Accelerated Degradation by Light Illumination or Current Injection During Heat Tests on Flexible Thin Film Modules

(from the PVQAT TG8 Japan Team's activity)

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PVQAT TG8 – working on thin film modules

International PV Quality Assurance Task Force

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International PV Quality Assurance Task Force

The International Photovoltaic Quality Assurance Task Force (PVQAT) is leading efforts to develop standards with three primary goals:

1. Provide comparative information about the relative durability of photovoltaic (PV) modules when exposed to a variety of stresses, giving solar customers a baseline for improving the accuracy of quantitative PV lifetime predictions
2. Create a guideline for factory inspections of the QA system used during manufacturing.
3. Establish capability to issue PV system certifications.

PVQAT includes the following Task Groups. More information is available on each group's progress and current status.

- Task Group 1: PV QA guideline for manufacturing consistency — leaders Ivan Sinicco, Yoshihito Eguchi, Govind Ramu, Gunnar Brueggemann, Wei Zhou
- Task Group 2: PV QA testing for thermal and mechanical fatigue including vibration — leaders Nick Bosco, Tadanori Tanahashi, Simon Xiao
- Task Group 3: PV QA testing for humidity, temperature, and voltage — leaders John Wohlgemuth, Takuya Doi, Neelkanth Dhere, Tony Tang
- Task Group 4: PV QA testing for diodes, shading and reverse bias — leaders Vivek Gade, Yasunori Uchida, Hubert Volz, Chandler Zhang, Paul Robusto
- Task Group 5: PV QA testing for UV, temperature, and humidity — leaders Michael Koehl, Tsuyoshi Shioda, Jasbir Bath, David Miller, Ganxin Jie
- Task Group 6: Communication of PV QA ratings to the community — leaders David Williams, Sarah Kurtz, Pierre Verlinden, Haiyan Qin
- Task Group 8: PV QA testing for thin-film PV — leaders Neelkanth Dhere, Masayoshi Takani, Veronica Bermudez, Yaohua Mai, Jingong Pan
- Task Group 9: PV QA testing for Concentrator PV (CPV) — leaders Nick Bosco, Itai Suez, Rafael Xing, Bruce Wang
- Task Group 10: Connectors — leaders Juris Kalejs, Tony Tang, Shilin Fan
- Task Group 11: QA for PV Systems — leaders Sumanth Lokanath, Shilin Fan, Niuchen Hui.

To volunteer for any of these Task Groups, please contact the leader directly or

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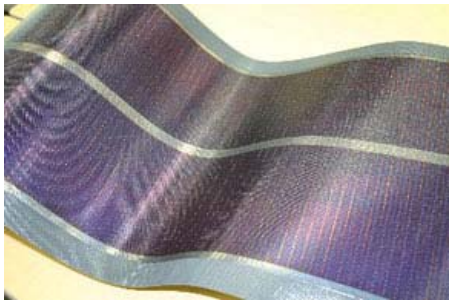
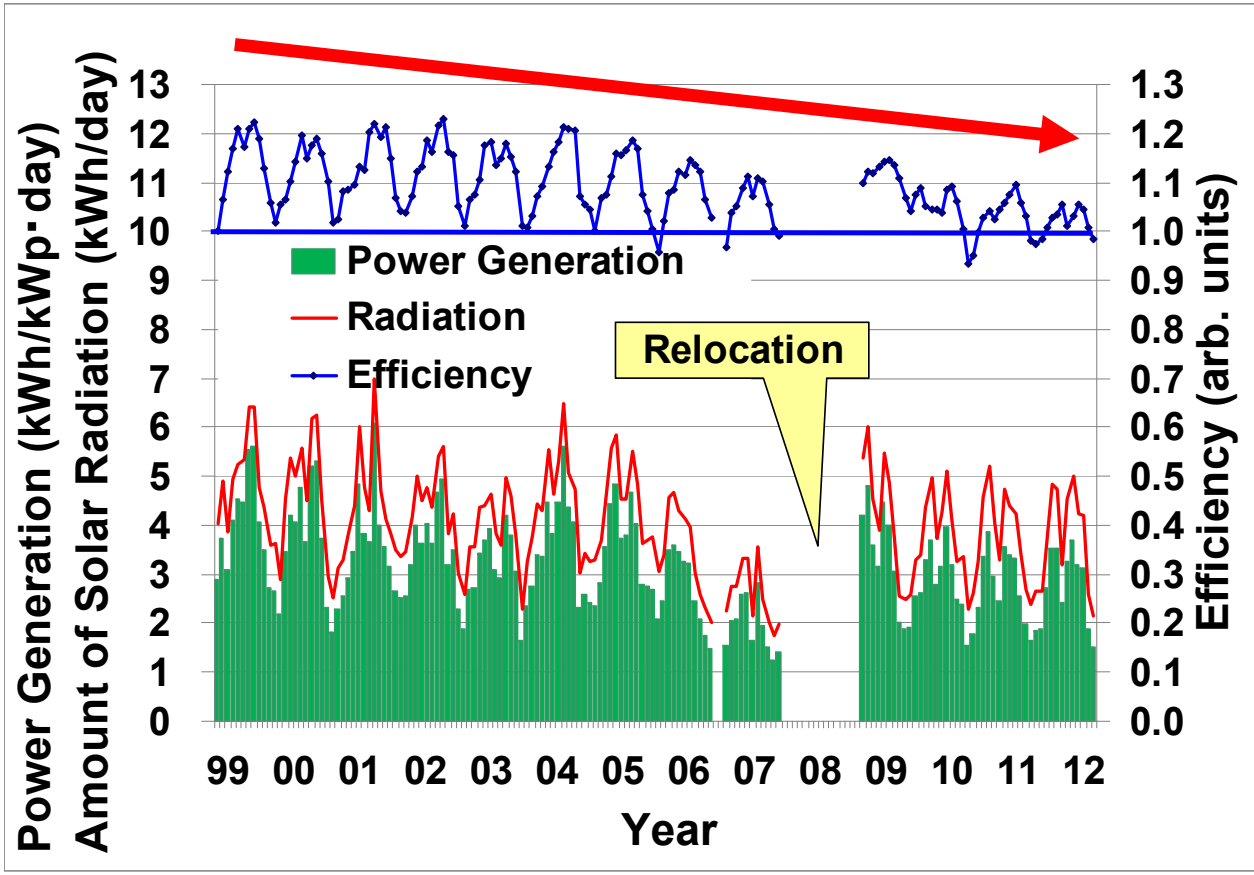


