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PID Failure of c-Si and Thin-Film Modules and Possible Correlation with Leakage Currents

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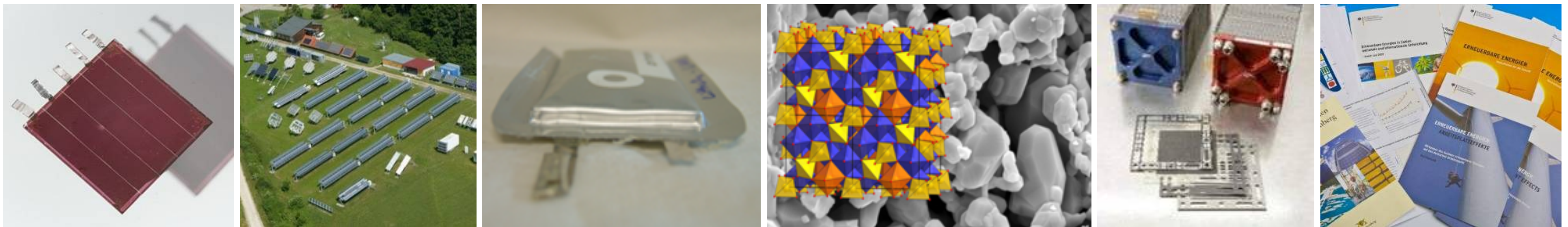

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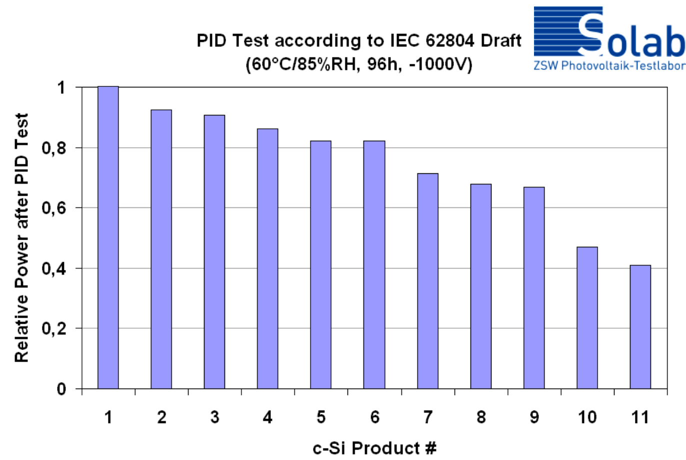
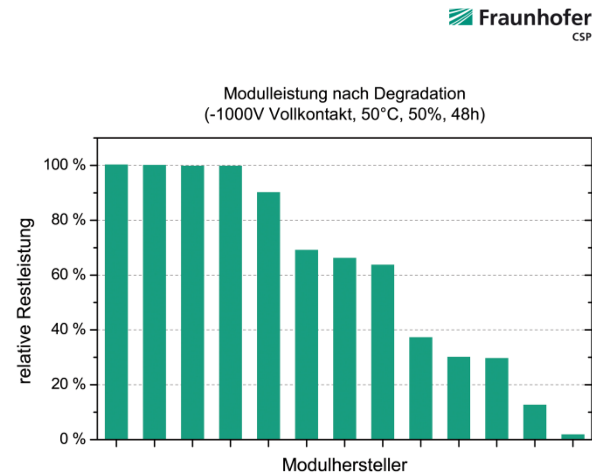
FAQs:





Source: Fraunhofer CSP, 2012

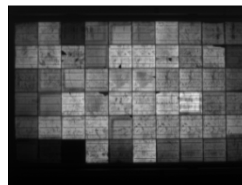
- Relation between different PID lab-tests and PID in the field?
- Is transferred charge a degradation indicator
  => time-to-failure estimation?
- Role of reversible effects?
- Thin-film tests to be based on the IEC Draft 62804 for c-Si?

Outline

- PID failure of c-Si and thin film
- Power degradation
- Evaluation of leakage currents from lab and field
- Does PID match with charge?
- Recovery effects

PID failure of c-Si and thin film modules

	c-Si	Si-TF (a-Si, µmorph) CdTe	CIGS
Degradation effect	Power loss	Power loss; Delamination	Power loss
Defect location	SixNy	TCO	CIGS
Trigger	Leak. Current	Leak. current; Moisture	Leak. current



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Approach

Indoor (climate chamber)

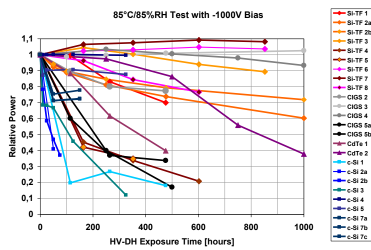
Leakage current (T-, RH-matrix)
Power loss (STC and low light)
Recovery

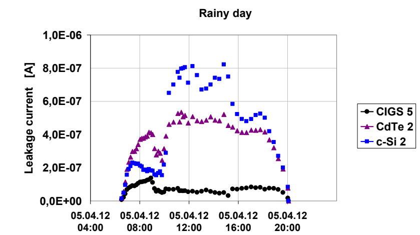
Bias -1000 V

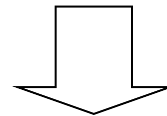
Field (Widderstall)

Leakage current (5min sampling)
Power loss (flasher)

Bias up to -800V (PV- Generator)





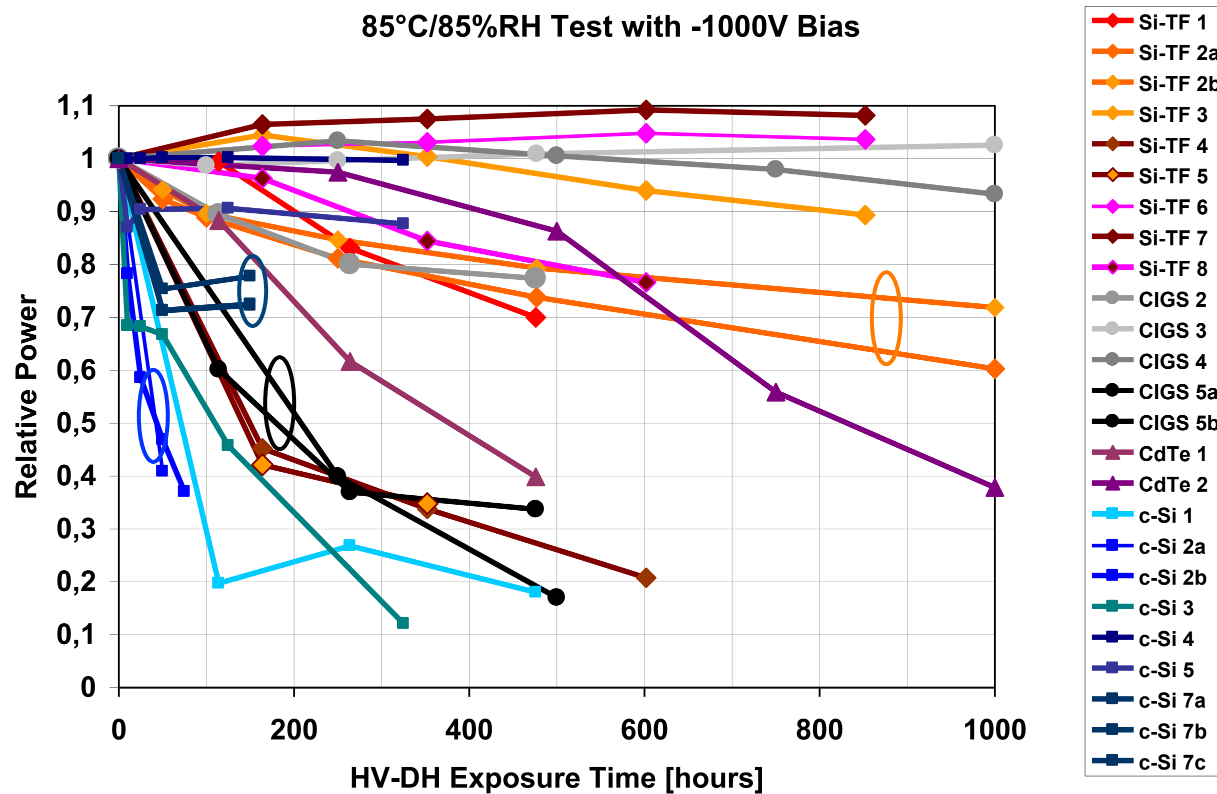


Time-to-PID-failure?

