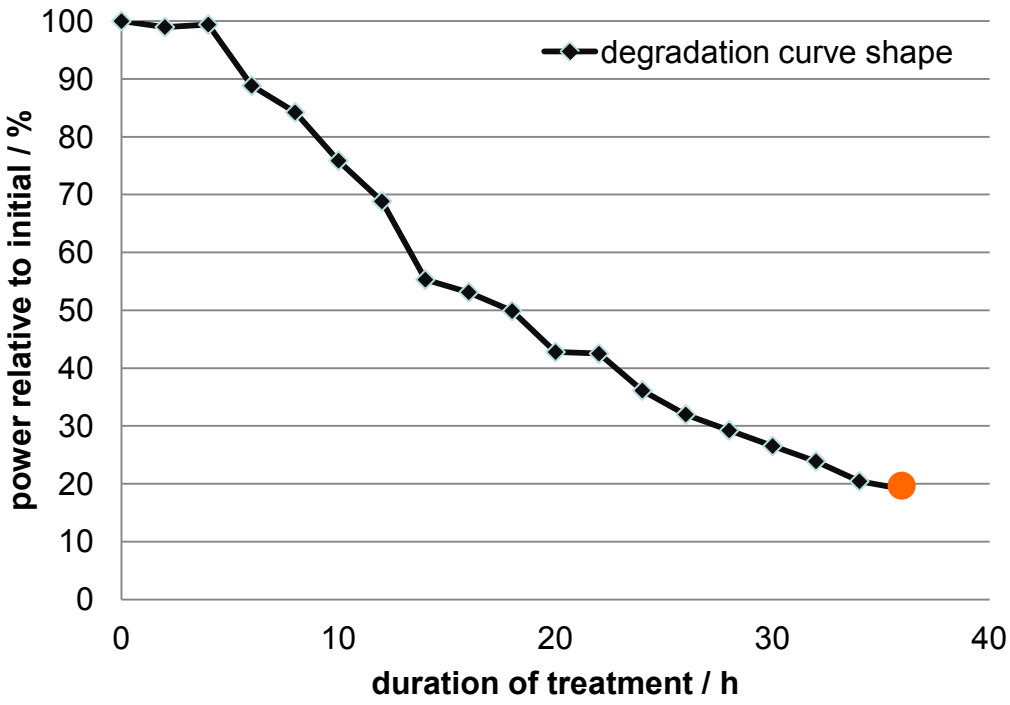


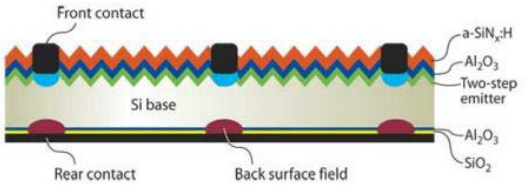
PID influencing parameters

PID influencing test parameters :

- Voltage
- Humidity
- Temperature
- Grounding

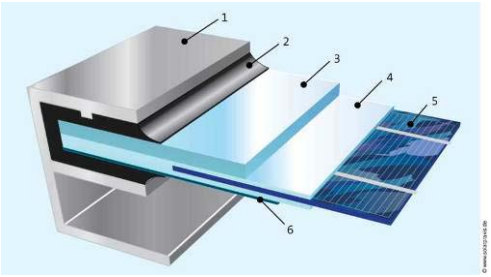
Influencing parameters on cell level:

- Anti reflective coating
- Emitter depth
- Type of base doping



Influencing parameters on module level:

- Front sheet
- Encapsulant material
- Back sheet
- Module design (frame, mounting, isolation)