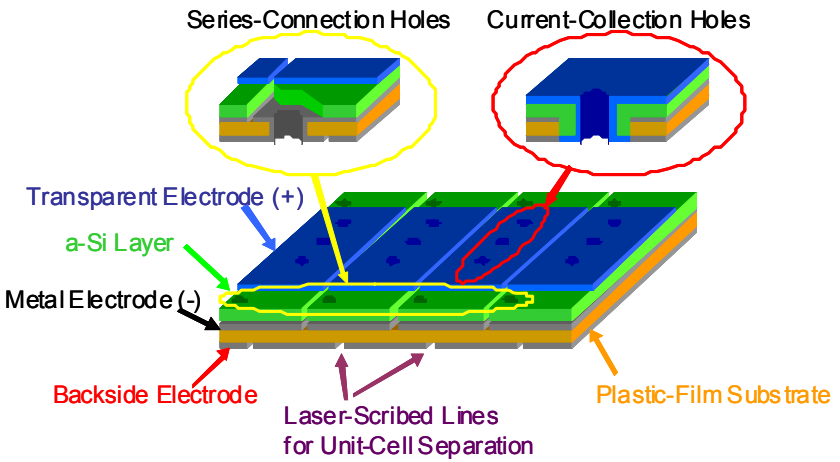
http://www.nrel.gov/ce/ipvmqa_task_force/

Unique degradation mode observed in a prototype Thin film Silicon flexible module(1)

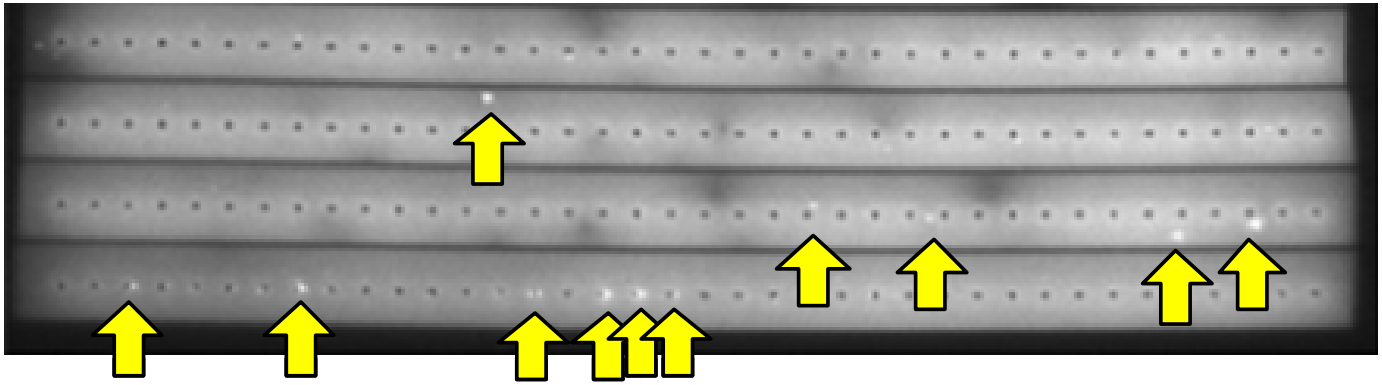


(A.Takano et al, EU PVSEC 2013, 3BO.5.4)

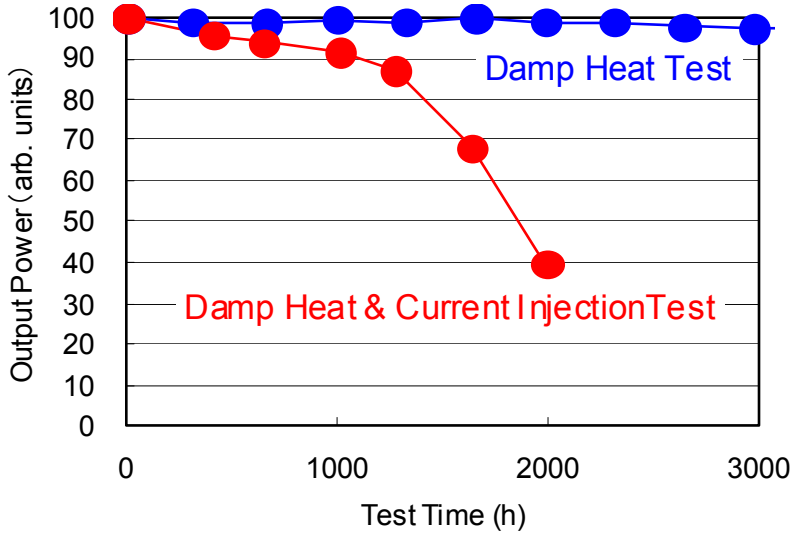
Unique degradation mode observed in a prototype Thin film Silicon flexible module(2)



EL image



(Leak points)



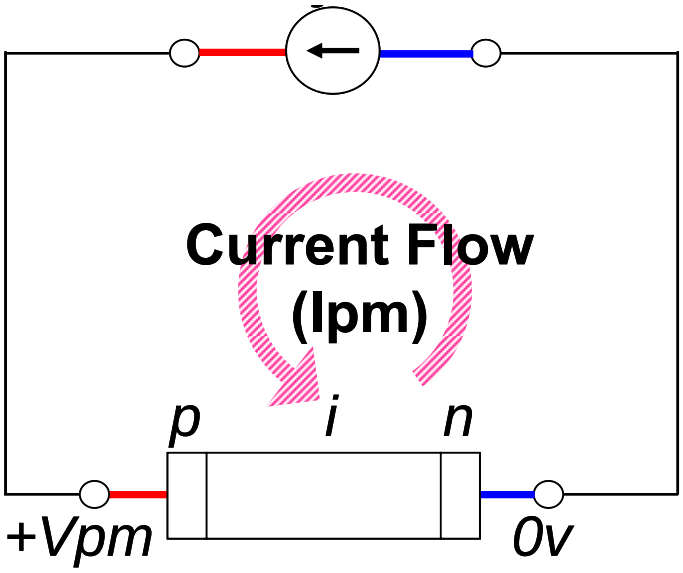
Degradation reproduced by Injecting current during damp heat testing (CDH test)

→ made it possible to fix the problem before mass production!