Outline

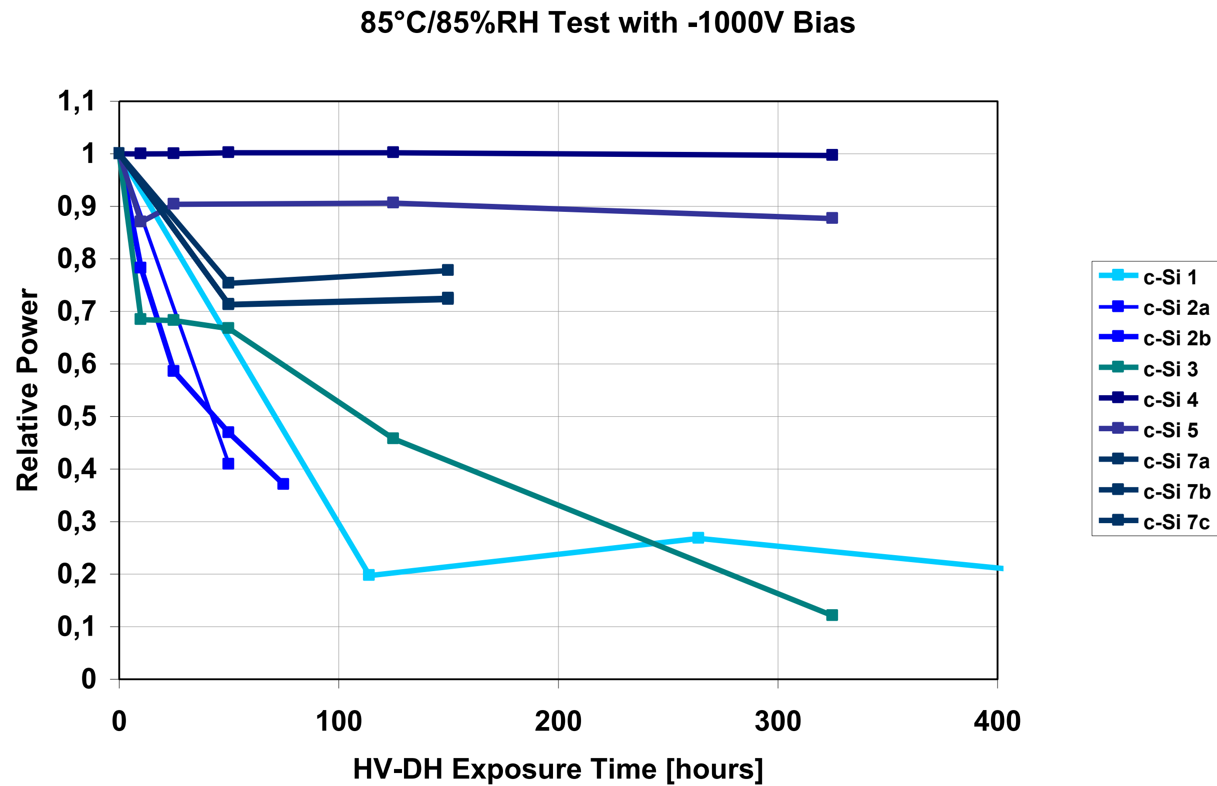
- PID-failure of c-Si and thin film
- **Power degradation**
- Evaluation of leakage currents from lab and field
- Does PID match with charge?
- Recovery effects

Module power after 85°C/85%-PID test: all technologies



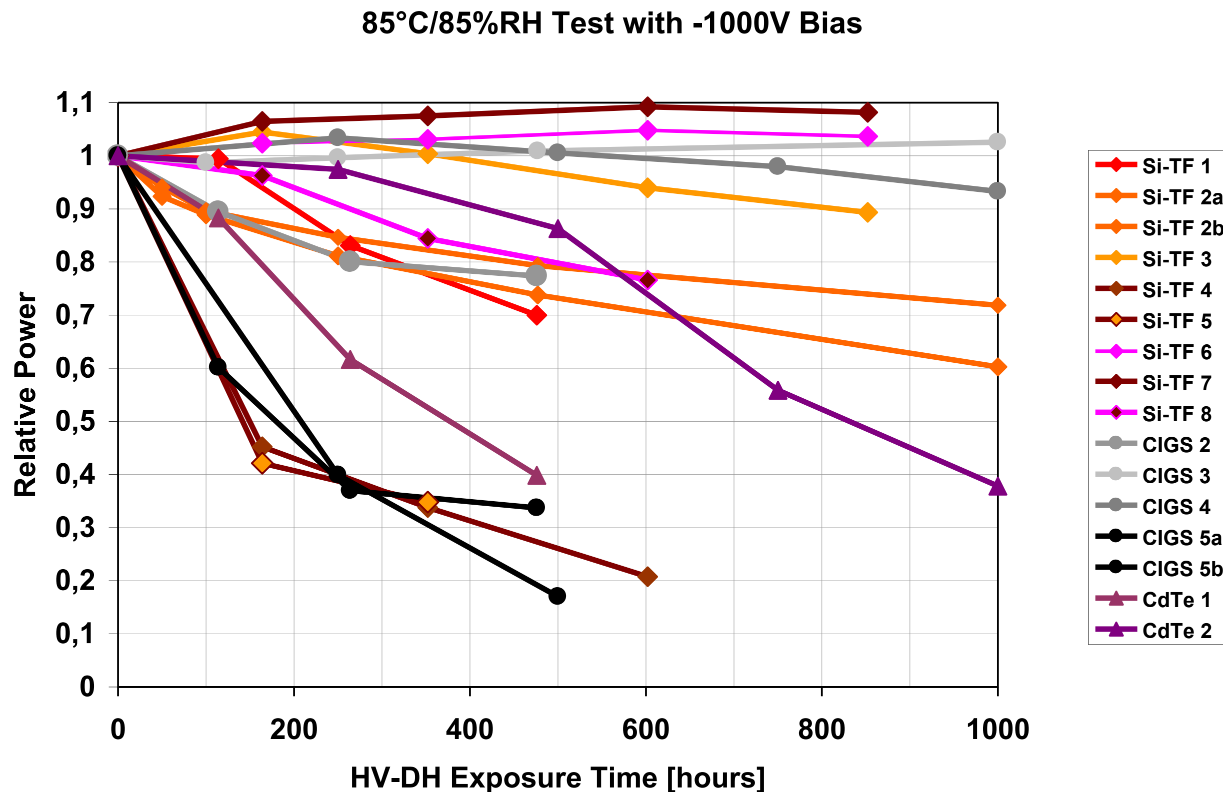
- Wide variation from stable to highly PID susceptible
- Reproducibility of PID failure is quite o.k.