PID influencing parameters

- **Applied voltage**

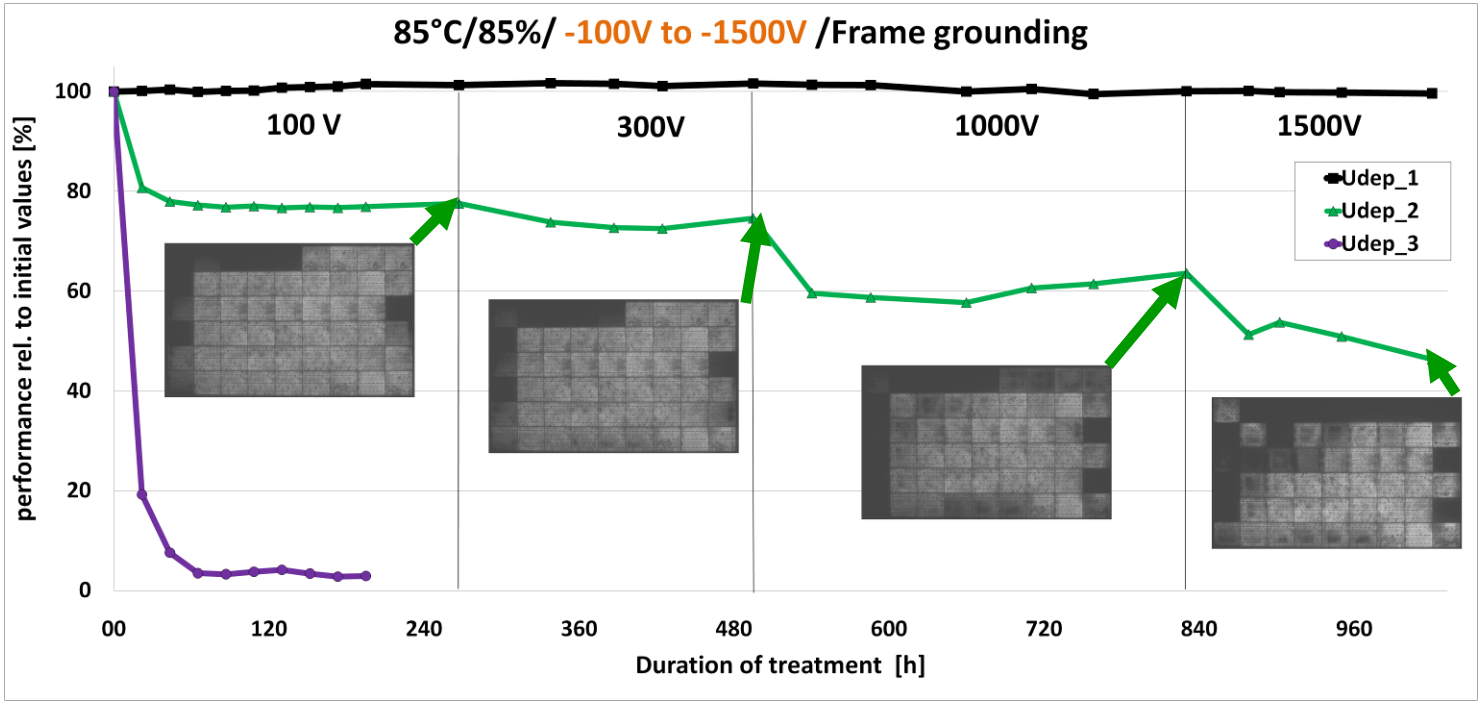
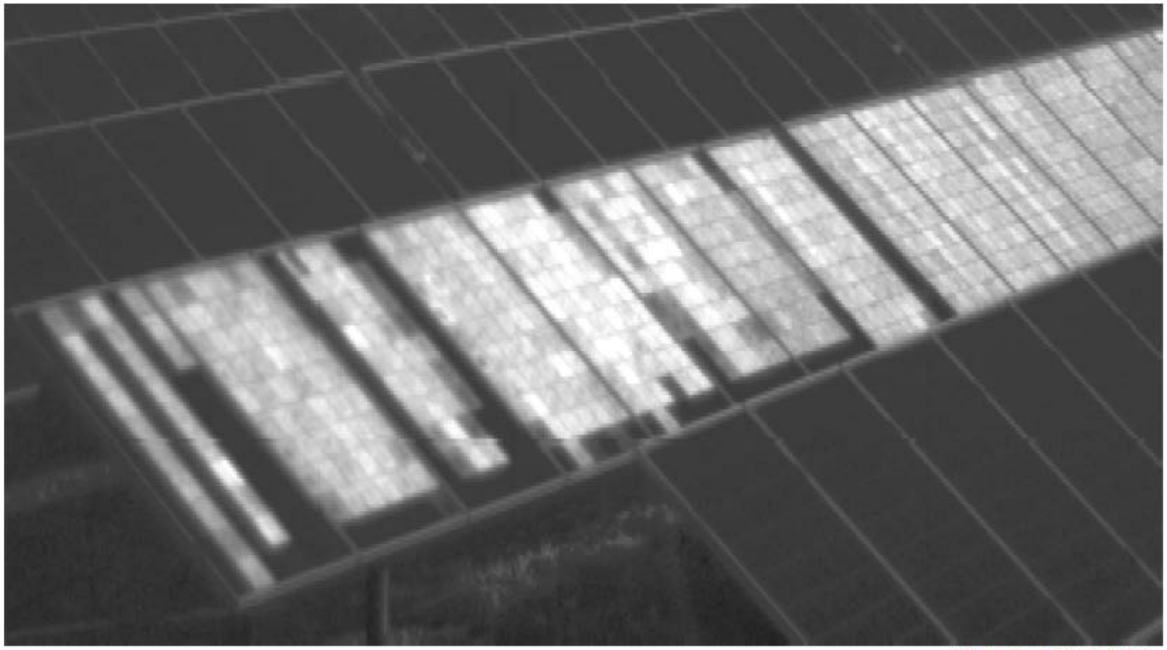


Fig. 2: Modules tested with increasing voltage

PID influencing parameters

- **Applied voltage**



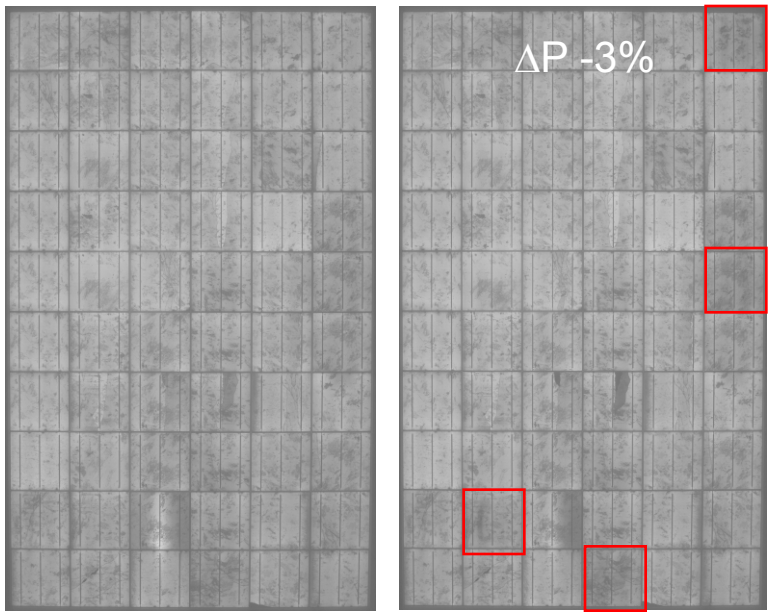
(Quelle: SOLON)

- *Applied voltage is influencing the degradation level*

PID influencing parameters

- **Temperature**

48h / 25 C / 85% RH / Frame grounding



48h / 85 C / 85% RH / Frame grounding

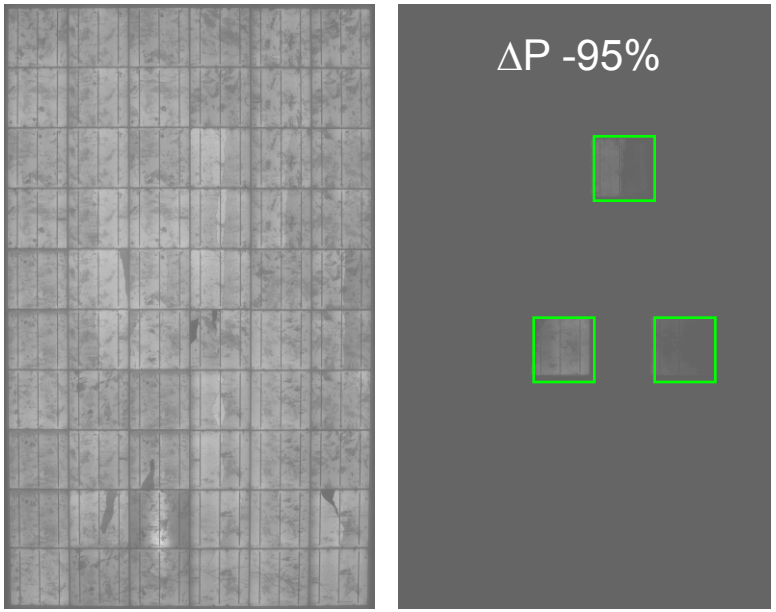
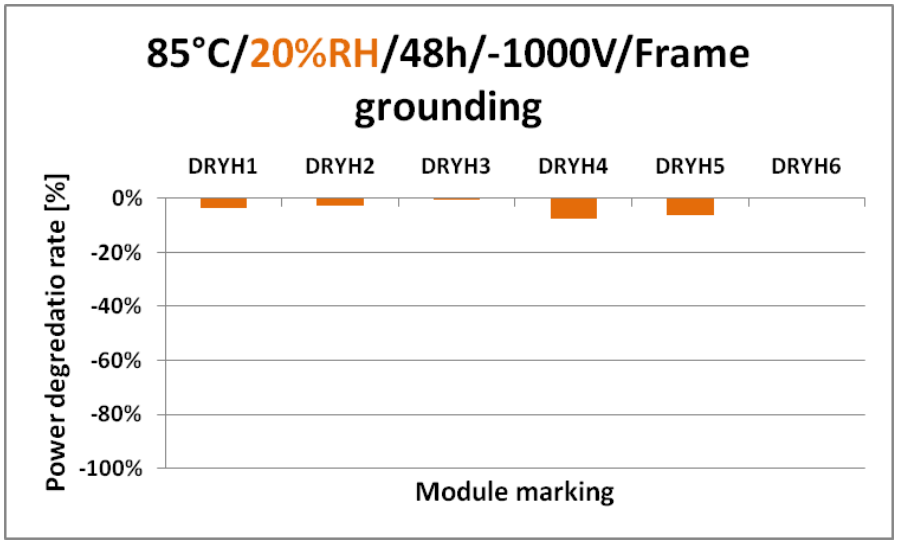


