

Thermal Cycling Combined with Dynamic Mechanical Load: Preliminary Report

Tadanori Tanahashi
ESPEC CORP.

Feb. 26, 2013
2013 PV Module Reliability Workshop

ESPEC: Products for Testing of Solar Modules

ESPEC



**Solar Panel
Large Walk-in Chambers**



**PID Evaluation System
(Chamber with Insulation Rack &
Leakage Current Meas.
System)**

DML -> TC Sequential Test

1. Recognition of Current Situation

- **TC 200 is not enough** (NREL PV Module Reliability Workshop, 2012).
- **Extended TC (ex. TC 600) may effective**, but the long-term period is required.
- In our experience, **the interconnectors- / solder bonds- failures have been observed** even in the moderate climate (ex. Japan).

2. Basic Concept

More Intense Stresses in Qualification Testing -> Depression of Infant Mortality
-> Long-term Survive (Probably) = Elongation of Service Lifetime

3. Requirements

- **Time Saving**
- **Similar Failure Mode with Thermal Cycling?**

4. Dynamic Mechanical Load (DML)

- DML induce the intense strain amplitude in ribbon (interconnector).
- DML is so fast.

5. Proposal: DML -> TC Sequential Test

- Consideration shall be given to the test condition (DML / TC)
- 1st trial is carrying out in TG-2 (JP).

PV QA Task Group #2: Current Status

(Discussion in IEC TC82/WG2 Meeting, Stresa & Oslo)

Proposed Test Sequence

1. Visual Inspection
2. EL image
3. Power Measurements
4. IR image
5. Insulation Resistance Testing
6. Wet Leakage Current Testing
7. **Dynamic Mechanical Load (based on NP 62782 Ed 1.0)**
8. **Temperature Cycling, TC/Humidity Freeze Cycling**
Consideration shall be given to the number of cycles, temperature ranges, rates of temperature change, and dwell times, etc.
9. Visual Inspection
10. EL image
11. Power Measurements
12. IR image
13. Insulation Resistance Testing
14. Wet Leakage Current Testing

DML / TC Test --- Notes for Discussion

What are the issues which need to be addressed before we can submit the NWIP?

1. Availability of **Extended TC**

- **Problems:** Become effective testing on the Today's PV modules?
(in the most recent technologies, components, and manufacturing techniques)
Become the rejection test for immature manufacturing?
- Massive survey for commercial modules is needed to recognize the current status.
- **To solve this issue, METI Project is ongoing.**

2. Availability of **DML**

- **Problem:** Differences / Similarities with the thermal fatigue.
Does the intense strain by DML induce a large number of cell crack?
- The experimental evidences are needed.
- **To solve this issue, NREL-AIST collaboration is carrying out.**

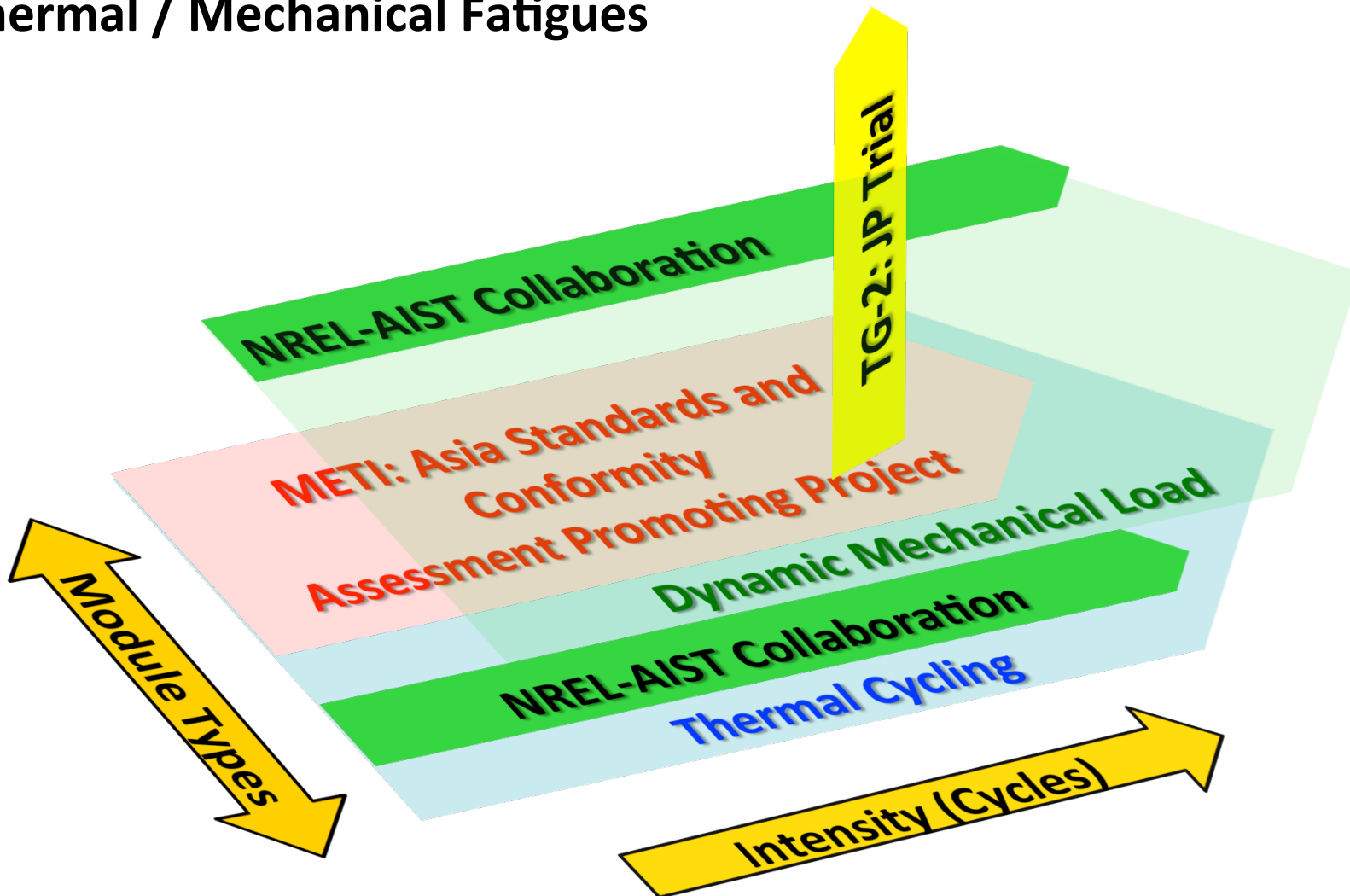
3. Availability of **Sequential Testing**

- **Problem:** To establish the effective test, can the deficit of TC be complemented by DML?
ribbon crack: induced by DML?
solder crack/delamination: induced by TC?
- The experimental evidences are needed.
- **To solve this issue, PV-QA TG-2 [JP] Trial is ongoing.**

4. Is there any other issues?

DML / TC Test

Ongoing Experiments
for the Establishment of Novel Test Procedure regarding with
Thermal / Mechanical Fatigues



Asia Standards and Conformity Assessment Promoting Project (Supported by Ministry of Economy, Trade, and Industry)

Aim:

Massive Survey for the Degradation Profiles of Commercial PV Modules

<Thermal Cycling Test>

c-Si PV modules:

- **13 Types of c-Si PV Modules (Mono- / Multi- c-Si)**
- **Sample Size: 10 or 5 Modules/Module Type**
- **Purchased from Market (JP and Other Manufactures)**
- **Most Recent Designed PV Modules (> 2011)**

Test Procedure:

- **According to IEC 61215**
10.11 Thermal Cycling Test
- **Thermal Cycling: 200, 400, and 600 Cycles**

