Acceleration of Potential-Induced Degradation (PID) by Salt-Mist Preconditioning in c-Si PV Modules

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Introduction & Procedures

Motivation: To Propose the Long-Term Reliability Testing

Salt-Mist Stress: - decrease the insulation level.
- not induce the drastic power loss.

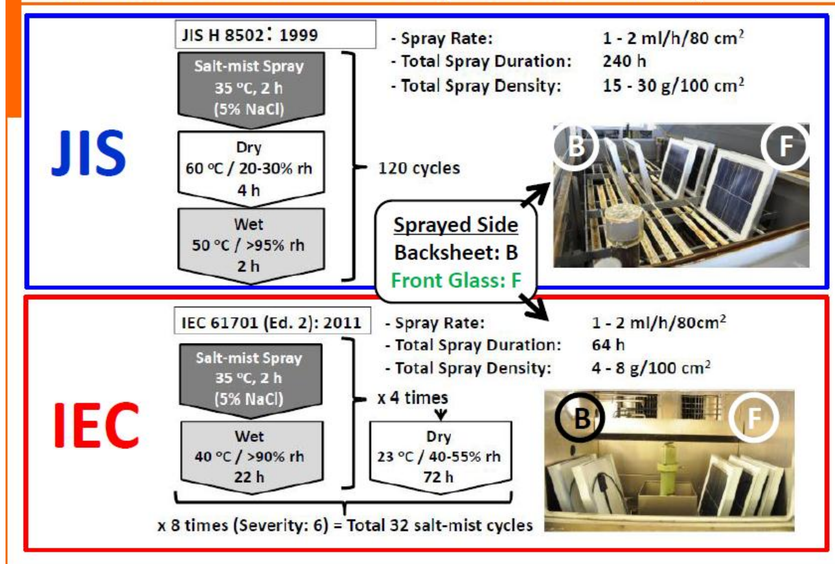
High System-Voltage Stress :
- induce the drastic power loss within relatively short-term (1 ~ 2 years).

It is assumed that the degradation by salt-mist stress will be relatively slowly compared to the PID from their characteristics.

Thus, the combined effects of these stresses may manifested themselves only after long-term exposure, not in the early "infant mortality" period.

-> Salt-Mist Stress Followed by High System-Voltage Stress

Experimental Procedures (Salt-Mist Stress)



Experimental Procedures (PID Testing)

ESPEC PID Evaluation System for Mini-PV Module

AMI-020-PID

Applying Voltage:
+/- 10 ~ +/- 2,000 V
Measurable Leakage Current:
+/- 0.1 pA ~ +/- 1 mA

Exp. Conditions in Present Work
60 °C / 85% rh
-1,000 V
based on IEC 62804 draft

PID Evaluation System for the Full-Size PV Module, Please Contact to
https://www.espec.co.jp/english/inquiry/inquiry_customer.html

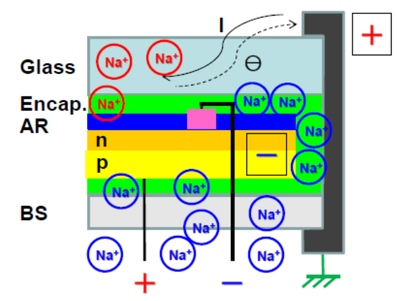
Summary

- We demonstrated that the drastic degradation of PV modules was caused by the salt-mist stress followed by the high system-voltage stress **[Panel 3]**.
- It is concluded that PID is accelerated by the salt-mist preconditioning, because the degradation profiles obtained by the current-voltage characteristics **[Panel 6 & 7]**, EL image **[Panel 8]**, LBIC image **[Panel 9 & 10]**, LIT image **[Panel 9 & 10]**, and the characteristics of PV parameters (increasing of ideally factor [n] and decreasing of Rsh) **[Panel 12]** are closely similar with those of PID phenomenon.
- PID accelerated by salt-mist stress crucially depended on the wet incubation just after the salt-mist spray **[Experimental Procedures & Panel 13]**, but not the penetration through Edge-Slit **[Panel 13]**.
- Exogenous sodium ions (which passed through the backsheet and then diffused in the encapsulant) also may be a crucial factor to induce PID, as well as the endogenous sodium ions contained in the front glass **[Panel 1]** . If so, the salt-mist penetration into PV modules would be a possible threat to the long-term reliability of PV modules installed near coast.