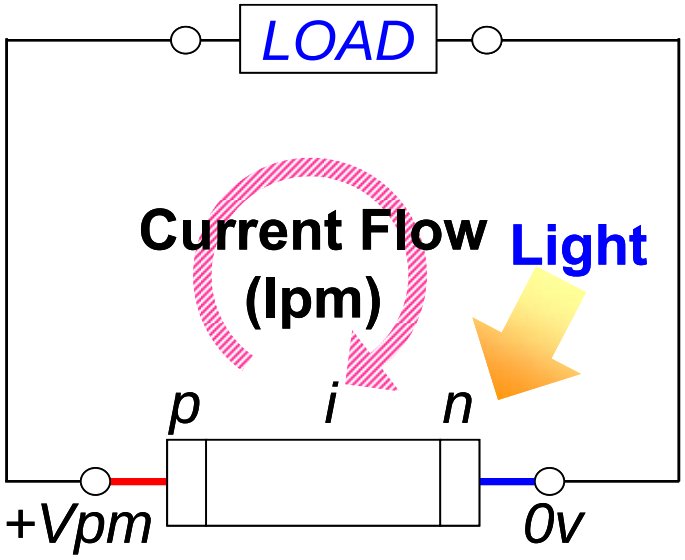
(A.Takano et al, EU PVSEC 2013, 3BO.5.4)

Current injection instead of light irradiation?

Current Injection + DH (CDH)

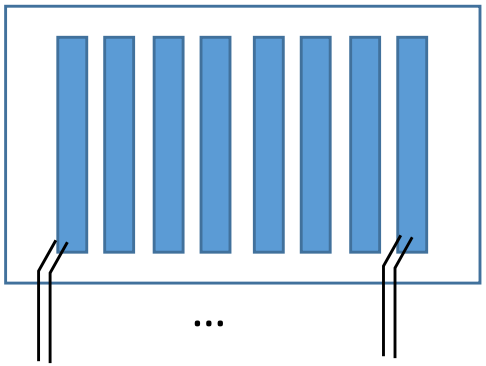


Light Irradiation+ DH (LDH)

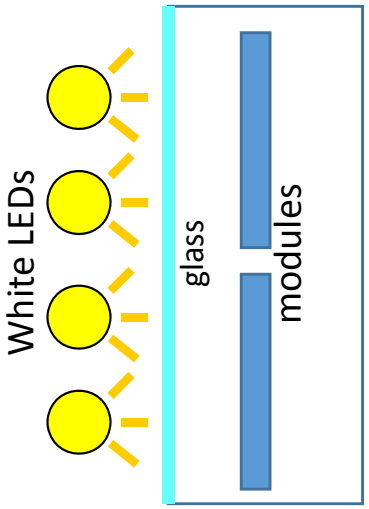


(A.Takano et al, EU PVSEC 2013, 3BO.5.4)

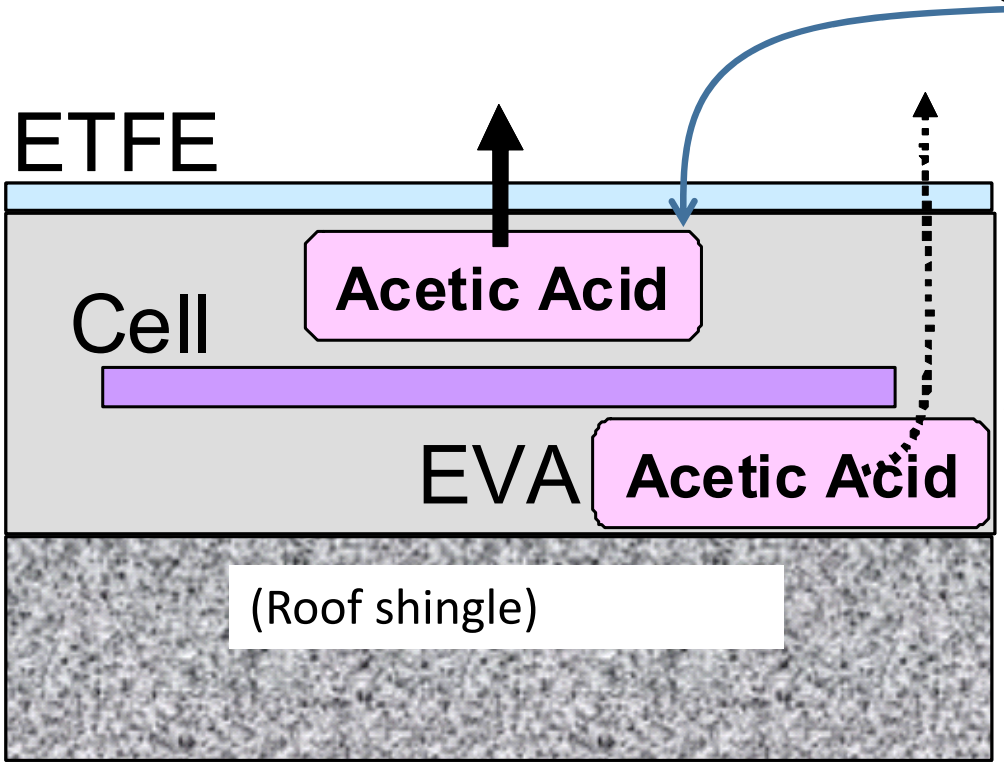
Many panels at one time
Reversed current flow