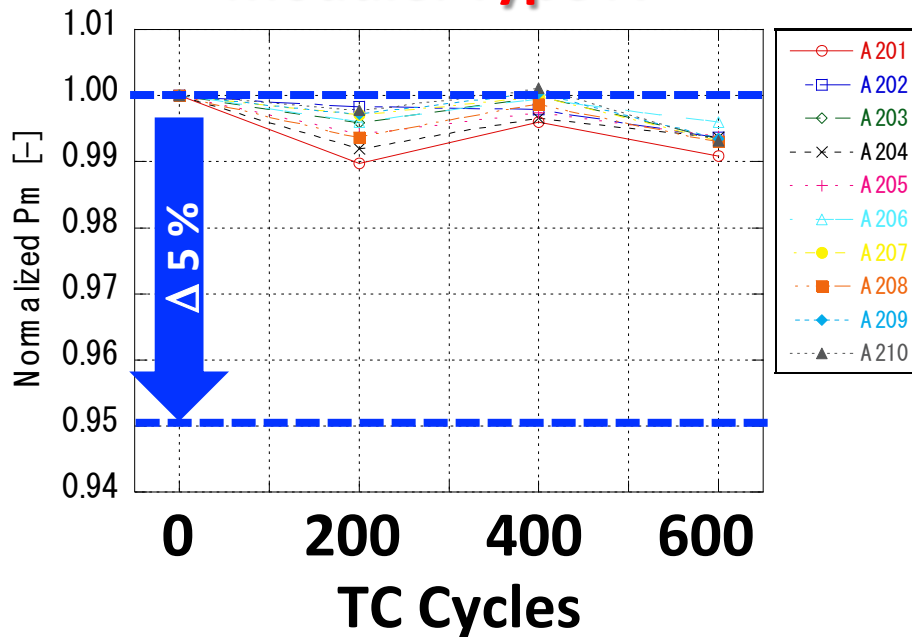
(Extended TC Testing)

Extended TC Testing (200, 400, and 600 cycles)

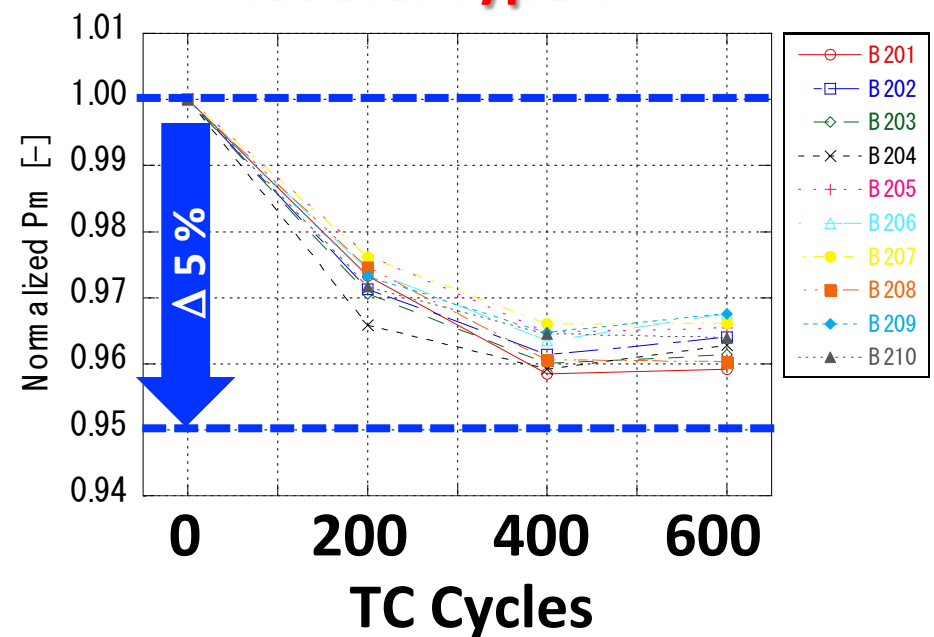
Sample: Commercial Available PV Modules (Multi c-Si)

2 Module Types, 10 Modules / Type

Module: Type A



Module: Type B



- Increase in R_s was observed in both modules (A: 2% , B: 6% in average).
- The changes of other I-V Parameters were little (almost stable).
- **The asymmetrical dark area along bus-bar did not appeared in EL images.**

Ref: T. Doi *et al.*, (2012) Statistical Evaluation of PV Modules with Extended Damp Heat Test and Extended Thermal Cycling Test, 2012 Annual Conference of RCPVT (AIST).

DML-TC Sequential Test

Contributors: AIST: Coordination
JET: Dynamic Mechanical Loading, Inspections
NPC: Laser Jsc Scanning (Inspection of Cell Crack)
ESPEC: Thermal Cycling Test

Objective: Compare with extended TC testing (TC: 600 cycles)
without Cell Cracks

- Power Loss

- EL Imaging

 - (Multiplication of Asymmetric Dark Area along Bus-Bar)

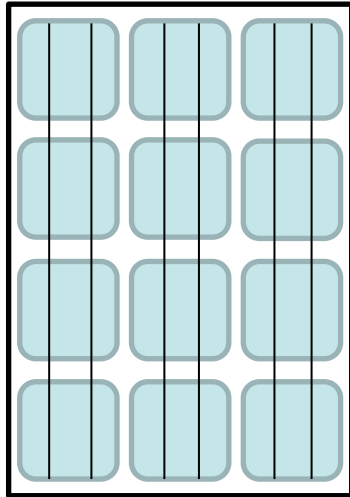
- Laser Jsc Imaging (Multiplication of Cell Crack)

Modules: Type A / B (Multi-c-Si)
(Module types are same with those in TC600 Testing)