Module power after 85°C/85%- PID test: c-Si only



- Shunting occurs (loss of FF, Rsh, very bad at weak light)

Module power after 85°C/85%- PID test: TF only



- TCO corrosion occurs for some Si-TF and CdTe products
- Shunting occurs for some CIGS products; no visual defects
- For most of the PID-susceptible TF modules grounding is mandatory

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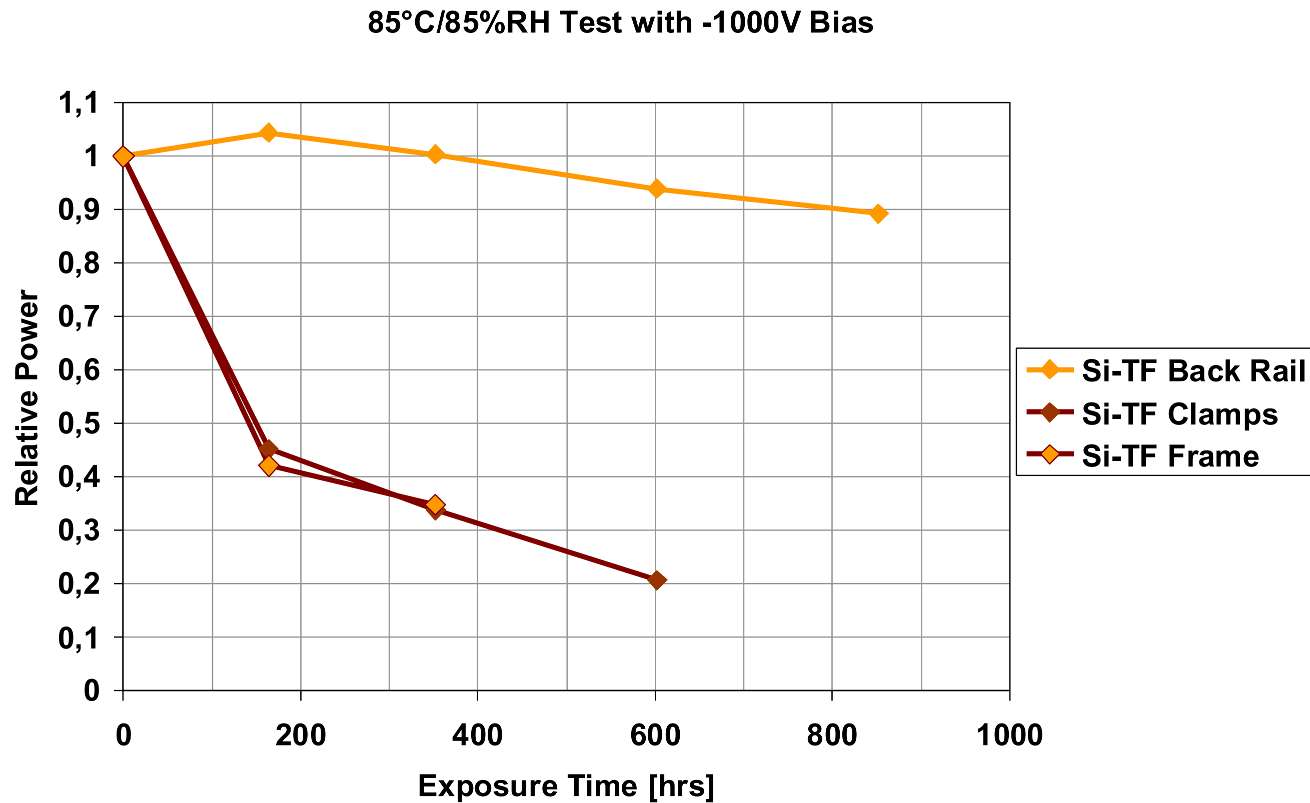
Optimization of PID-resistivity by choice of mounting: Si-TF module



- Back Rail mounting reduces susceptibility for TCO-corrosion

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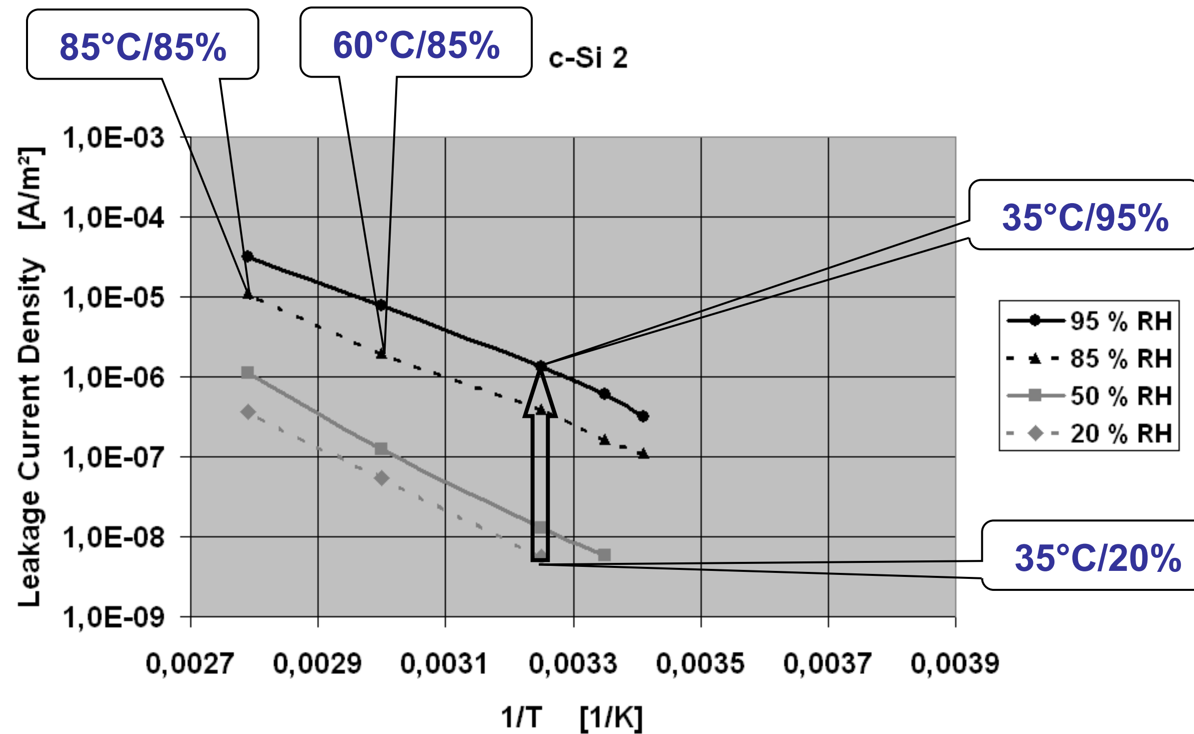
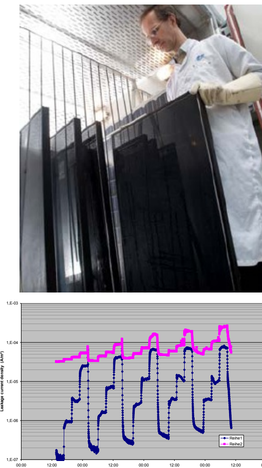
Outline

- PID-failure of c-Si and thin film
- Power degradation
- **Evaluation of leakage currents from lab and field**
- Does PID match with charge?
- Recovery effects

Arrhenius plot of leakage currents from the lab:





- Activation energy E_a typically between 0.6 and 0.8 eV
- Current is strongly dependent on humidity