Fig. 3: Modules tested at different temperatures

- *Temperature is increasing the degradation rate*

- **Humidity**



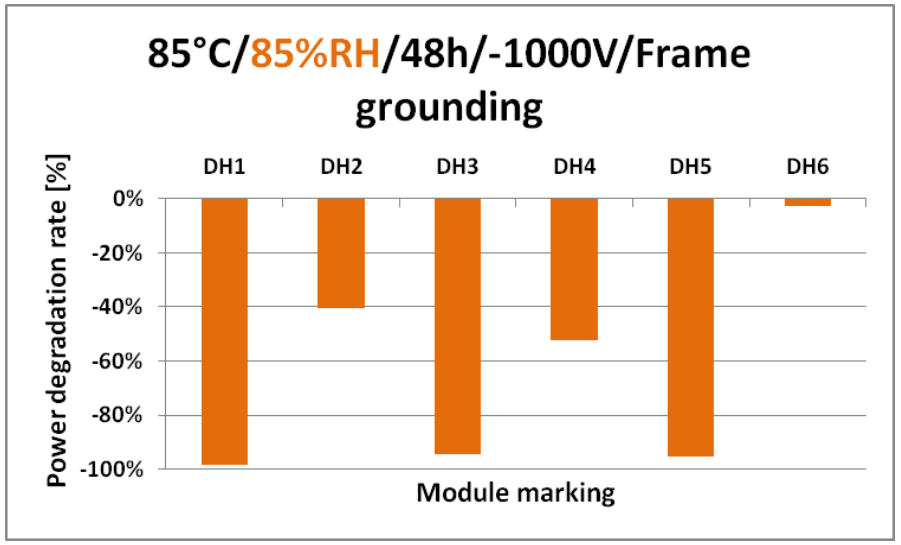


Fig. 4: PID treatment with different humidity conditions

- *Humidity is influencing the degradation rate*

PID influencing parameters

- **Contact situation**

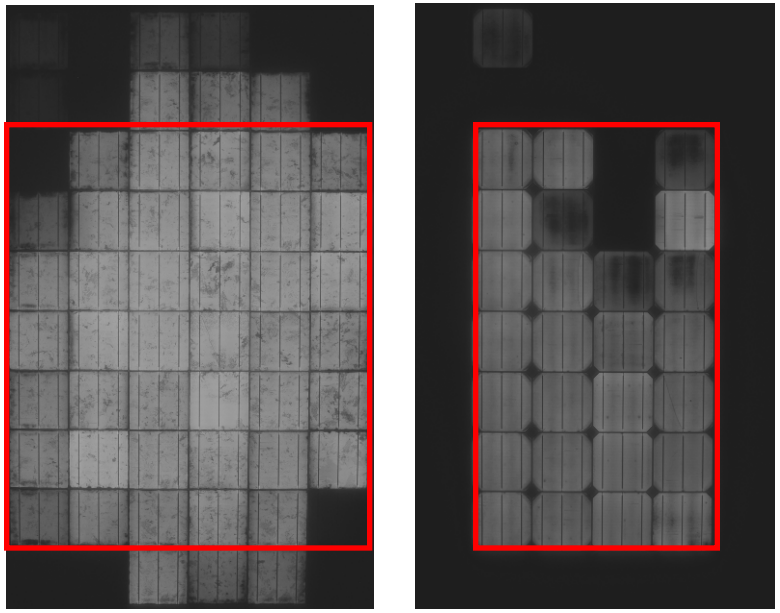


Fig. 5: Lab tested modules – frame grounded

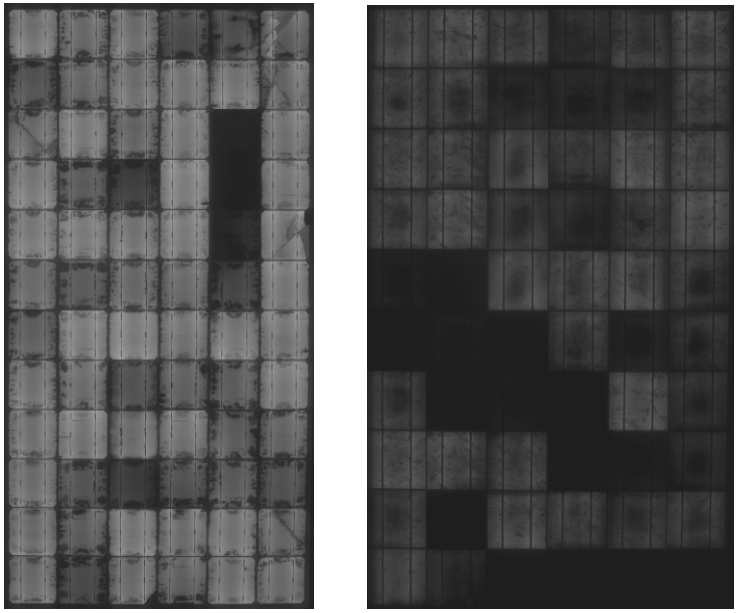
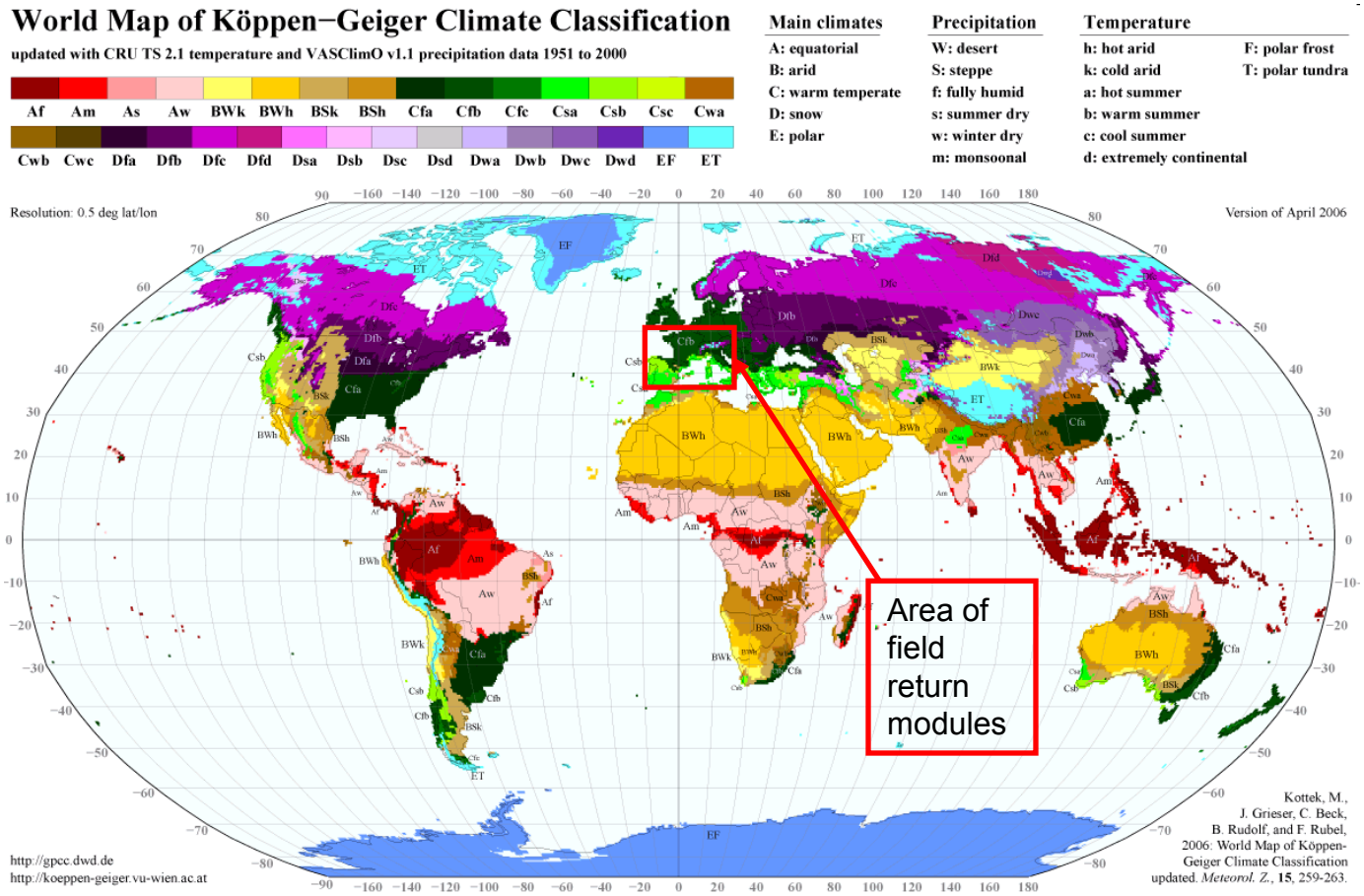