DML-TC: Each 2 Modules of 2 Types

Reference: Each 1 Module of 2 Types

DML-TC Sequential Test



DML



Thermal Cycling



**Multi-c-Si
Modules**

Type: A
192.5 W

Type: B
185.0 W

IEC 62782

+ / - 1,000 Pa
1,000 Cycles
3 cycle/min
at RT

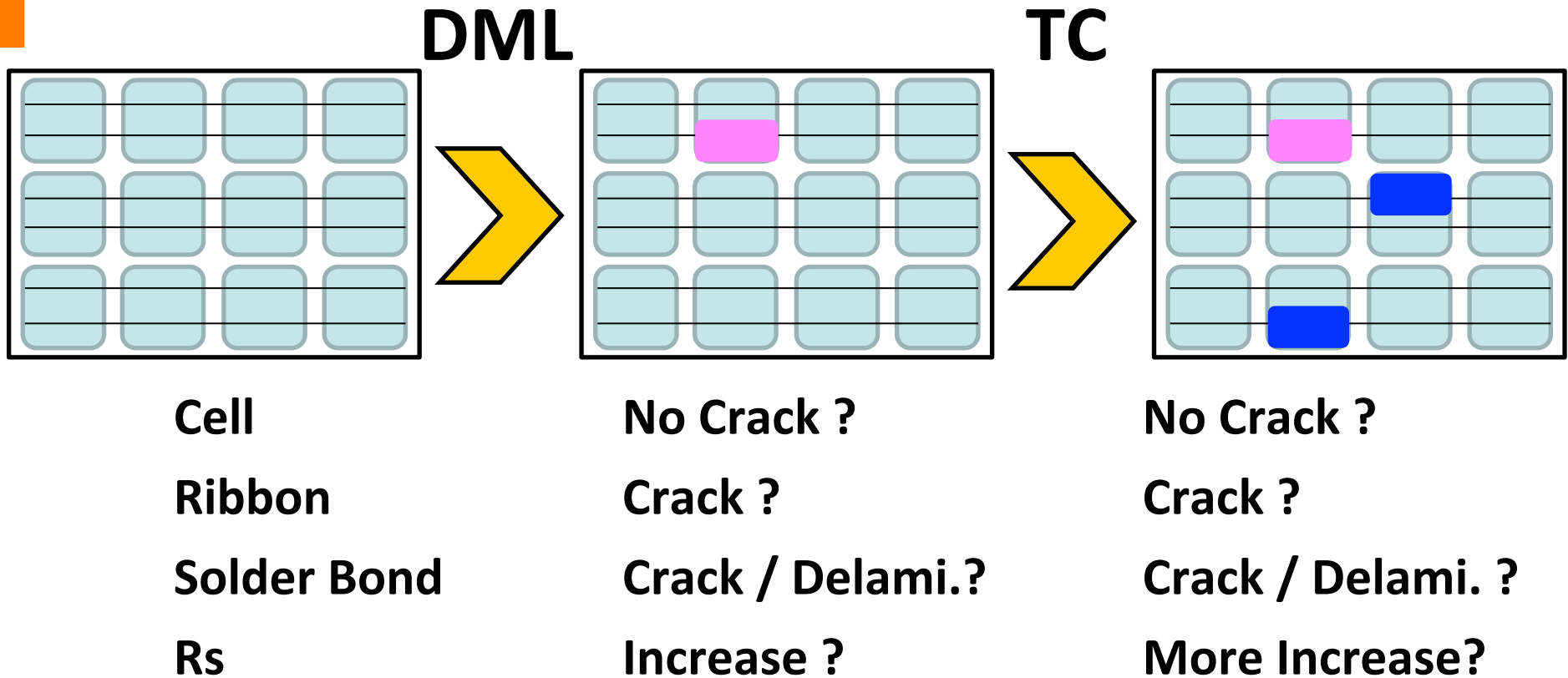
IEC 61215:2008

10.11 Thermal Cycling Test
-40 / 85 °C
200 Cycles
w/ Current (Ipm,
at > 25 °C)

DML-TC Sequential Test

Putative Results (Ideal)

Focus:
Ribbon / Solder Crack, but not Cell Crack



  Asymmetric Dark Area along bus-bar in EL Image

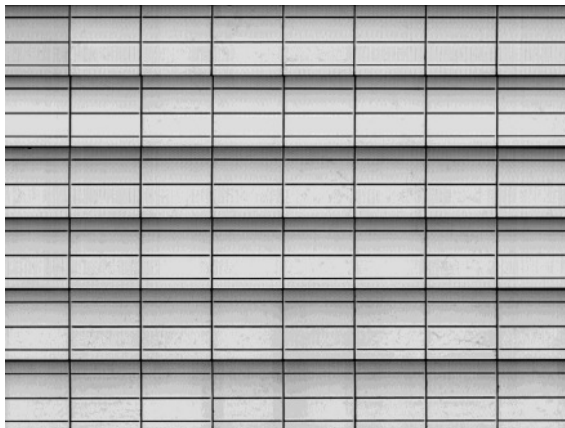
“No Cell Crack” was inspected by Laser Imaging

DML-TC Sequential Test

Laser Scanning Crack Detection

NPC Incorporated : “Module Laser Inspection Machine (NLS-M)”

- Laser scanning (narrow spot) with optimized bias current
 - > Reconstitution of Jsc Image
- SEMI PV Group (JP): Proposed a Standard as “Cell Crack Inspection Method’



Laser Jsc Scanning Image



DML-TC Sequential Test

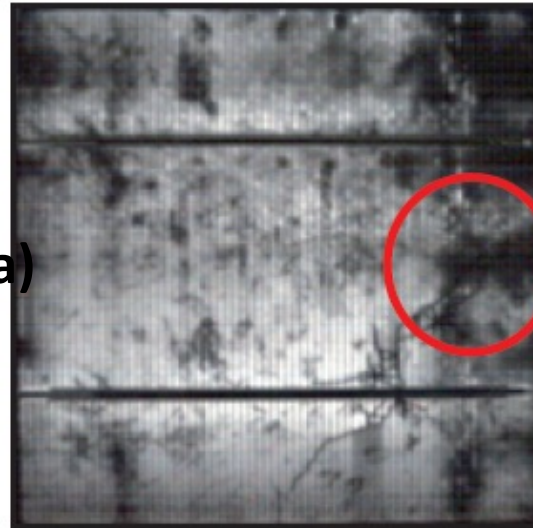
Laser Scanning Crack Detection

Cell Crack

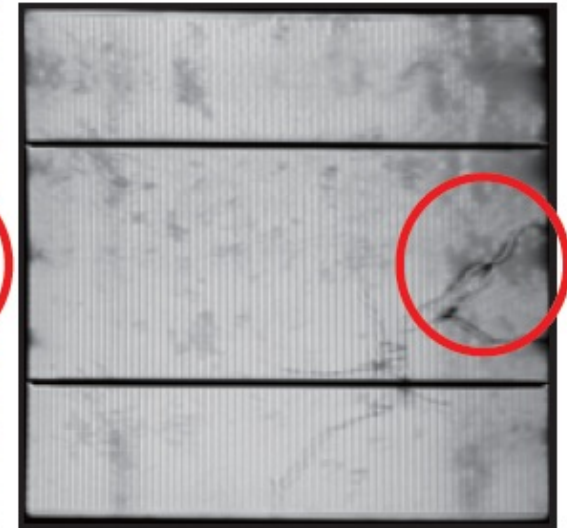
EL: Pseudo-Negative
(Not Clear in Dark Area)

LS: Positive
(Clear)