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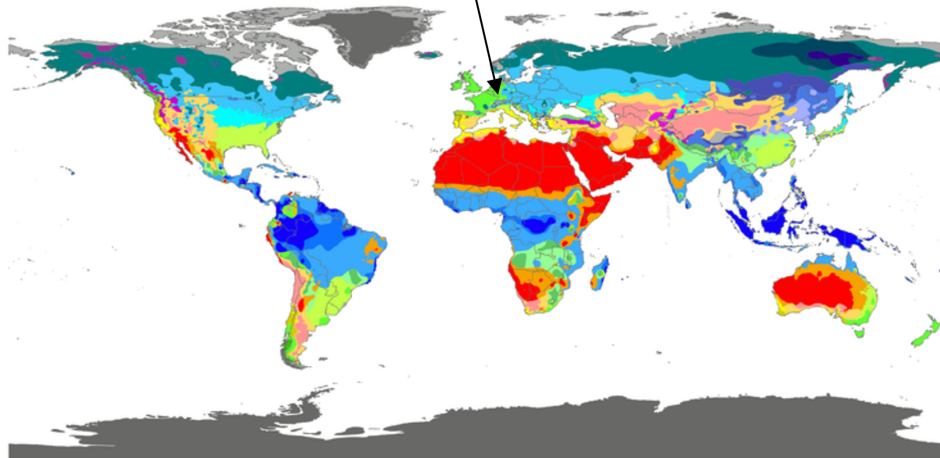
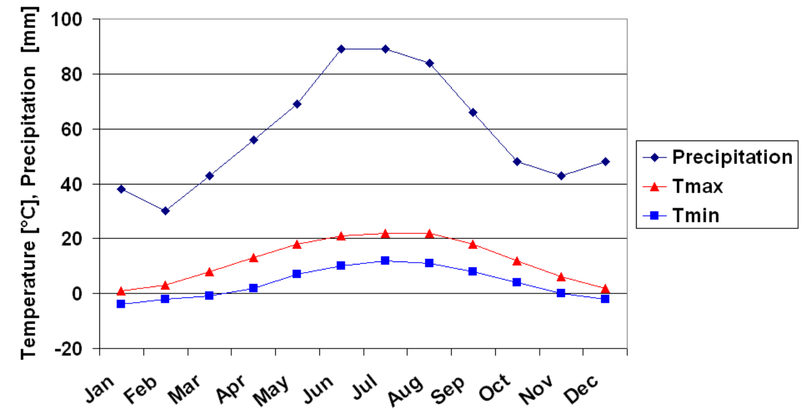
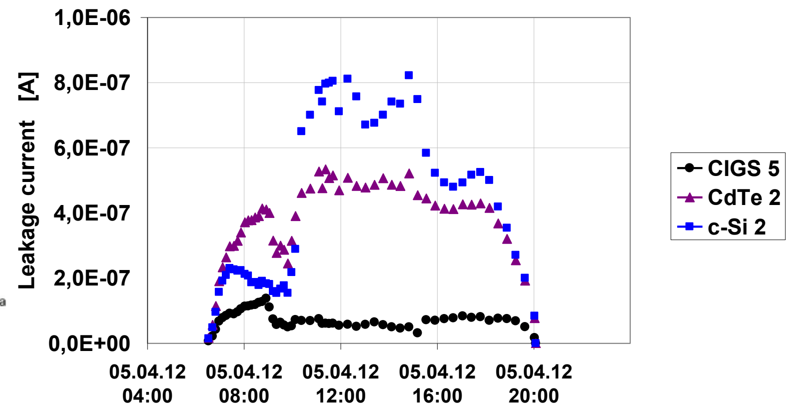
Evaluation of leakage currents in the field

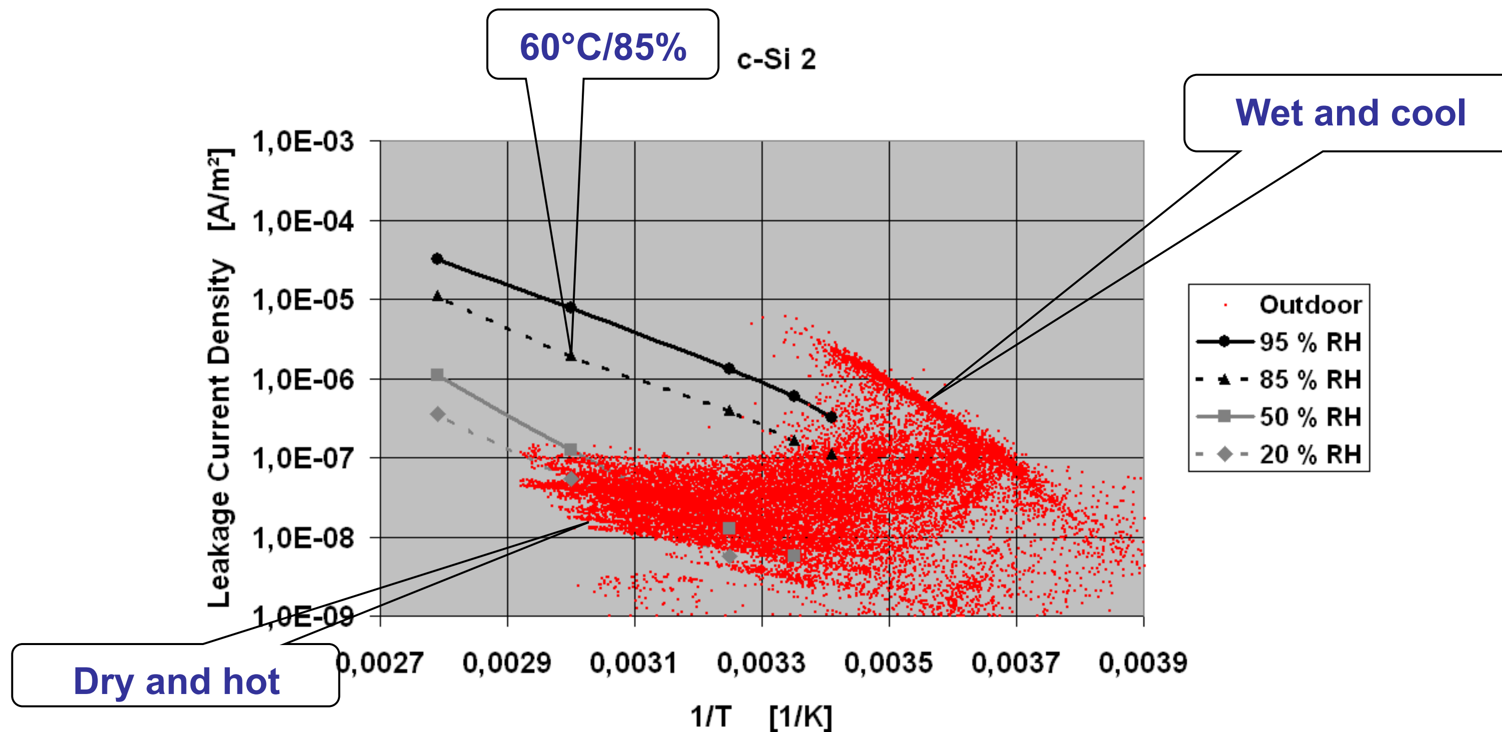
Location: Widderstall, Southern Germany
9.713°E, 48.537°N, 750m AMSL