Fig. 6: Lab tested modules – surface grounded

- *Grounding is influencing the degradation pattern*

Comparison between field returns and laboratory tests



Comparison between field returns and laboratory tests

- **Contact situation**

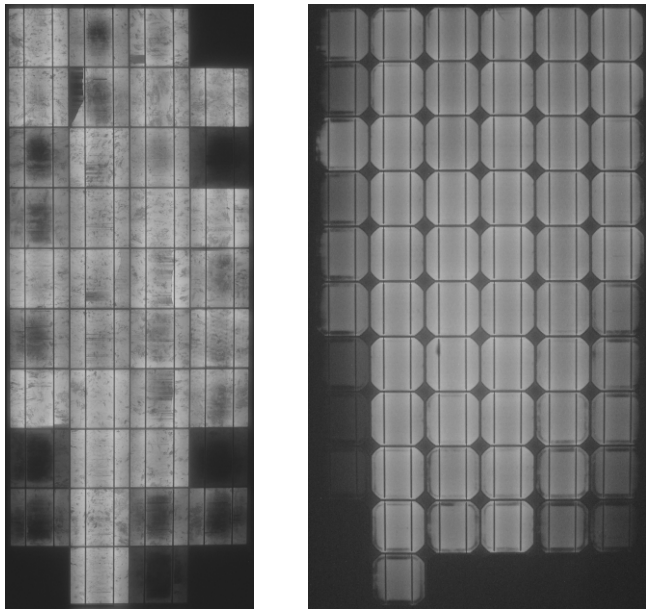


Fig. 7: Field return modules from different suppliers and power plants

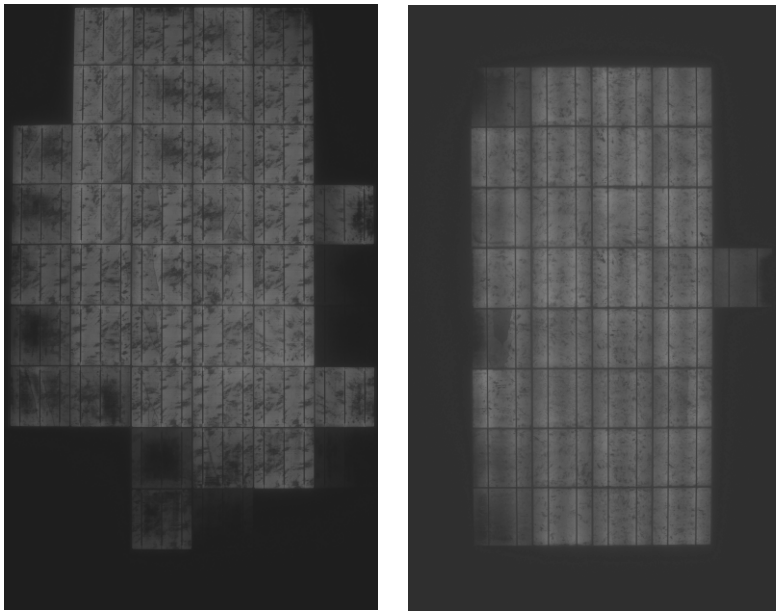


Fig. 8: Modules which were grounded via the frame

- *Field return modules show similar pattern like modules grounded via the frame*