EL Image



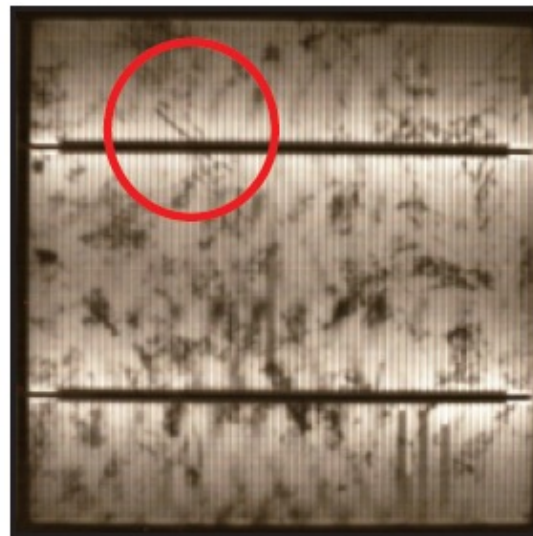
Laser Scanning



Cell Crack

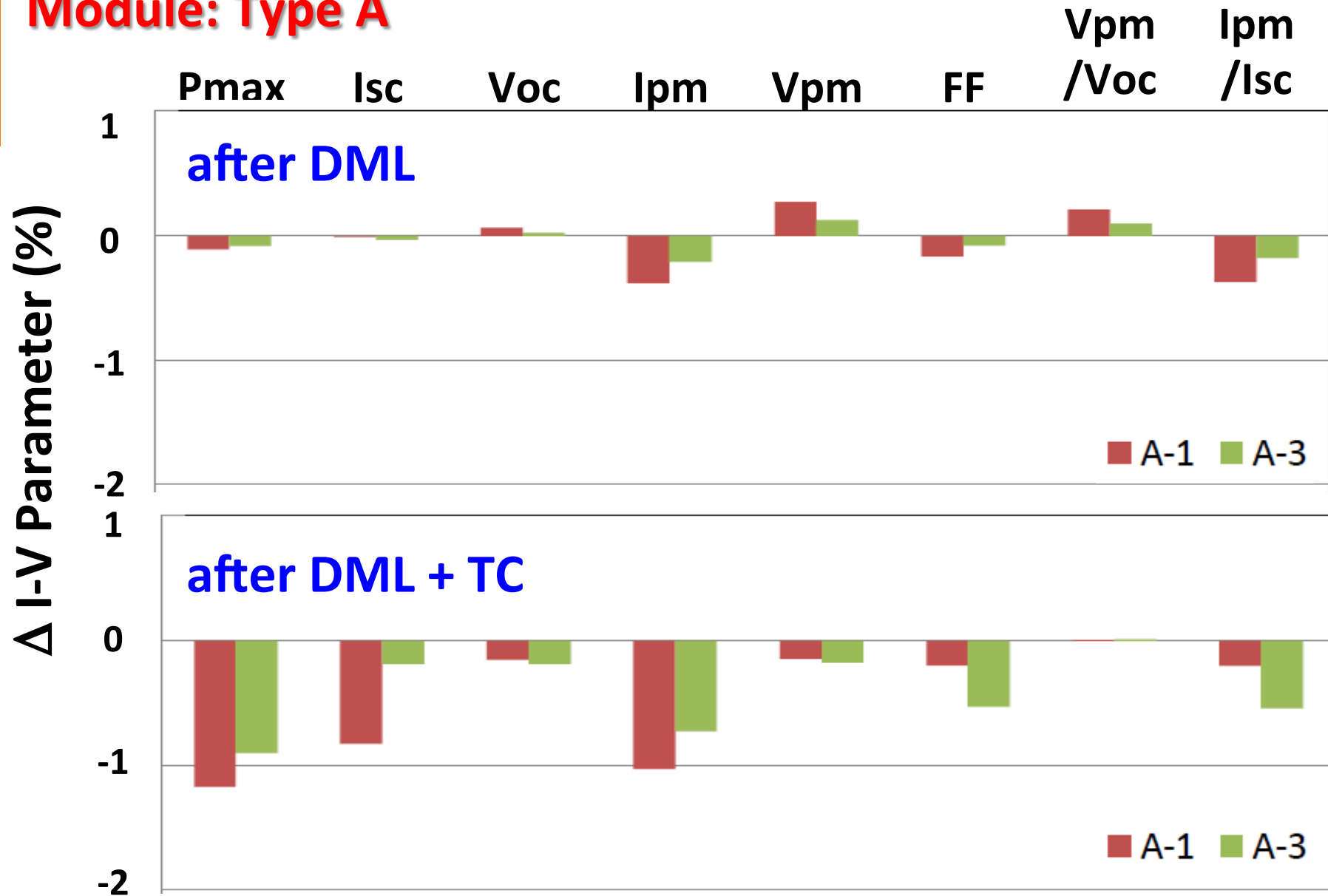
EL: Pseudo-Positive

LS: Negative



Changes of I-V Parameters after DML/TC Testing

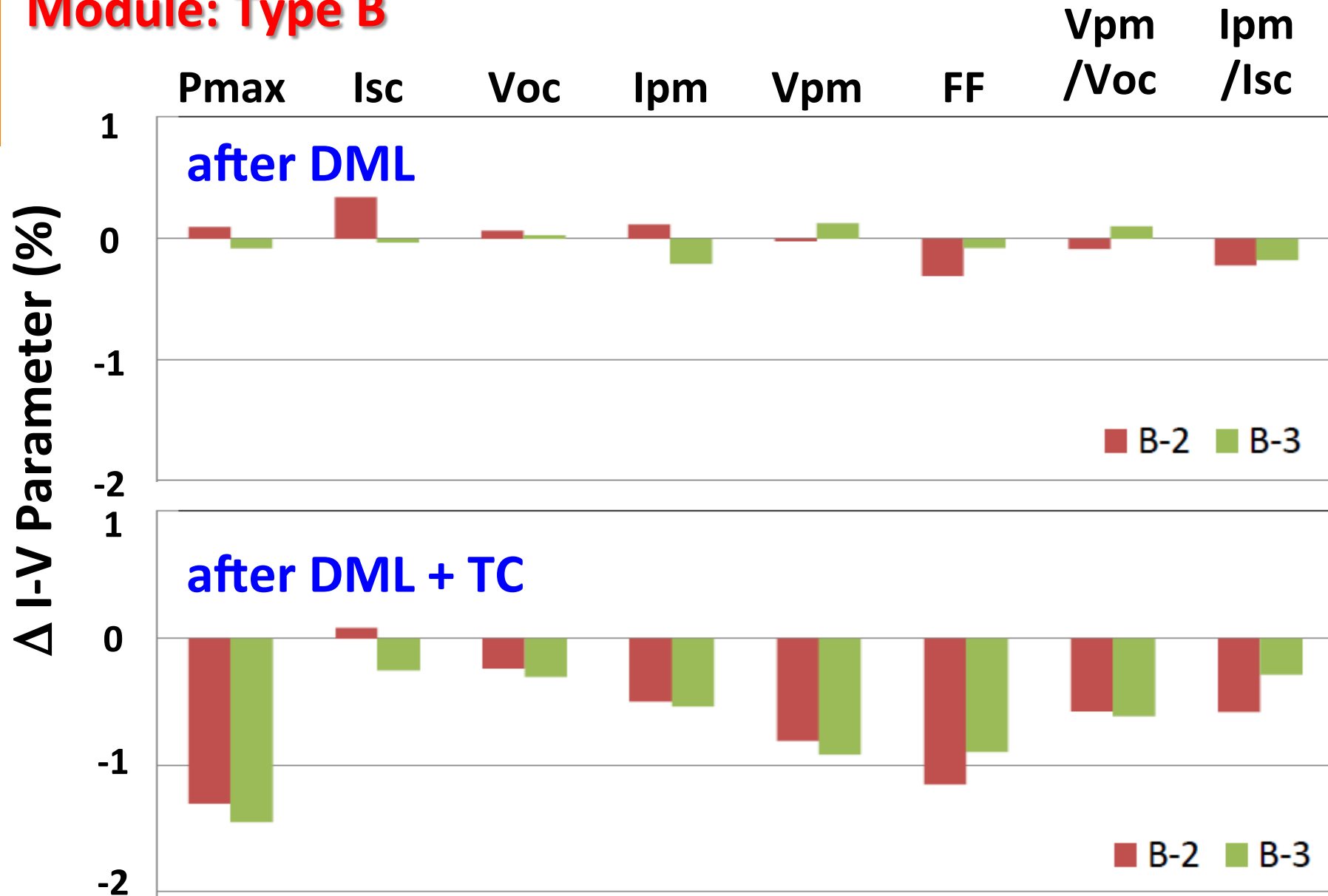
Module: Type A



Changes of I-V Parameters after DML/TC Testing

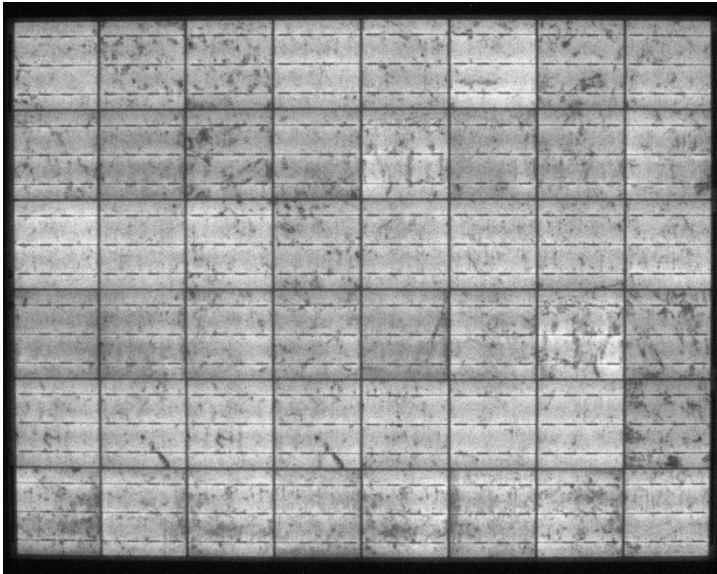


Module: Type B

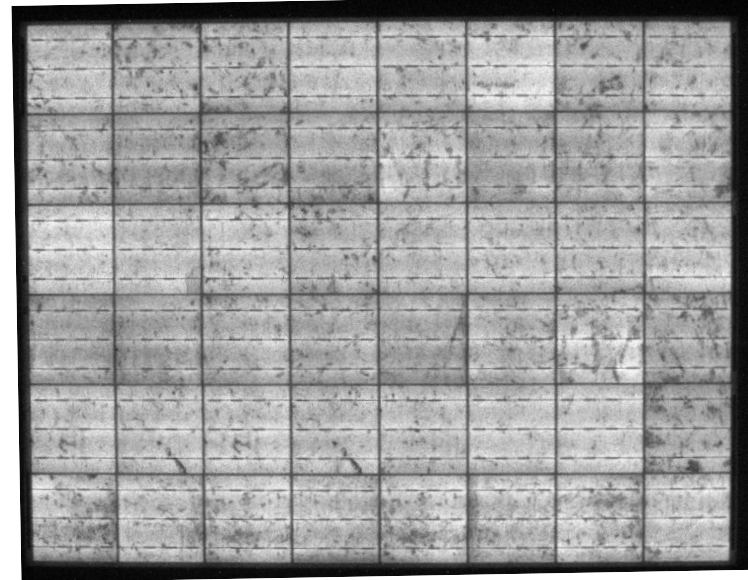


DML-TC Sequential Test (EL Images) : **Module A** (A-1 Module)