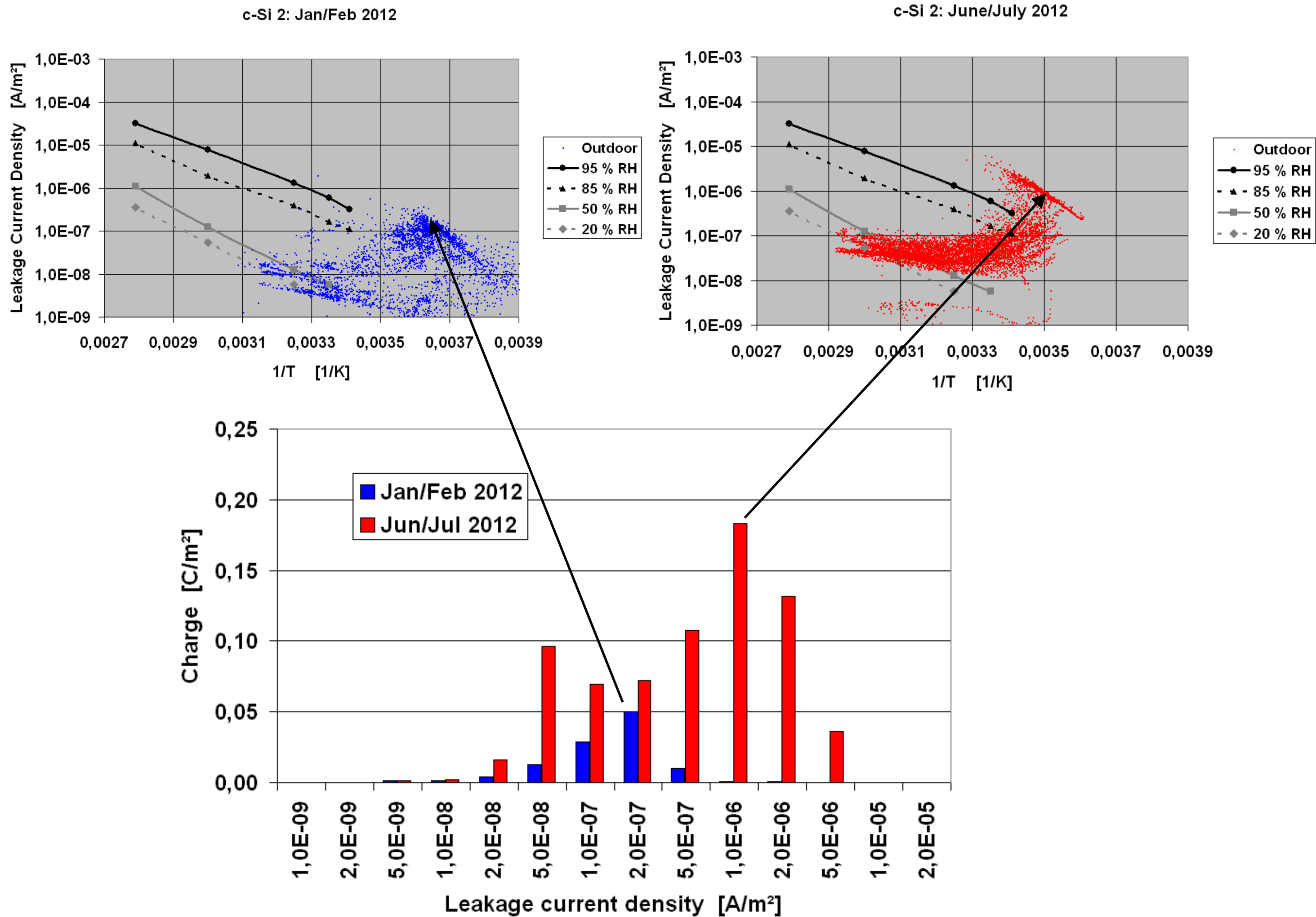


Superposition of chamber and field measurements
Outdoor from Jan to Jul 2012



- High currents for wet and cool modules
- Low currents for dry and hot modules
- Moderate “acceleration” at 60°C/85% vs. “wet and cool”

Summer/winter distribution of leakage currents and charge



- **major contribution to transferred charge stems from wet/cool modules**

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Estimation of time to 90% initial power (P90)

- If charge transfer would be the only PID-trigger -

Module type	Q from 85/85 for P90 [C/m²]	Qd from Outdoor [mC/m²]	Outdoor time)* to Q for P90 [yrs]
c-Si 2	0.6	7.5	0.2
Si-TF 2	33	32	2.8
CIGS 5	1.4	1.3	3.1
CdTe 2	23	6.1	10
CIGS 4	> 87	0.6	> 4*E2
CIGS 3	> 37	0.25	> 4*E2
Si-TF 6	> 300	1.4	> 5*E2

)* valid for location Widderstall, at about -800V Potential

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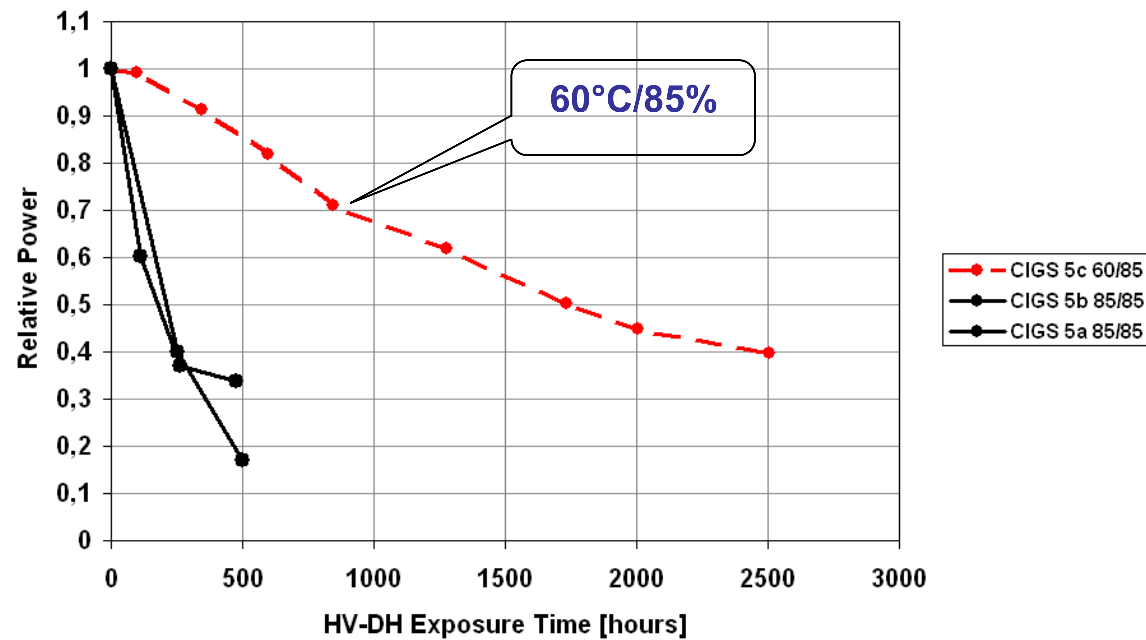
Does PID match with transferred charge?
Example: CIGS 5