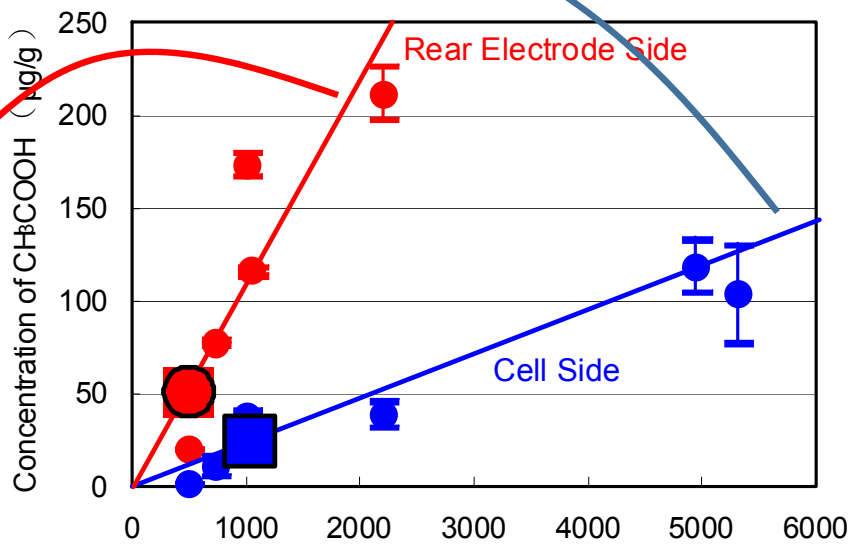


Large chamber (small number of panels)
Normal current flow

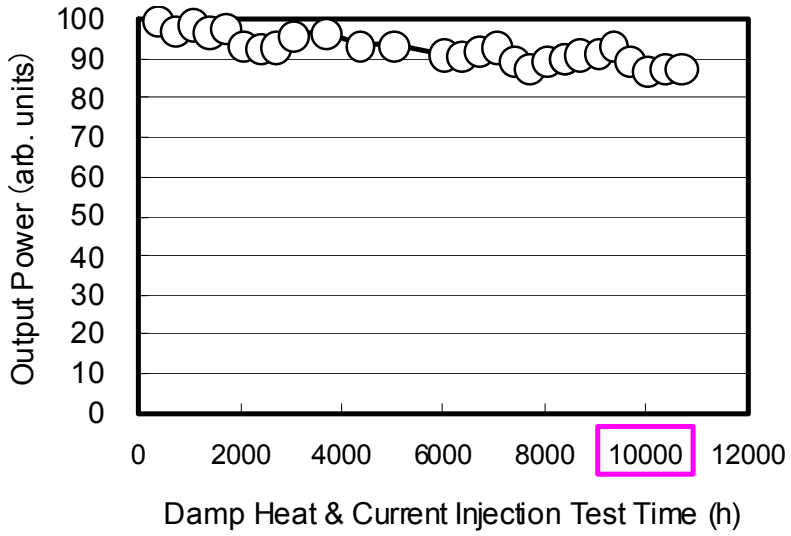


Cause of degradation?



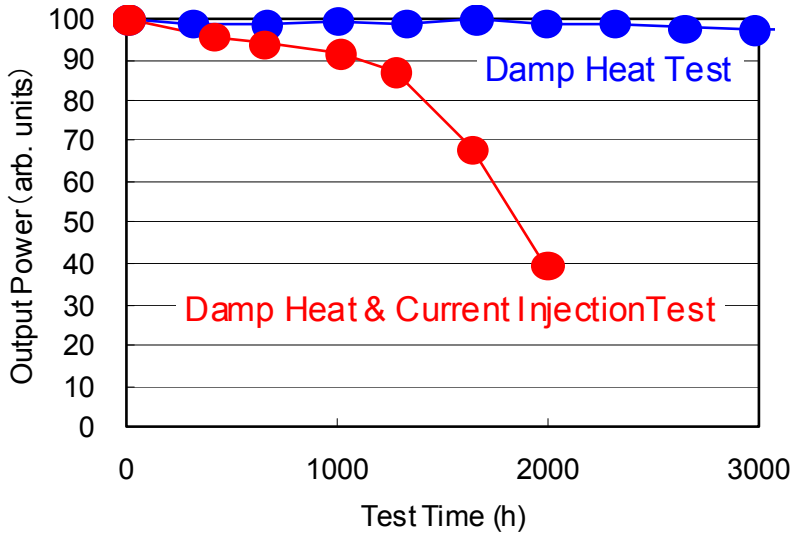


Change EVA to acid-free encapsulant→ longer lifetime



(A.Takano et al, EU PVSEC 2013, 3BO.5.4)

Question…



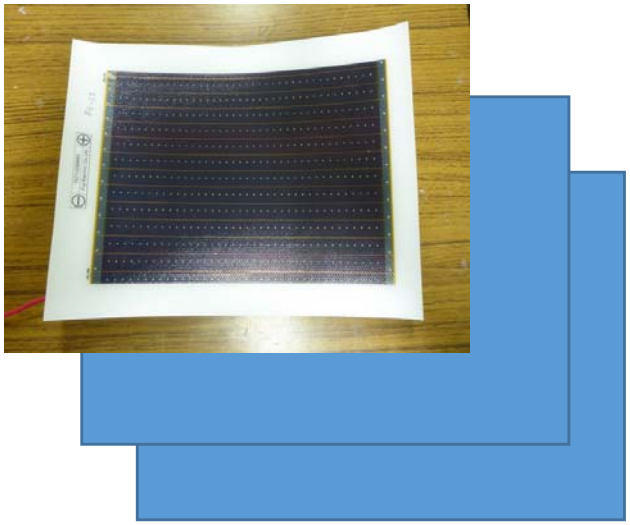
(A.Takano et al, EU PVSEC 2013, 3BO.5.4)

Is there any difference in results between current injection and light irradiation?

Would this CDH test reproduce degradations better on other types of modules as well?