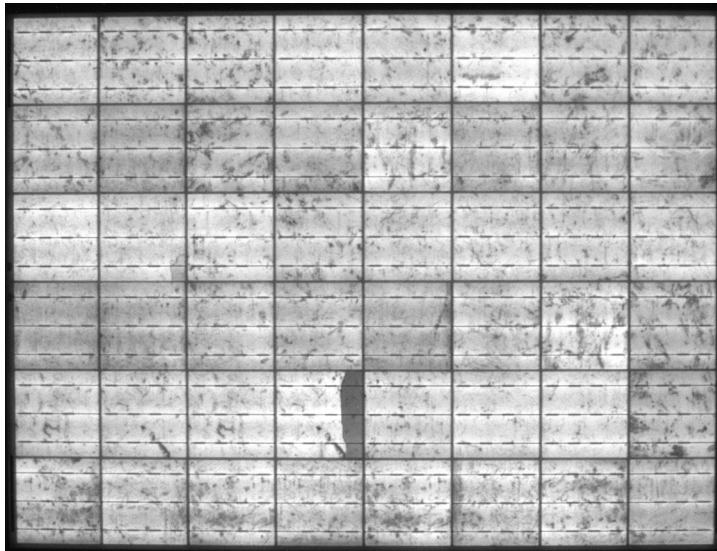
ESPEC



Initial



after DML



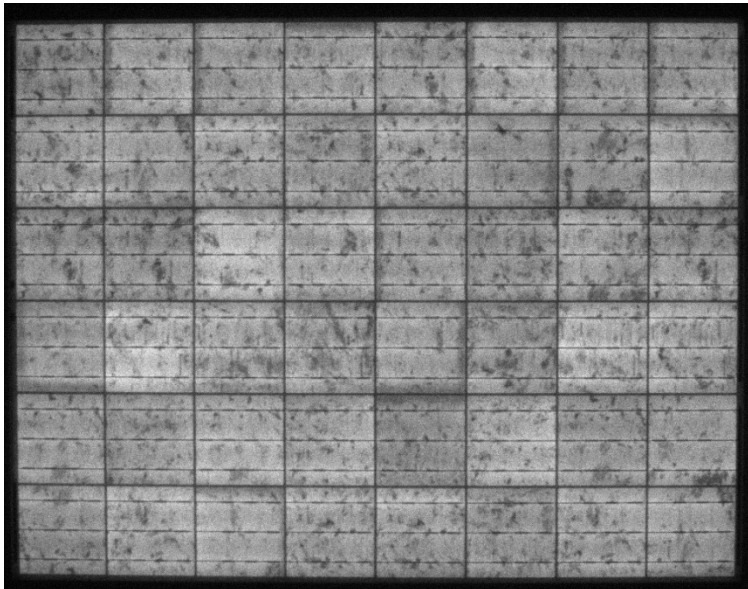
after DML + TC

The multiplication of asymmetrical dark area along bus-bar **was not observed** in the modules after DML & TC.

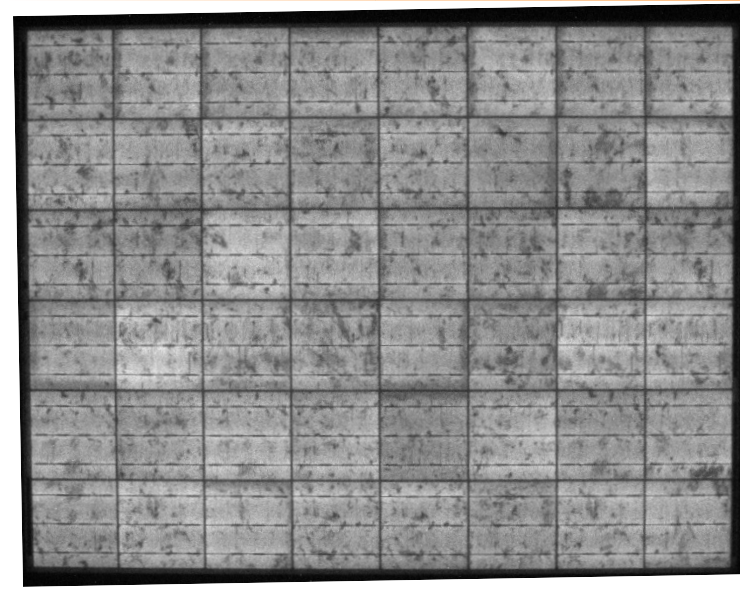
After DML & TC, the cell crack was observed in EL image.

DML-TC Sequential Test (EL Images) : **Module A** (A-3 Module)

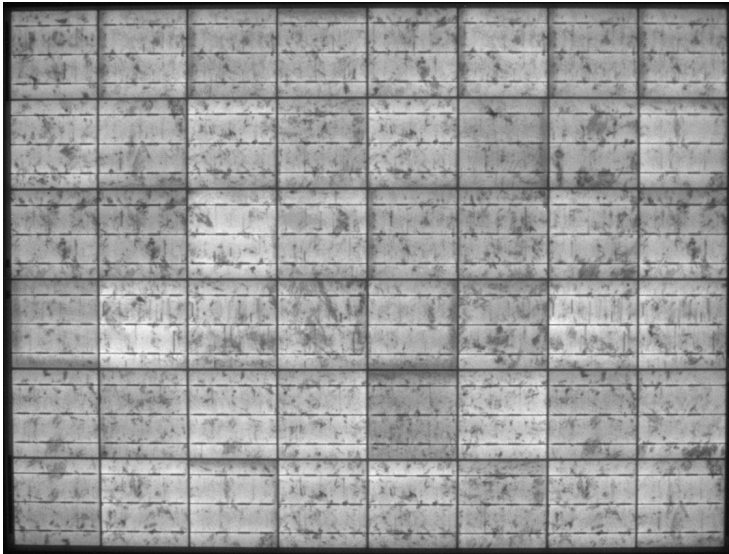
ESPEC



Initial



after DML

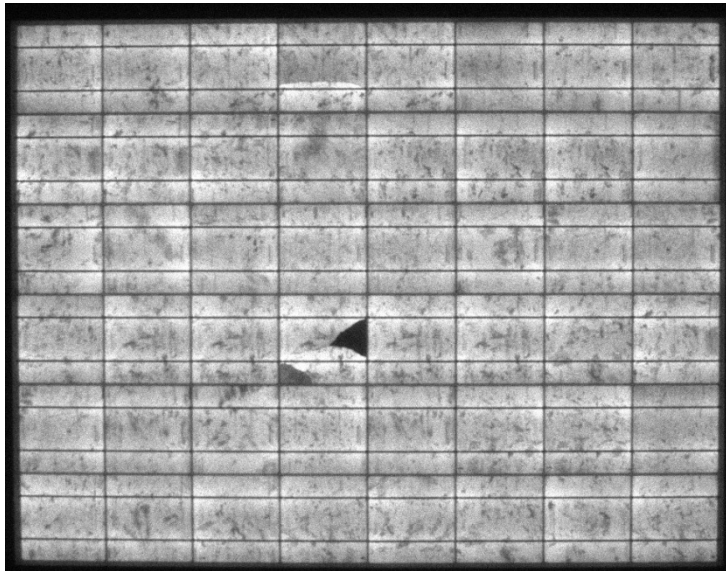


after DML + TC

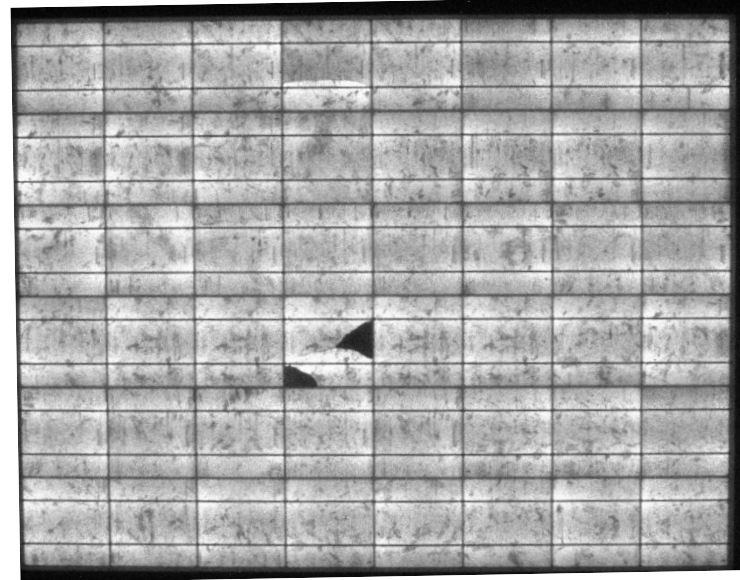
The multiplication of asymmetrical dark area along bus-bar **was not observed** in the modules after DML & TC.