P90

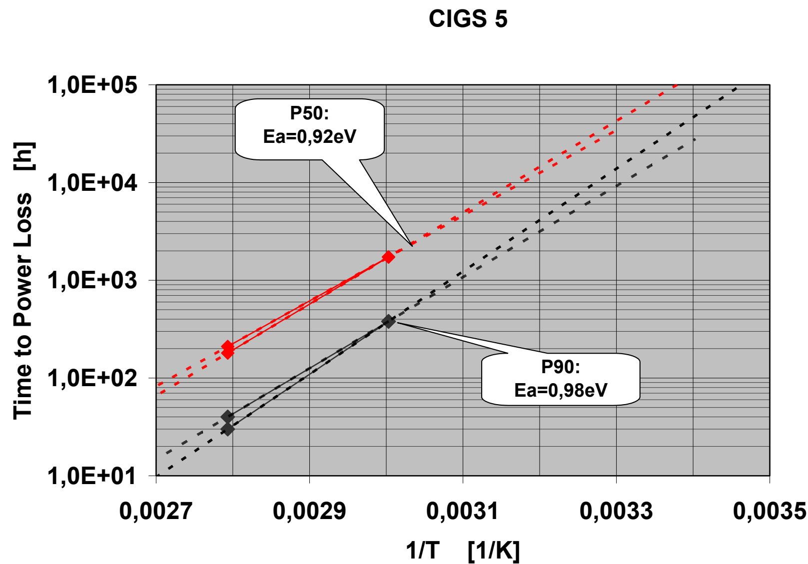
CIGS 5: 60/85/-1000 and 85/85/-1000

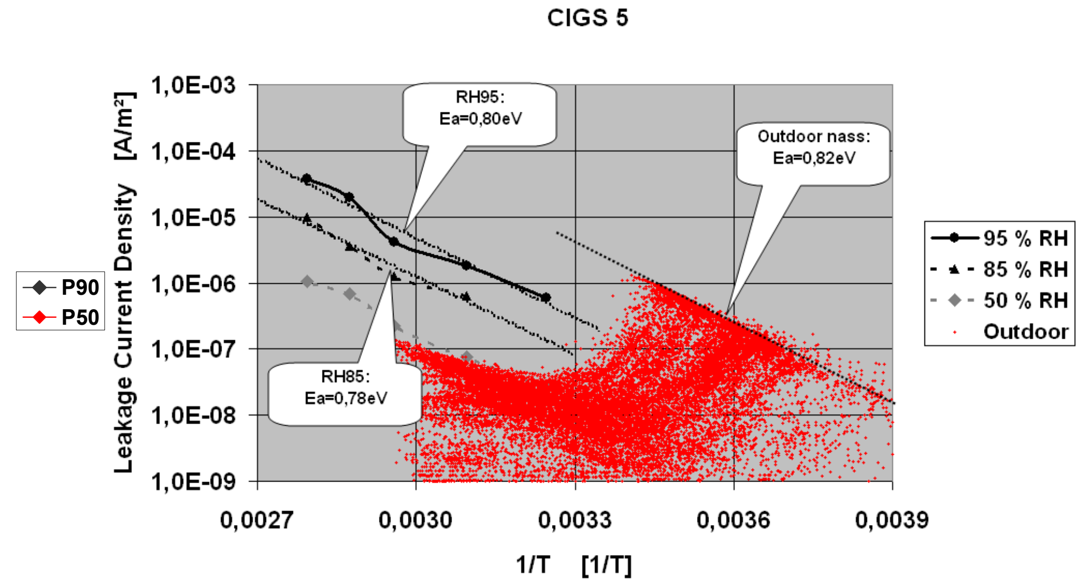


85°C/85%

Power loss vs. time

Activation energy for power loss and leakage currents CIGS 5



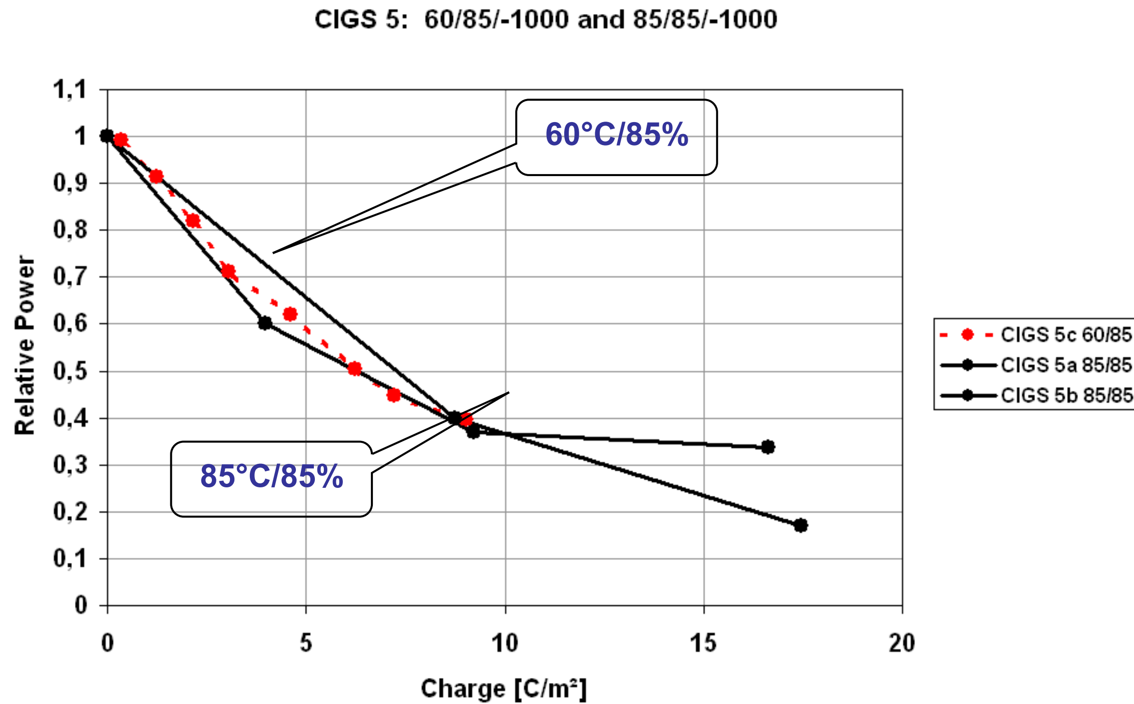


P-loss:
E_a = 0.92….0.98eV

Leakage current:
E_a = 0.78…0.82eV

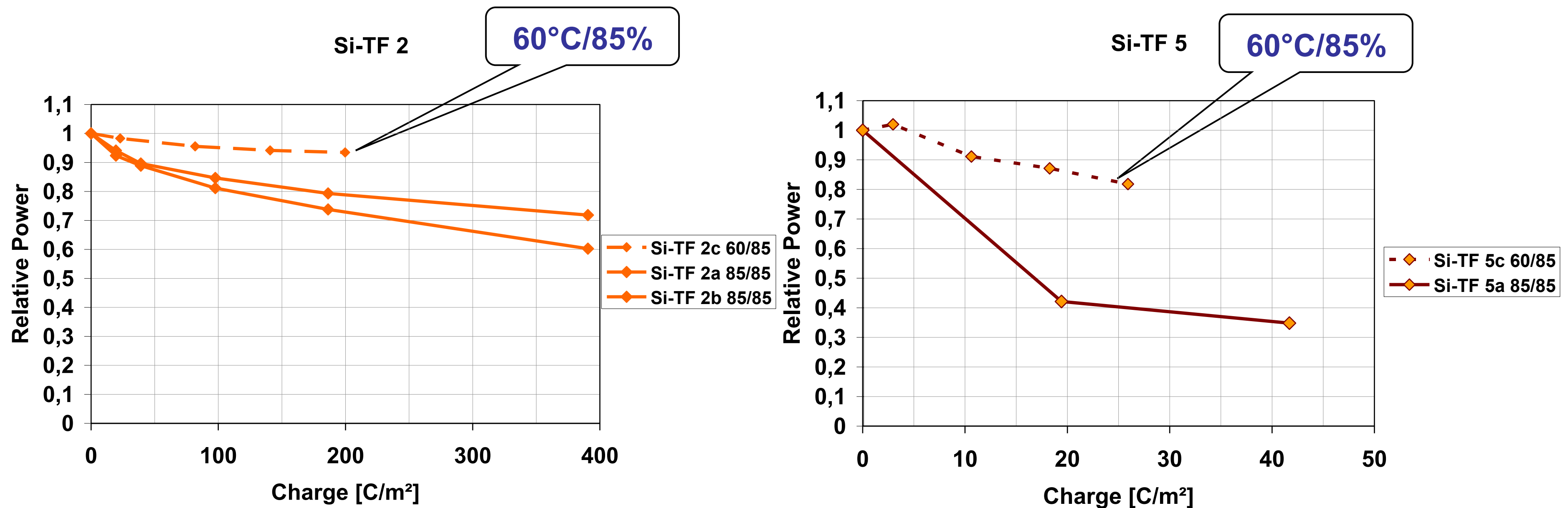
- E_a similar for P-losses and temperature activated leakage current