Reasearch on cell level

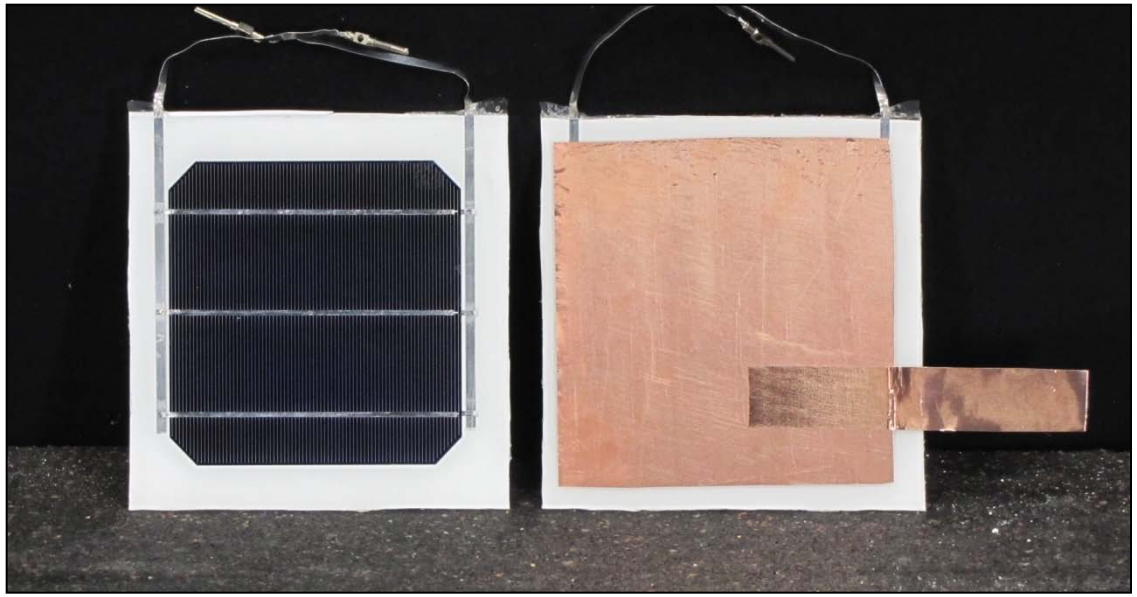
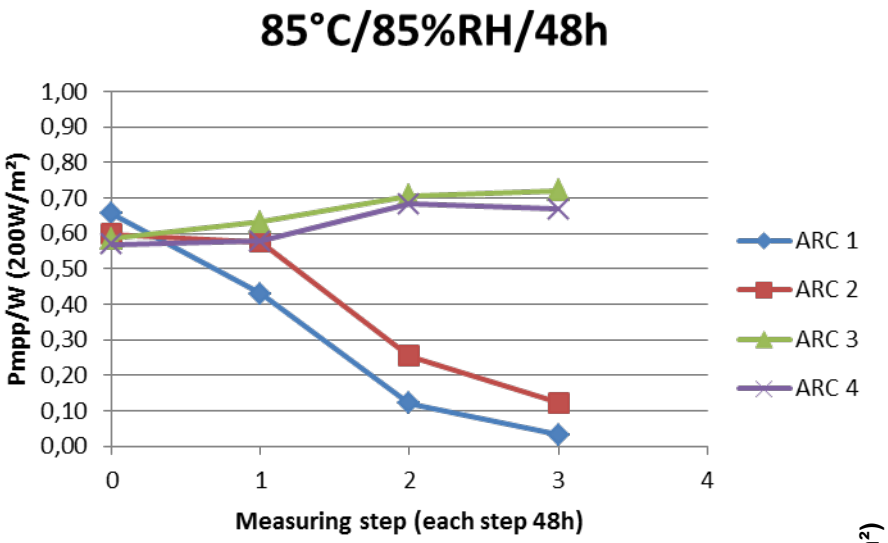


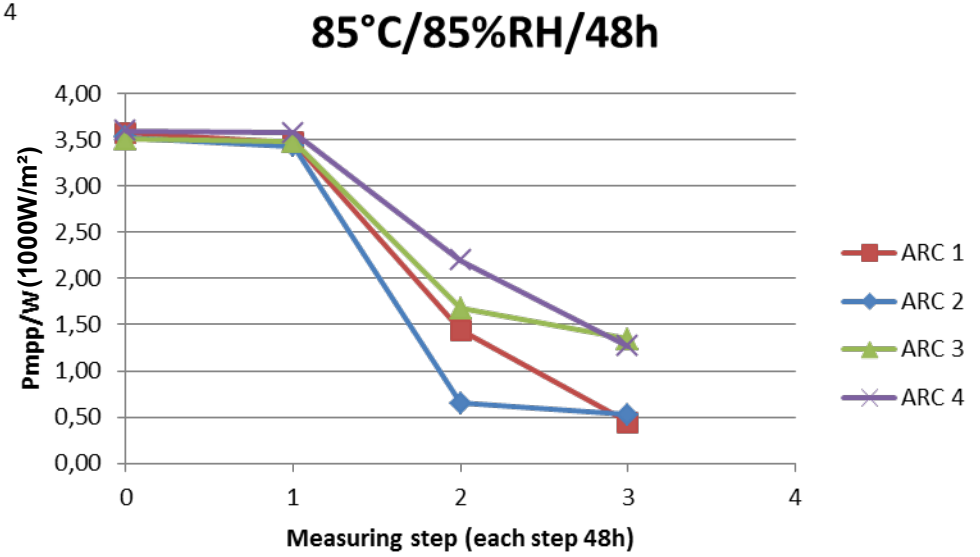
Fig. 9: Typical one cell module

- Investigations on different anti reflective coatings and their optimation against PID
- Research on small one cell modules with 200 x 200 mm
- Contact via copper foil on the whole front side
- Apllied voltage between 50 and 200 V