DML-TC Sequential Test (EL Images) : **Module B** (B-2 Module)

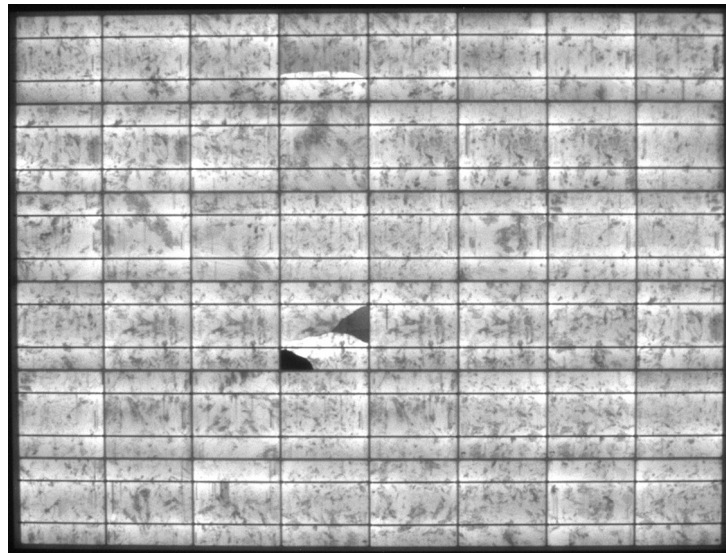
ESPEC



Initial



after DML

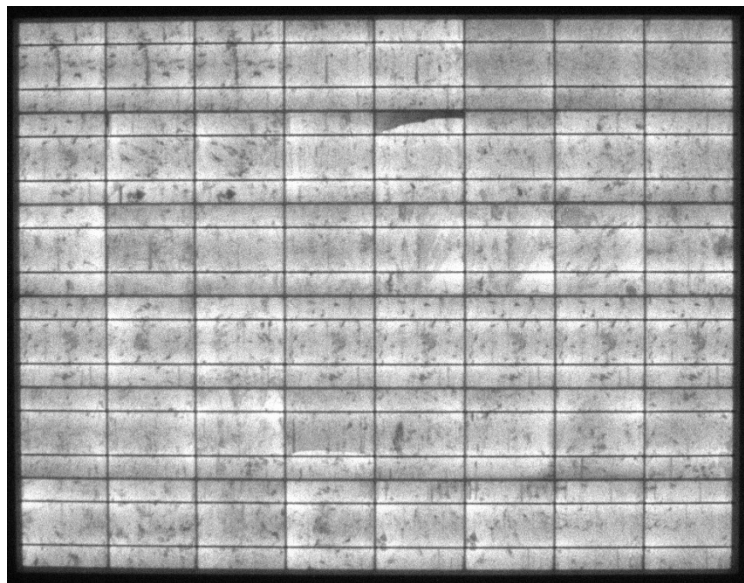


after DML + TC

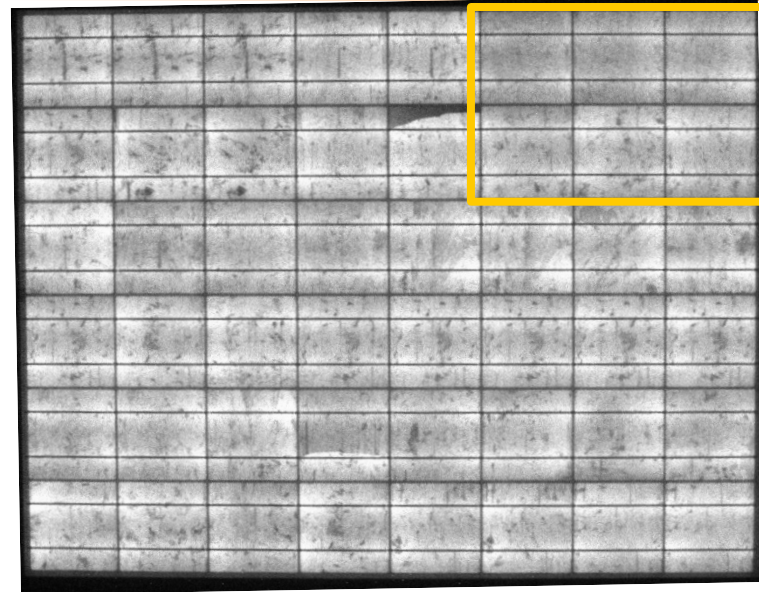
The multiplication of asymmetrical dark area along bus-bar **was not observed** in the modules after DML & TC.

DML-TC Sequential Test (EL Images) : **Module B** (B-3 Module)