PID vs. charge
CIGS 5



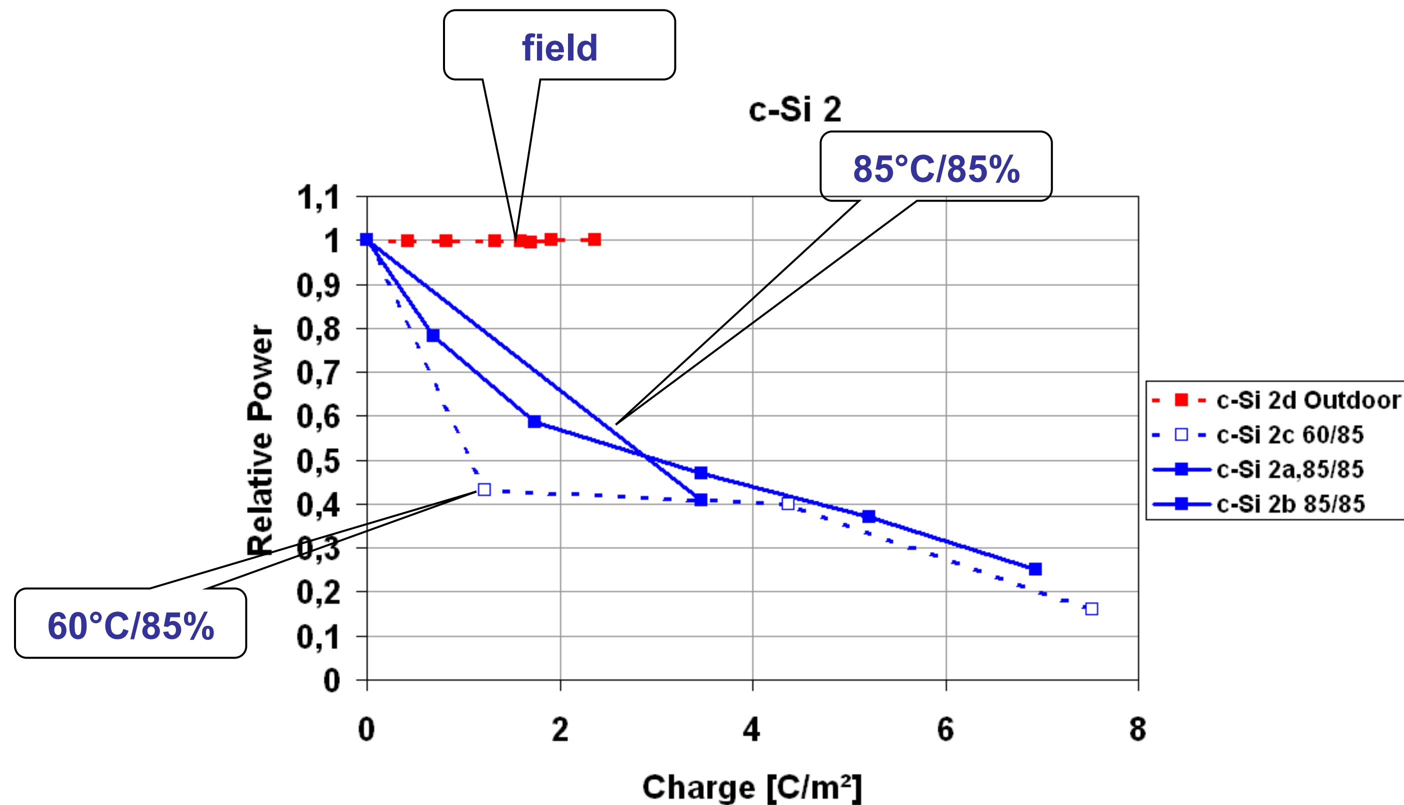
- Match of PID with transferred charge
- Field sample also seems to match with charge (not shown)

Does PID match with transferred charge?
(2) Si-TF



- No match of PID (TCO-corrosion) with transferred charge for Si-TF
- E_a = 1.1 to 1.2eV for power loss, much higher than E_a for leakage current
- Moisture ingression probably limiting at low temperature

Does PID match with the transferred charge?
(3) c-Si



- Possible match of PID with charge for 60/85 and 85/85
- No PID after more than 1 year in the field
- Module type failed IEC62804 test

Outline

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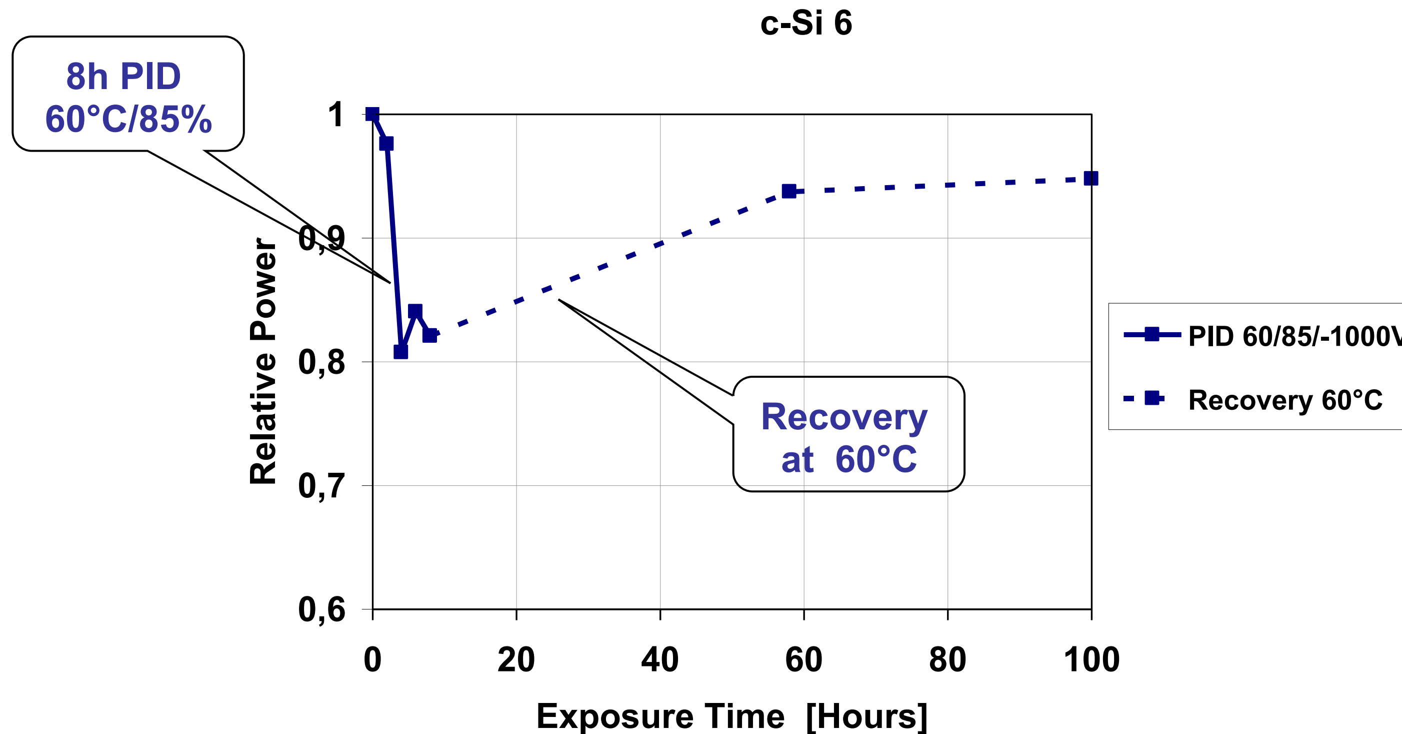
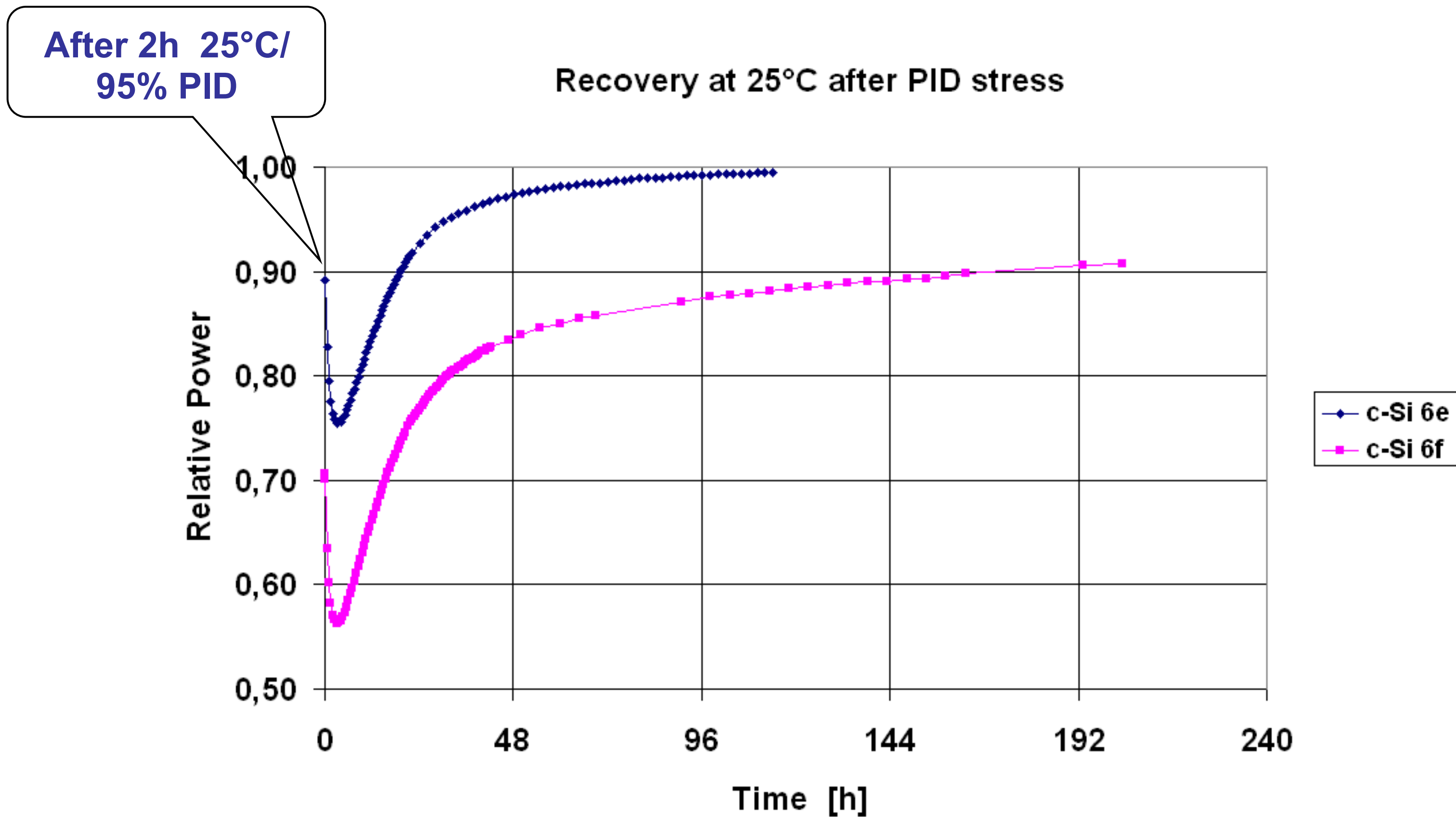
- Does PID match with charge?
- **Recovery effects**