Anti reflective coating

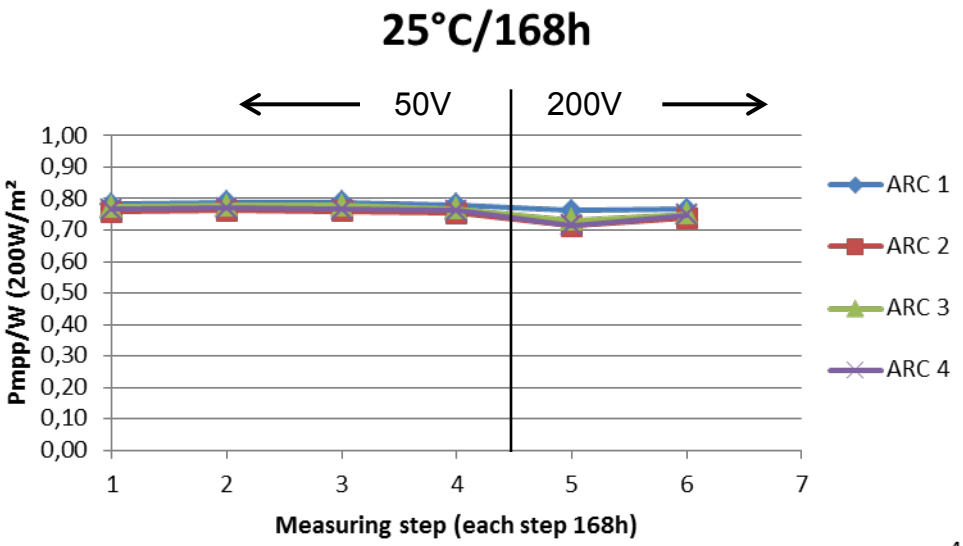


- Equal wafer material
- Four different anti reflective coatings
- Two different Encapsulate materials



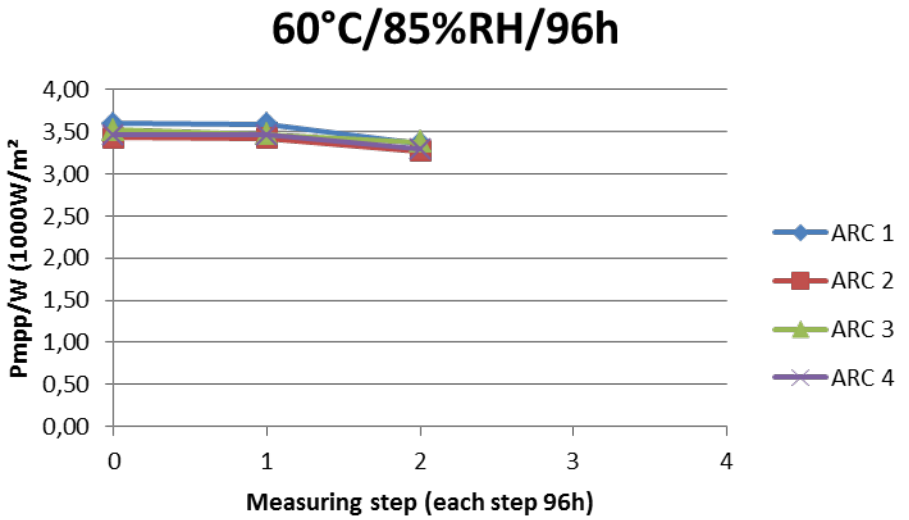
- Segnificant spread between ARC 2 and ARC 3 for both materials
- The influence between encapsulant and anti reflective coating havn‘t been clearifite yet

Anti reflective coating



Three different test methods:

1. 85 C/85%RH/48h
2. 25 C/168h
3. 60 C/85%RH/96h



- No segnificant difference during 25 C test
- Small power drop after increasing the voltage to 200V
- No significant power drop after two cycles for the 60 C test