- other flexible thin film Si products?
- flexible CIGS?
- rigid thin films?

Experiments



Flexible TF modules
- Thin film Si
- CIGS purchased in the market
  (not really designed for long-term use)

DryHeat (75～85℃ 20%)
(module temperature)
With visible light
irradiation

Damp/DryHeat with
Current injection

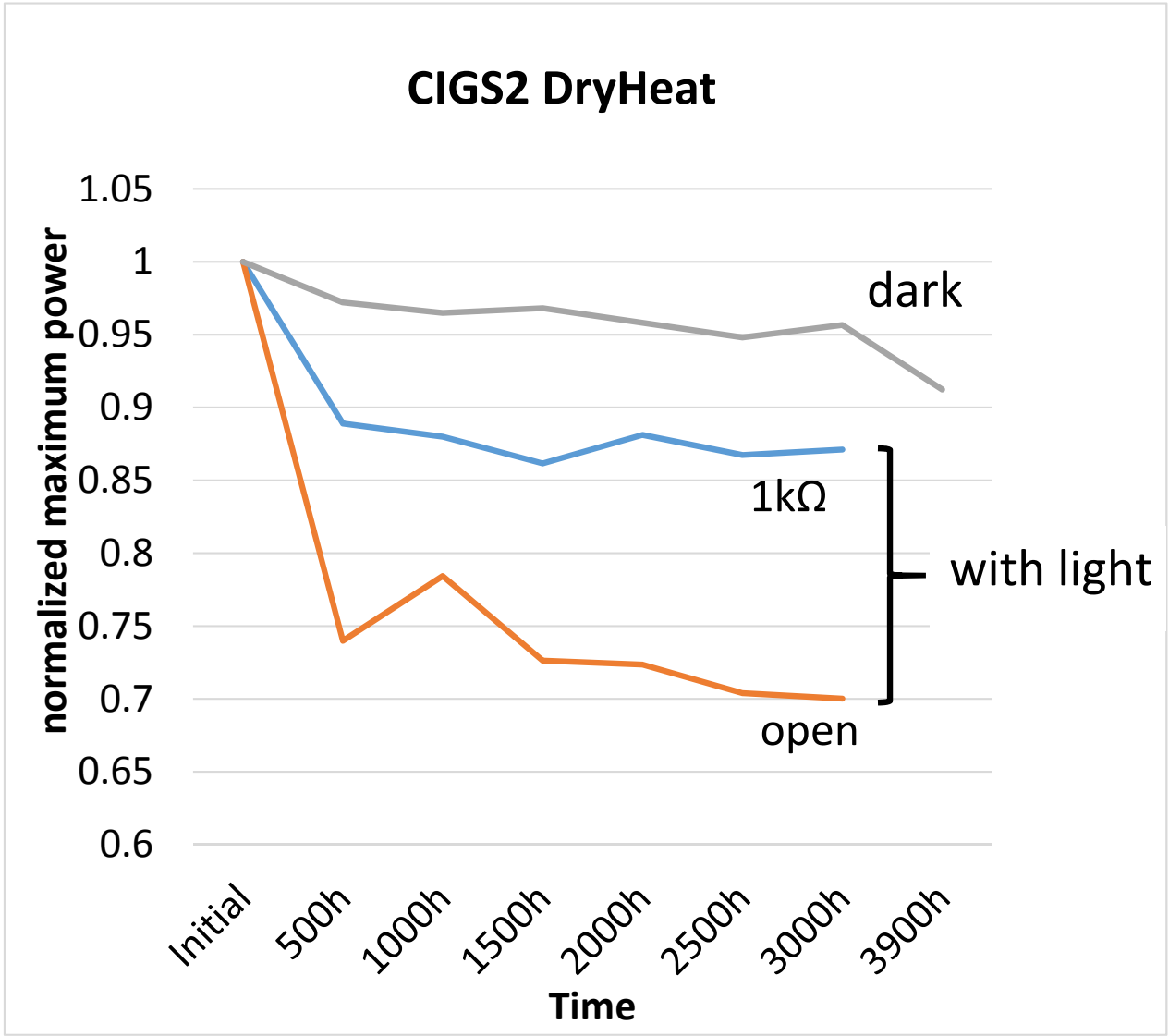
DryHeat (85℃ 20%)
or DampHeat
(dark)

Outdoor

(75～85℃ 20%r.h.
white (=blue+yellow)
LED, power close to
1kW/m^2)

Compare the degradation
(I-V, EL)