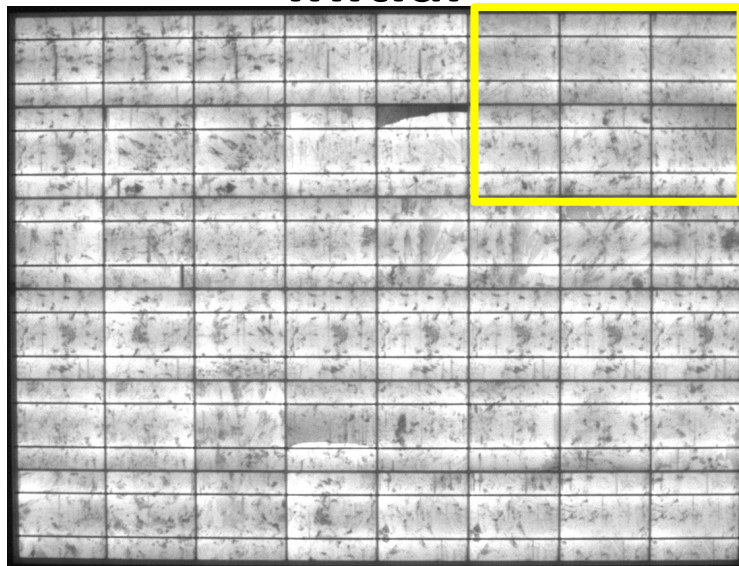
ESPEC



Initial



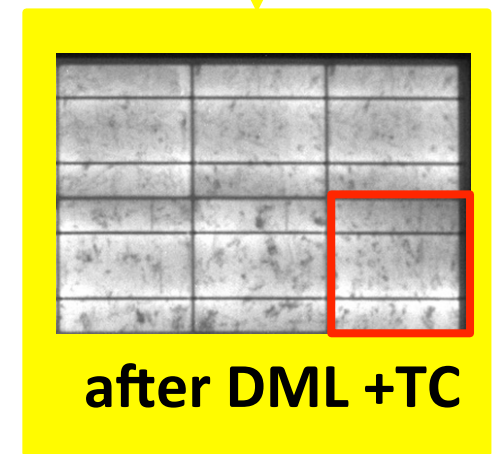
after DML



after DML + TC



after DML



after DML +TC

Cracked Cell Number

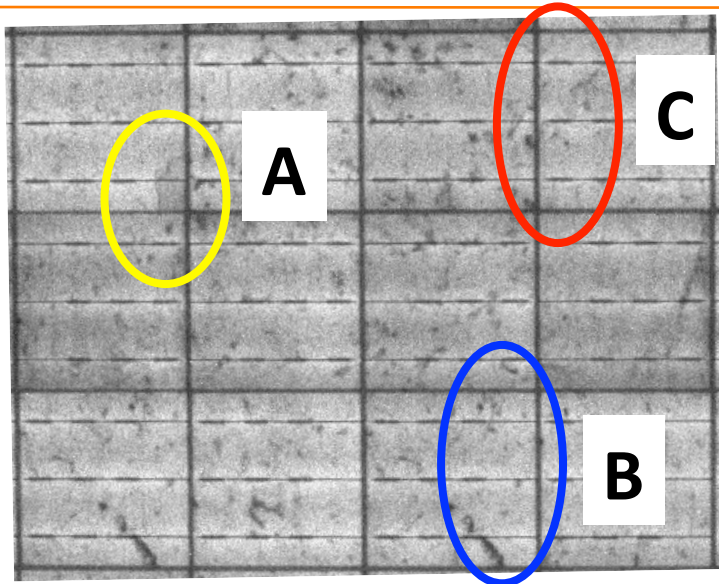
Module		Initial	after DML	*after TC
Type A	Reference	0	1	
	A-1	0	3	
	A-3	1	3	
Type B	Reference	1	8	
	B-2	4	4	
	B-3	4	5	

* Under the inspection, now

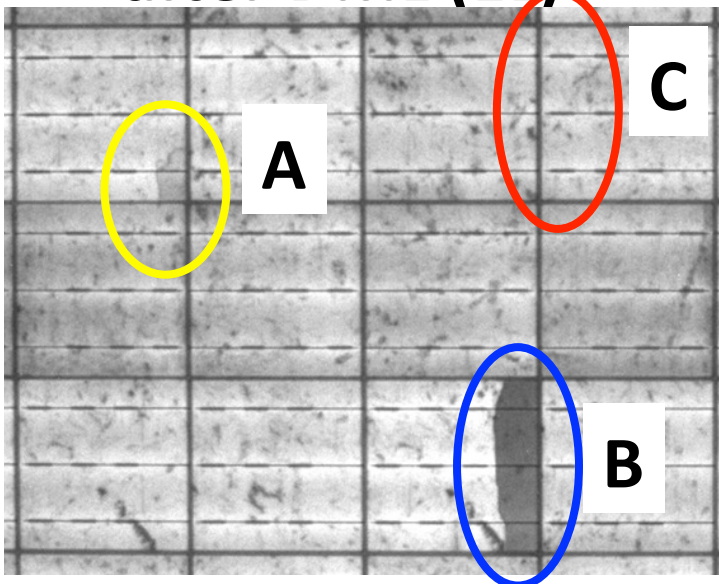
DML-TC Sequential Test (LS Images) : **Module A**

(A-1 Module)

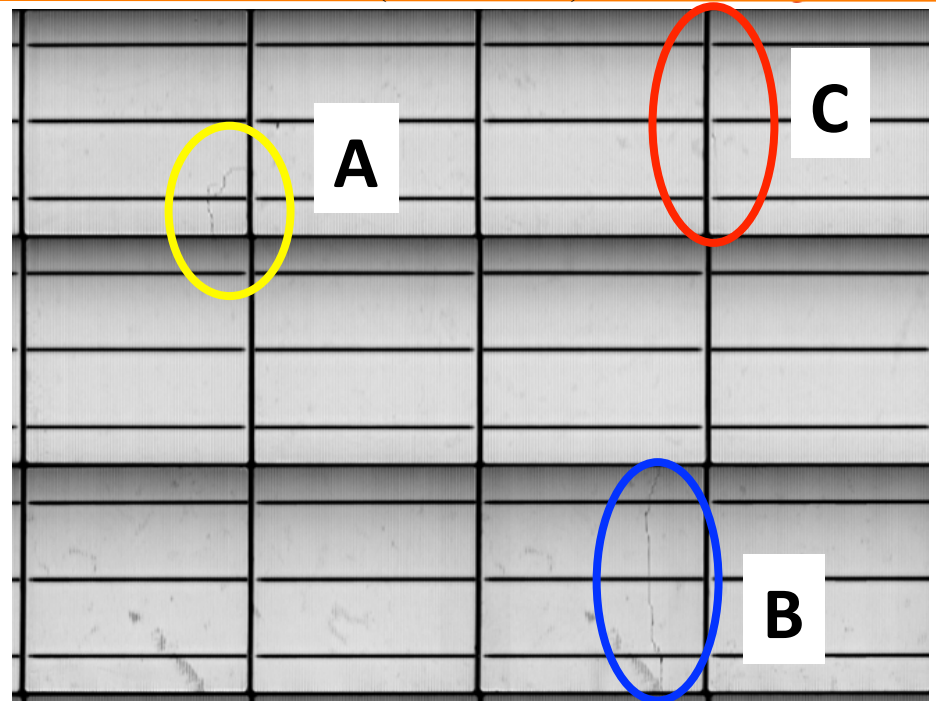
ESPEC



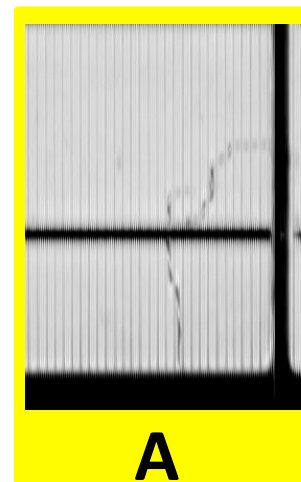
after DML (EL)



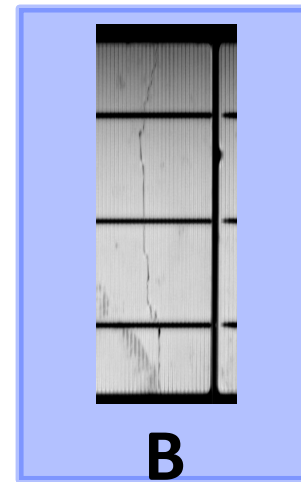
after DML + TC (EL)



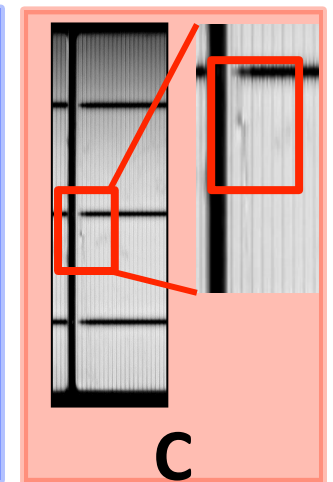
after DML (LS)