Encapsulant materials

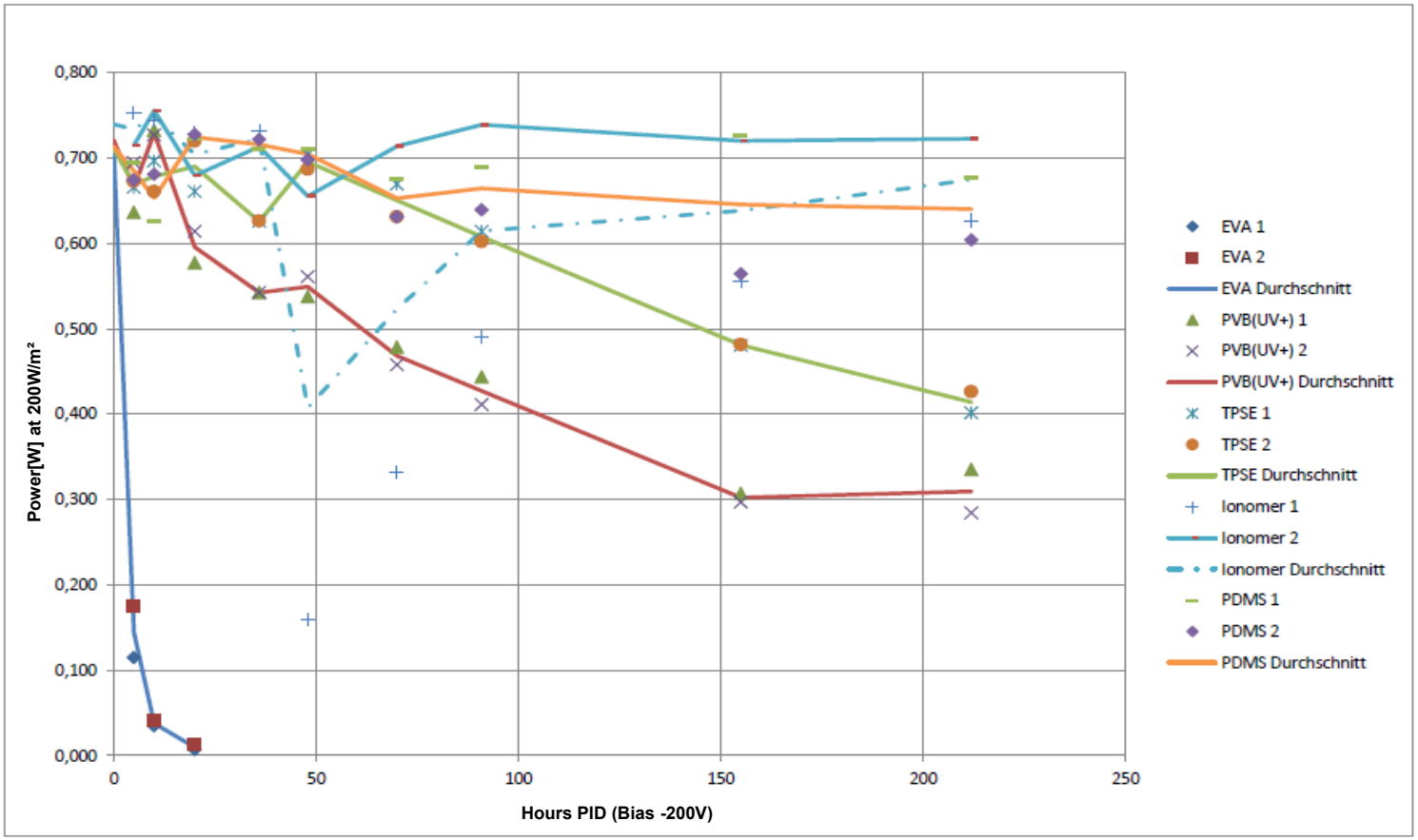


Fig. 10: Investigation on different encapsulant materials

Outlook

- **PID in the field – Procedure from PI/PIExpert**

1. Analysis of modules in the PI Berlin laboratory

•Degradation

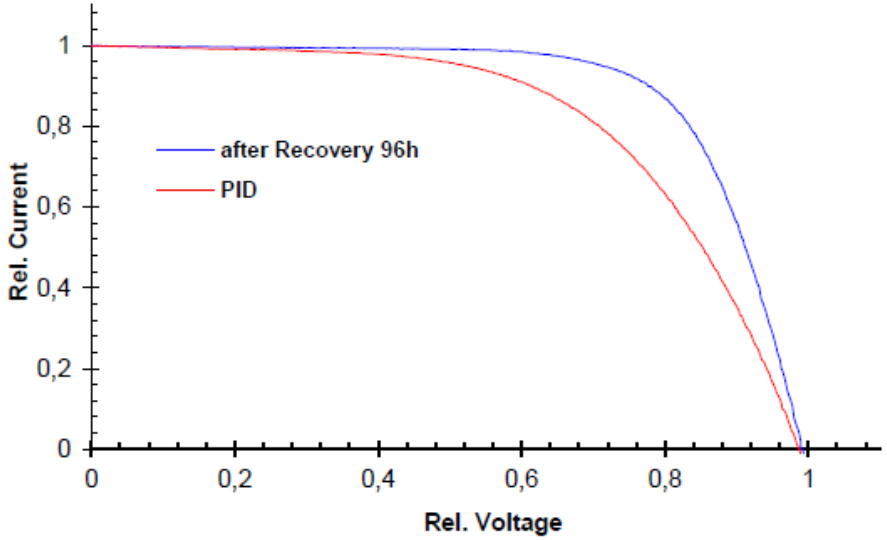
•Recovery

2. Field analysis + action monitoring

Outlook

1. Analysis of modules in the PI Berlin laboratory

- PID testing
- Recovery testing
- Analysis methods: IV, EL, IR



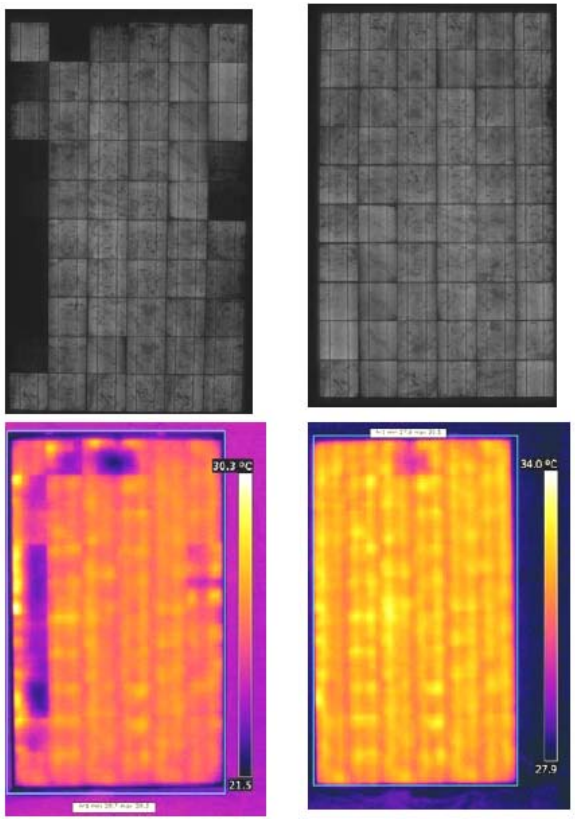
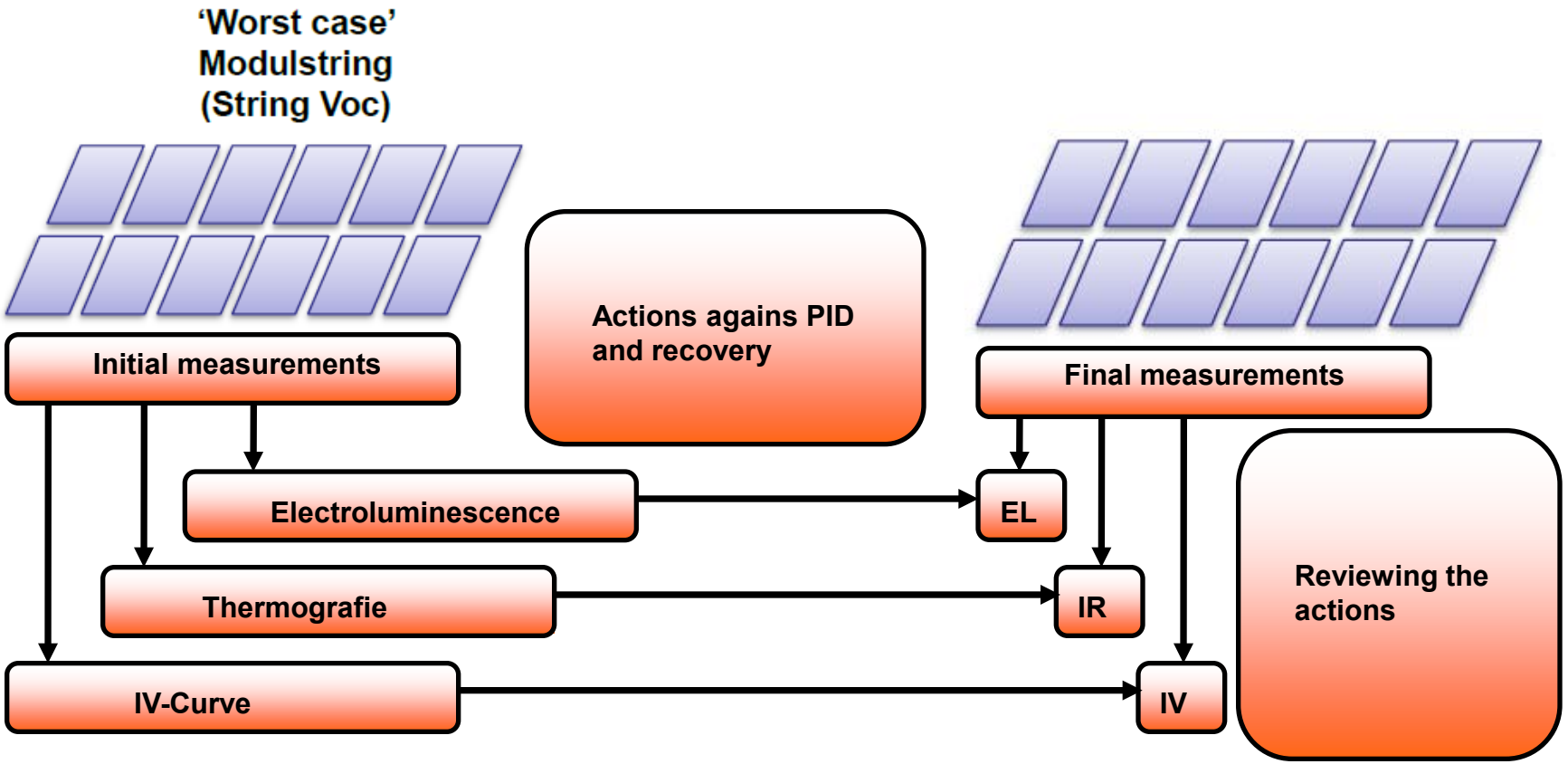