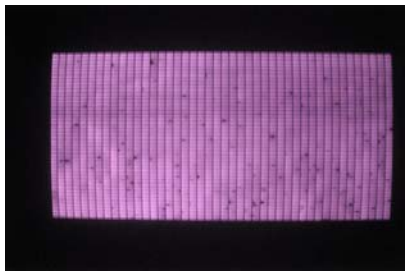
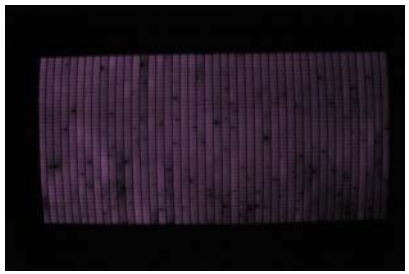
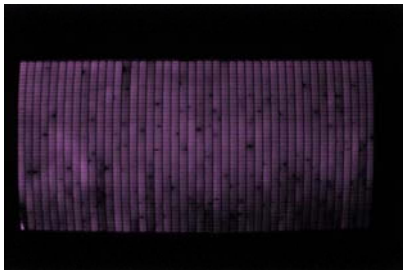
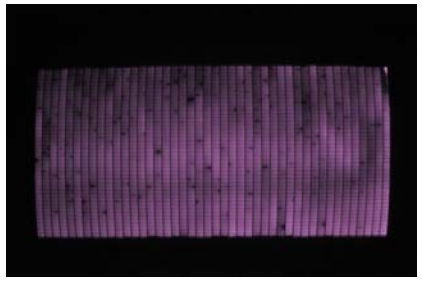
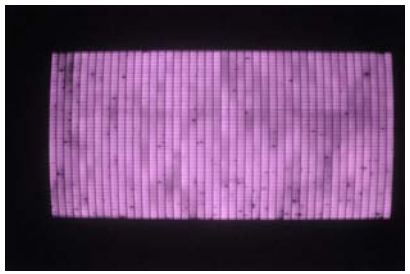
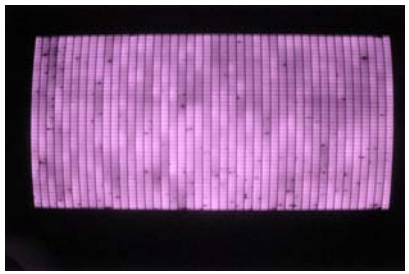
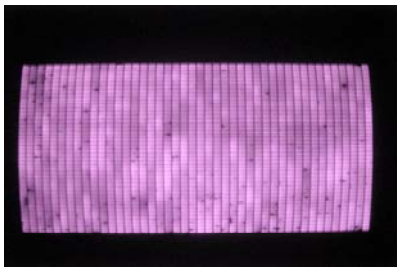
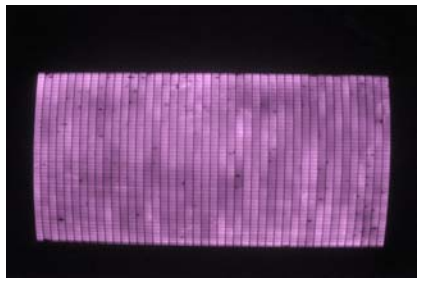
light + DryHeat : I-V: CIGS flexible product 2



- quick initial degradation followed by slow (or no) degradation
- decreased Voc & FF
- retained Isc

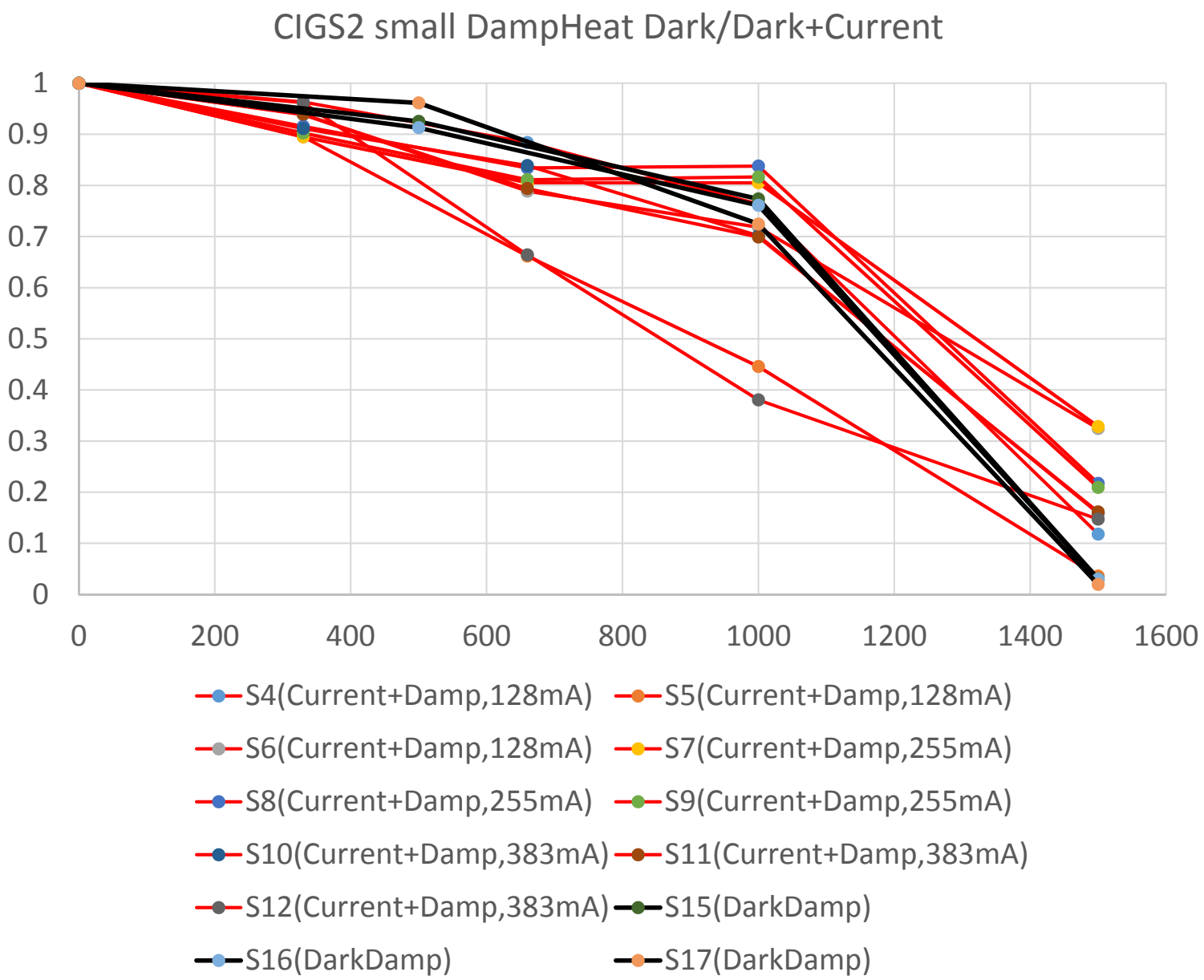
Note: sample number is small, individual difference may be present

light+DryHeat : EL: CIGS2

	initial	500hrs	1000hrs	3000hrs
CIGS2 Light+Heat(1kΩ)				
CIGS2 Light+Heat(open)	(Data lost)			
CIGS2 Heat (dark)				