Thermal recovery of c-Si after PID stress



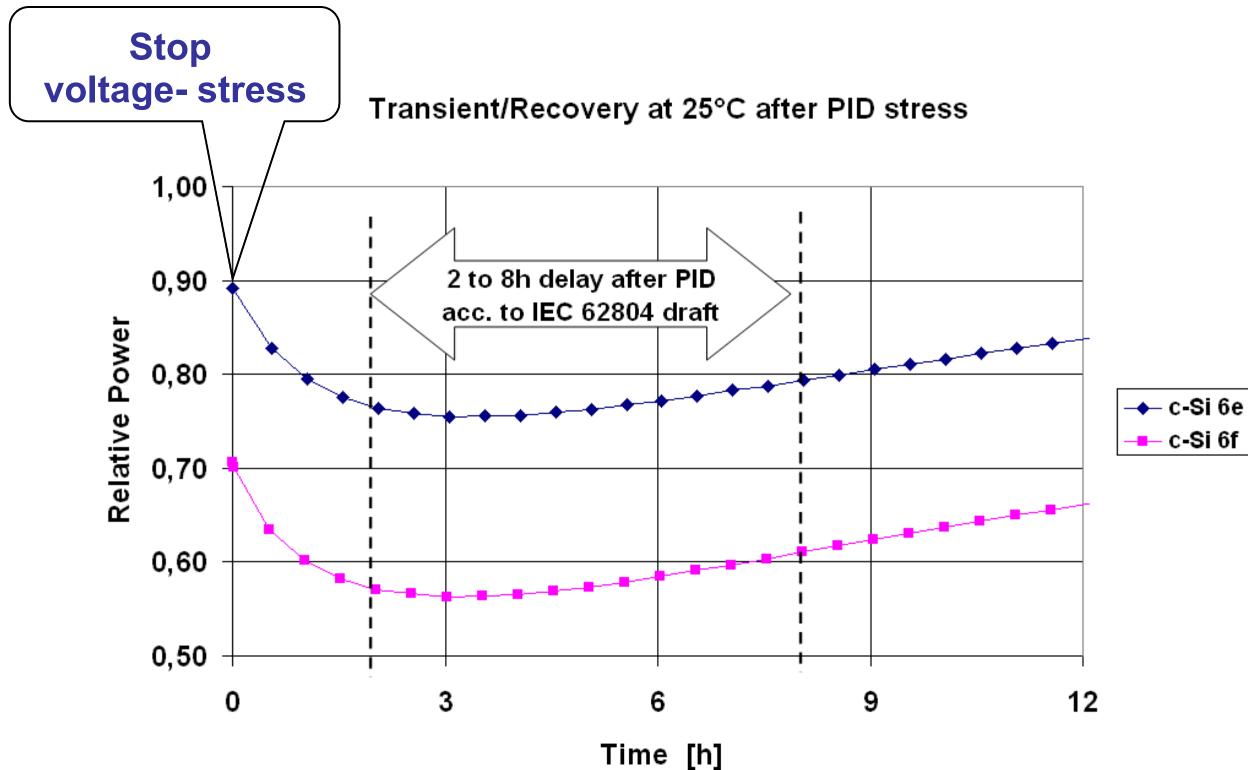
- Thermal recovery at low temperature is relevant for c-Si
- Is important for the field behaviour of c-Si:
  balance between periods of leakage current driven PID
  and temperature driven recovery

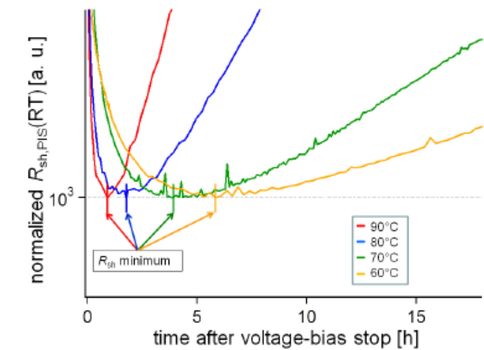
Thermal recovery of c-Si after PID stress (2)



- Relevant recovery even at 25°C possible
- Acceleration at higher T
- E_a is 0.7 to 0.8 eV

Thermal recovery of c-Si after PID stress (2)





C. Taubitz, EUPVSEC, 2012

- After stop of PID: power degradation continues for hours
- Within the 2 to 8h period after stress (62804 draft): power is not stable

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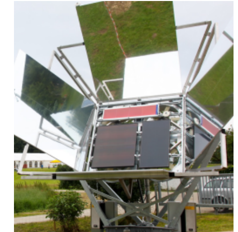
Conclusions and summary



- Leakage currents are
  - temperature activated with Ea 0.6 to 0.8eV and
  - significantly driven by humidity
- CIGS: Correlation of PID (60/85 and 85/85) with transferred charge
- Si-TF: No correlation of lab-PID with transferred charge; moisture ingression might be limiting for TCO-corrosion
- c-Si:
  - Correlation with transferred charge definitively not true for PID in the field
  - Thermal recovery from PID at low temperature can be relevant: needs to be addressed in the IEC Draft?
  - Thermal recovery might reduce the "acceleration" of stress tests at high T
  - Balance of leakage current driven degradation and thermal recovery controls PID for c-Si in the field

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Thank you for your attention

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