Fig. 11: EL/IR of field modules (left)
EL/IR after recovery (right)

Outlook

1. Field analysis + action monitoring



Summary

- PID is just one of many effects which are caused by high system voltage
- PID rate is influenced by:
  - System voltage
  - Humidity
  - Temperature
  - Contact situation
  - Cells
  - Module materials
- PI-Berlin/PI-Experts: Pakage for analysis of PID in the field + action monitoring
- The PID test can just show if a module is susceptible to PID or not. Till now there are no simulation programms available which allow a forecast for module behaviour in the field. PI-Berlin is working on different R&D projects about indoor/outdoor corolations at the moment.

Thank you for your attention!

koch@pi-berlin.com

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PID test according to PI-Berlin standard

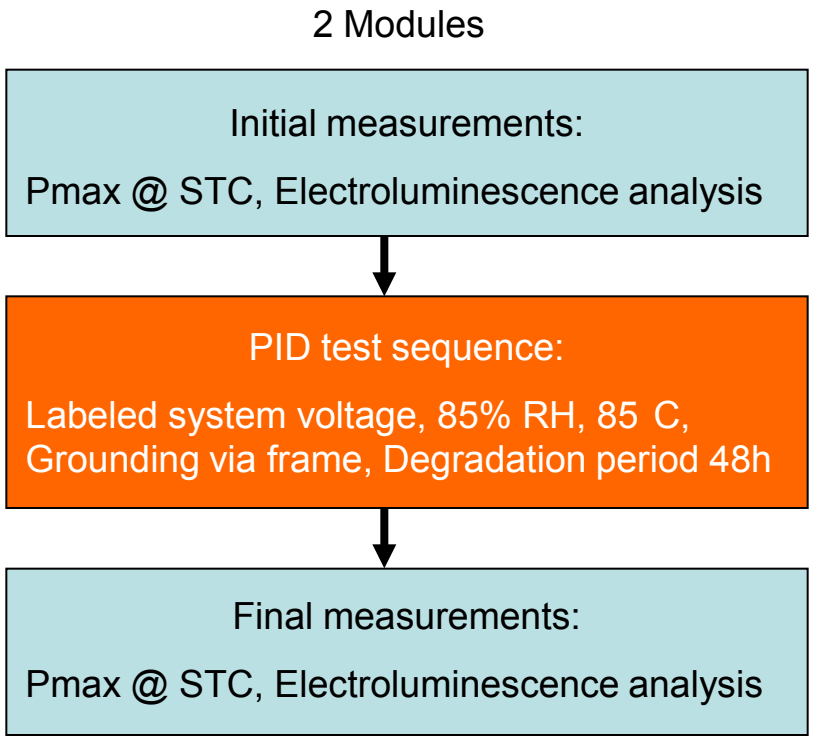


Fig.10: PID standard test sequence

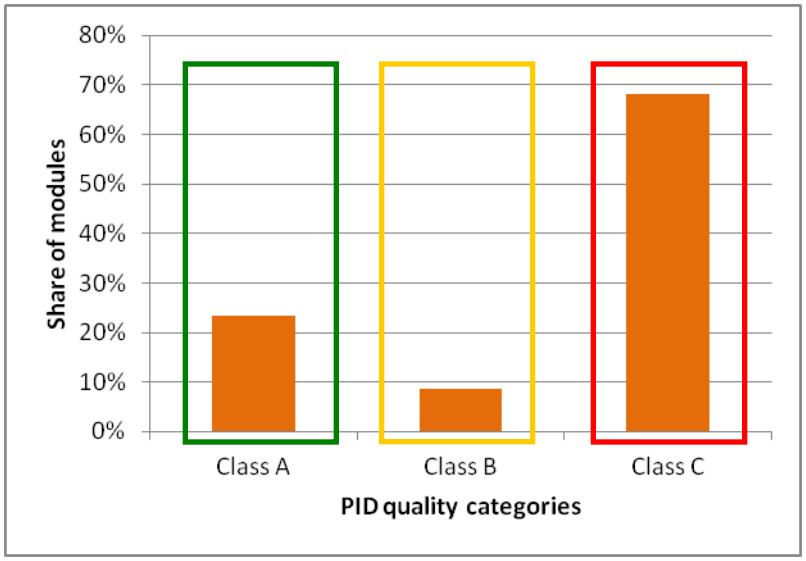
PID quality categories:

Class A → ΔP < 5%

Class B → 5% < ΔP < 30%

Class C → ΔP > 30%

PID test according to PI-Berlin standard



PID quality categories:

Class A → ΔP < 5%

Class B → 5% < ΔP < 30%

Class C → ΔP > 30%

Fig.8: Summary of ~50 modules tested with PID standard test sequence