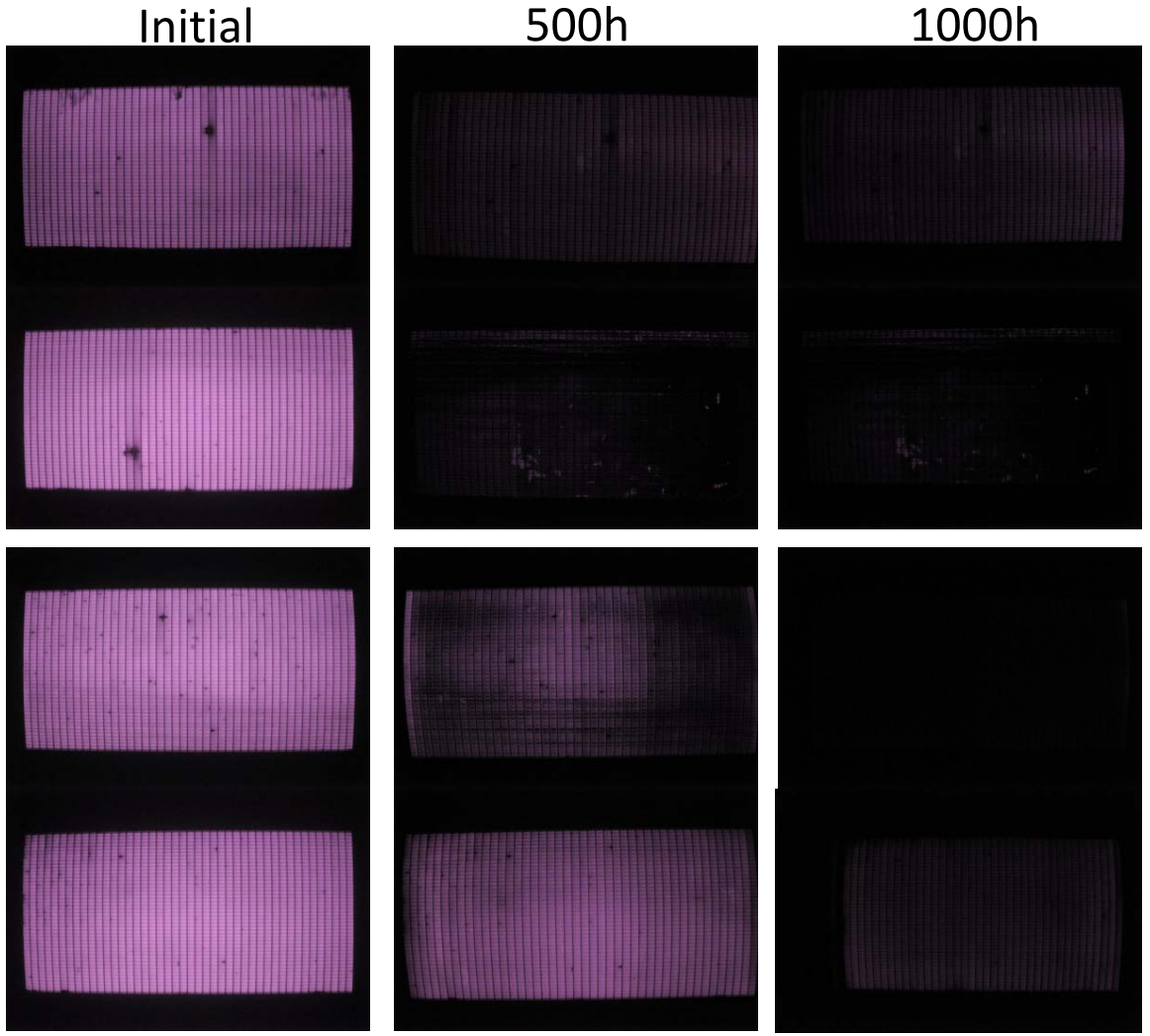
EL images darkened within first 500hrs of Light+DryHeat

current + DampHeat : I-V: CIGS flexible product 2



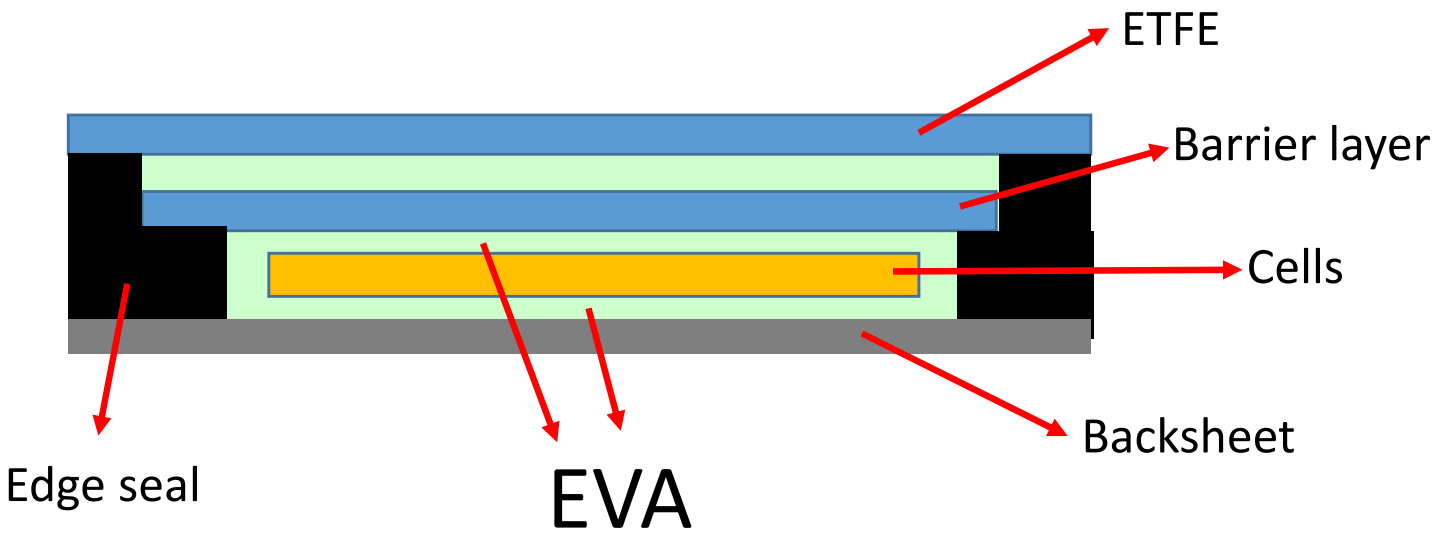
Degrades too fast under DampHeat conditions
-- couldn't observe any dependency with current

light+DampHeat : EL: CIGS2



Darker EL with light + DampHeat too --- darker EL seems clear
(However, difference in I-V not distinguishable up to 1000hrs
-- further tests underway)