A



B

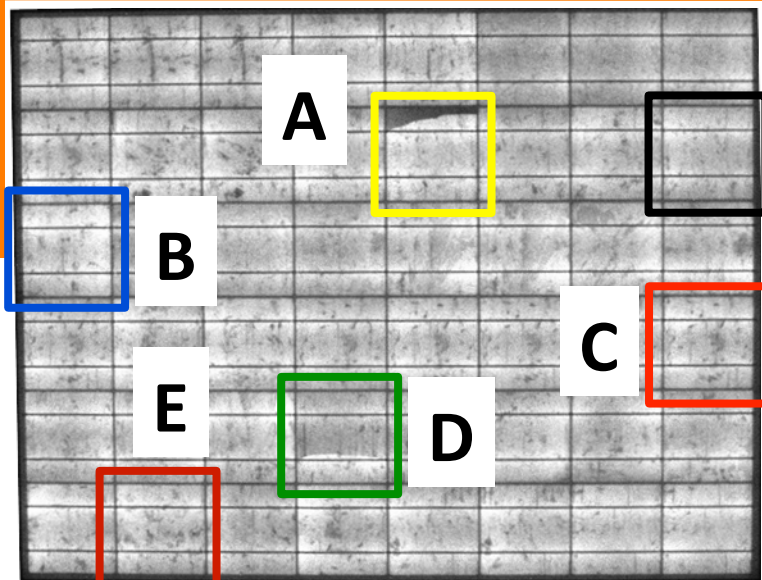


C

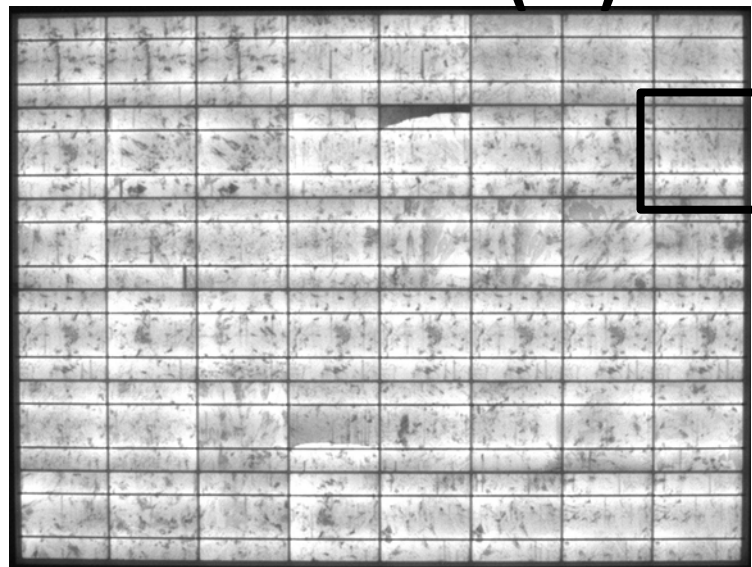
DML-TC Sequential Test (LS Images) : **Module B**

(B-3 Module)

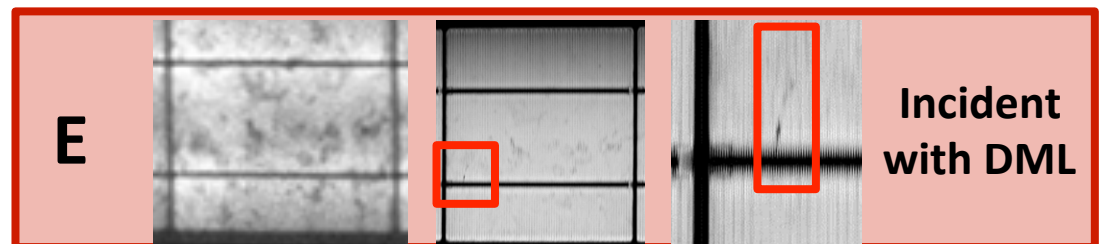
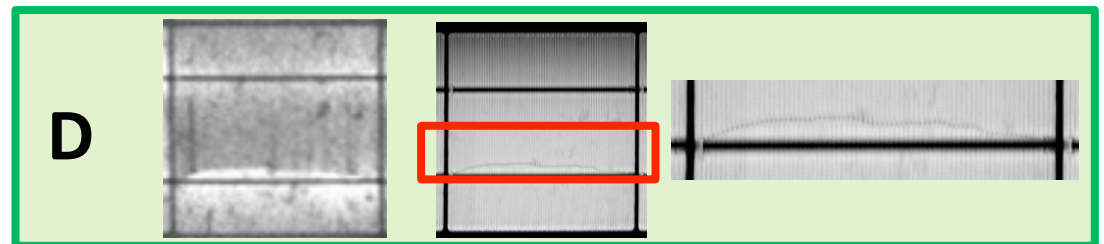
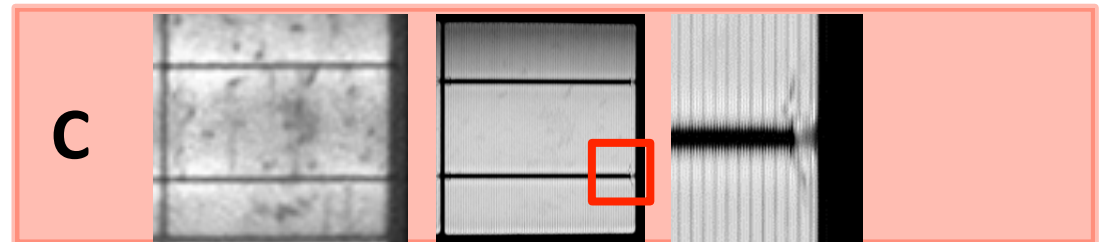
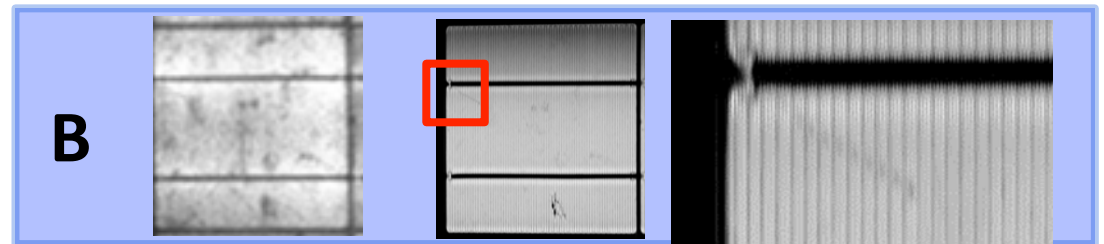
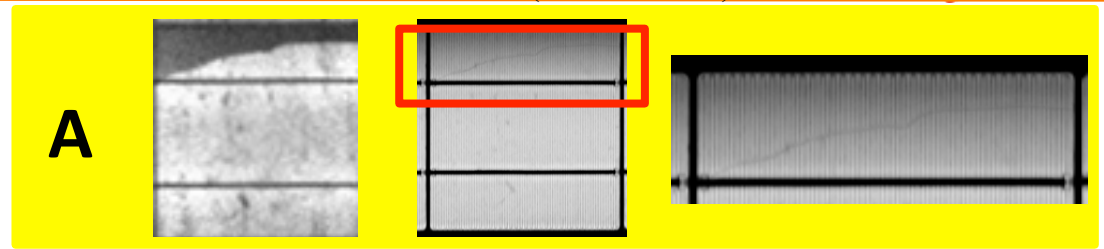
ESPEC



after DML (EL)



after DML + TC (EL)



1. Extended TC

- Massive survey of commercial PV modules is carrying out.
- As of now, the drastic failures (> 5% power-loss) have not been observed in almost PV modules at TC 600 cycles.
- Even in TC 600, the asymmetrical dark area along bus-bar is not detected in EL images.

2. DML-TC Sequential Test

Step 1: DML

- The changes of I-V parameters is relatively-little.
- The asymmetrical dark area along bus-bar did not appeared in EL.
- A little cells are cracked by DML defined in IEC 62782.

Step 2: DML + TC

- Power-loss (ca. 1%) was observed in each type of module with the reduction of FF.
- The asymmetrical dark area along bus-bar appeared in EL images (1 module / 4 modules).
- For the cell cracks, the inspection is carrying out now.

DML-TC Sequential Test

- For the availability of DML-TC sequential test, it has not been determined by our experiments.
- The optimization of DML condition may be needed to establish the effective DML-TC sequential test.
- However, we found that the asymmetrical dark area along bus-bar appeared in EL image, by the combination of DML with TC, under the condition that the cell cracks were not practically induced.

This phenomenon may related to the ribbon / solder-bond failures in c-Si PV modules.

- To establish the new test procedures for the comparative rating standard (Part 2), we would like to optimize the DML conditions, in collaboration with global Task Force 2

Contributors to DML-TC Sequential Test



National Institute of Advanced Industrial Science and Technology
Tetsuo Fukuda and Masaaki Yamamichi



Japan Electrical Safety & Environment Technology Laboratories
Hiroshi Kato, Yoshikuni Asano, Kohji Masuda, Yasunori
Uchida, and Katsuaki Shibata



NPC Incorporated

Shin Watanabe, Shinji Miyoshi, Seiji Yoshino, Teiji Morita,
and Masayuki Oouchi



ESPEC CORP.

Manabu Okamoto and Tadanori Tanahashi

Thank you for your attention.

If you have any question, please contact us.

mailto : t-tanahashi@espec.co.jp