CIGS2: Destructive analysis



rip off EVA close to the cell

- Ion Chromatography
- FT-IR (ATR)

Samples:

- Reference (as-purchased)
- Dark+DryHeat 3900hrs
- Light+DryHeat 3100hrs

CIGS2: Ion Chromatography (Reference / Dark+DryHeat / Light+DryHeat)

Acetic acid content in EVA（μg/g）

Reference (as-purchased)	10
Dark+DryHeat	140
Light+DryHeat	34

Increased acetic acid content by DryHeat
Large difference between Light and Dark samples

CIGS2: FT-IR comparison (Dark vs Light, both DryHeat)

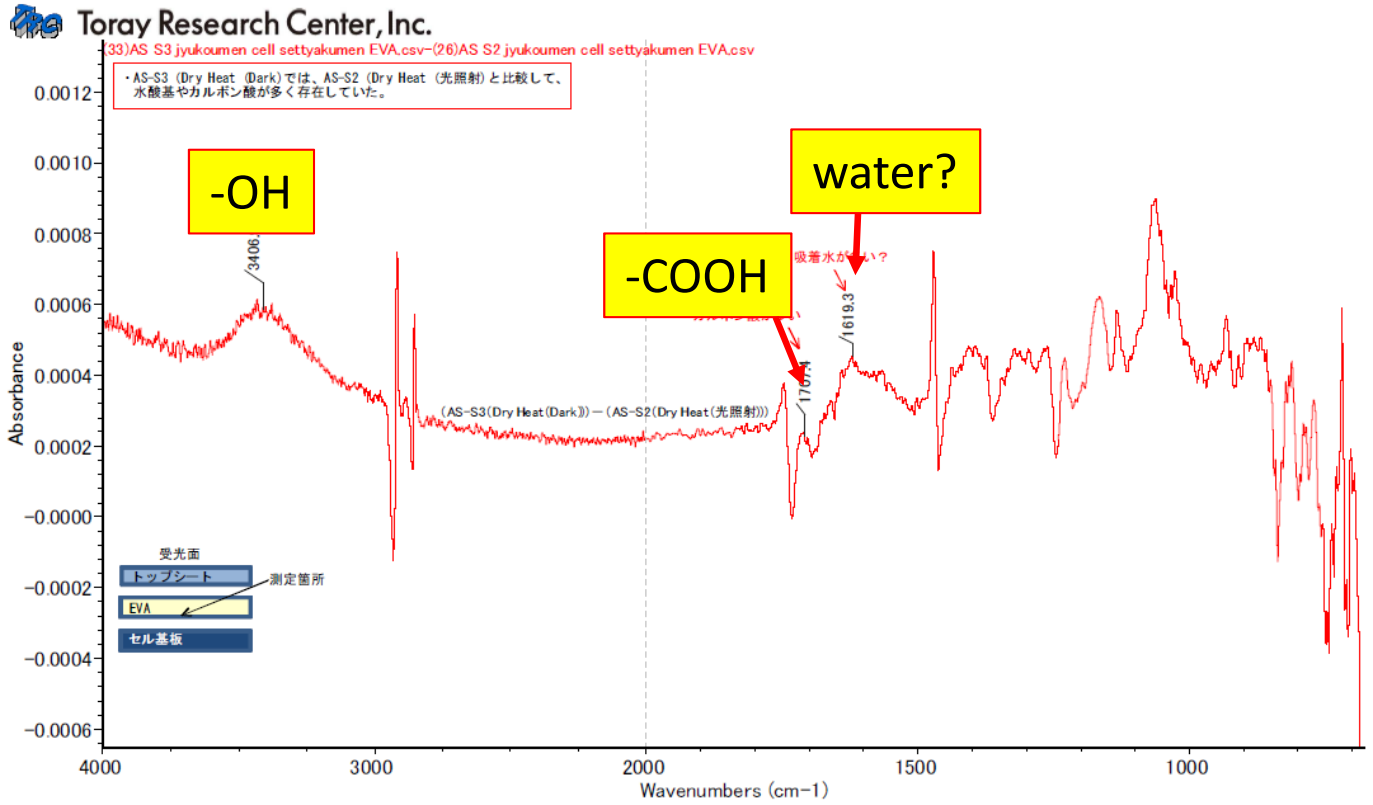


図17：AS-S2（Dry Heat(光照射)）とAS-S3（Dry Heat(Dark)）のFT-IR-ATRスペクトル比較
縦軸スケール：任意
縦軸オフセット：任意
差スペクトル基準ピーク：EVA由来1370cm-1

More -OH and -COOH observed in EVA of Dark+DryHeat sample

Summary

What can be said now:

Adding current injection (or light illumination) to conventional DH test

- was a must for at least one prototype flexible TF-Si
  actually did a crucial job to improve a product's durability
- may work better for at least one flexible CIGS product
  - darker EL by light illumination during DryHeat/DampHeat tests
  - degradation in Voc&FF by light illumination (possible)
  - change in acetic acid content in EVA by light illumination (possible)

If it is proved that the current injection does work better for multiple samples, then it would be worth considering modification of the IEC standard.

More "not-so-robust" samples & tests are needed.

If you can contribute, join us!

Thank you!

Further experiments

Small flexible modules

continue to gather more data (add more samples)

- Compare with outdoor results
- Add rigid modules as well?

Large flexible modules

- Light + Heat:

  underway at AIST
- Outdoor, Current injection+DH:

  To be tested at FSEC