Conclusion — Panel 1

Endogenous Na Ion Liberated from Front Glass
=> No PID Induction in Our Exp. Conditions

Exogenous Na Ion through Backsheet from Ambient
=> Possibly a Crucial Factor to Induce PID



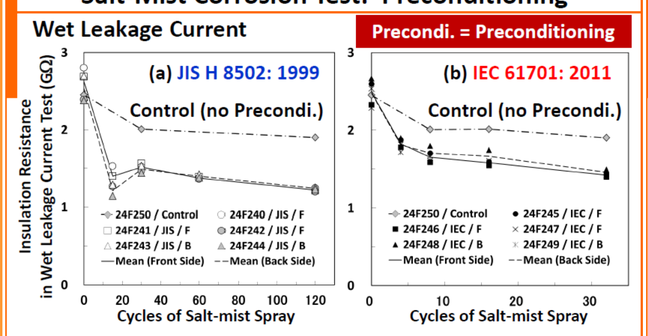
Experimental Results

Panel 2

Salt-Mist Corrosion Test: Preconditioning

Wet Leakage Current

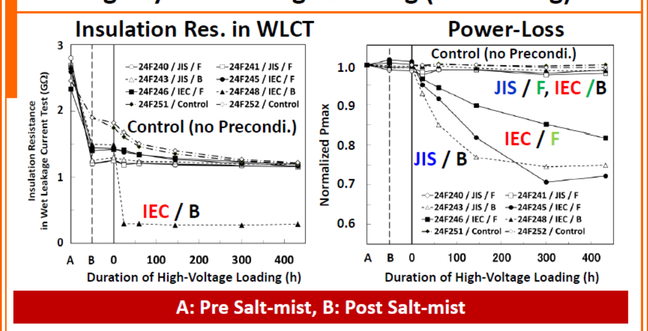
Precondi. = Preconditioning



The insulation resistance was reduced by two-thirds (**JIS** protocol) and by three-quarters (**IEC** protocol), relative to controls. However, this resistance remained well above the critical value (250 MΩ in this module) specified in IEC 61215: 2005, clause 10.15.

Panel 3

High System-Voltage Loading (PID Testing)



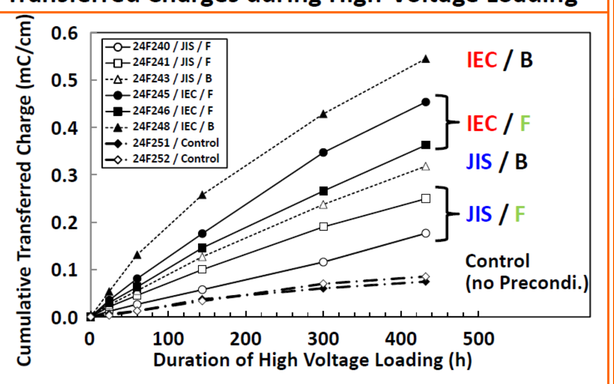
A: Pre Salt-mist, B: Post Salt-mist

IEC / B module was the only module that came close to having its electrical insulation fail in the initial phase of high-voltage loading.

Two types of salt-mist preconditioning can induce a critical loss of power during high-voltage loading, but "**Control**" was not degraded.

Panel 4

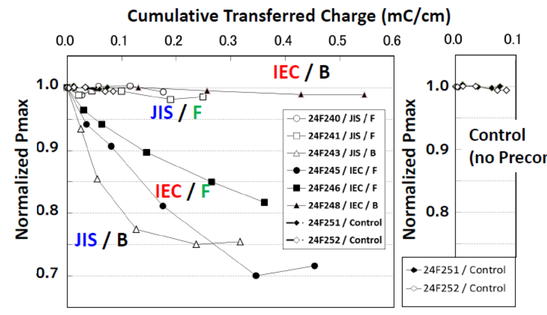
Transferred Charges during High-Voltage Loading



The properties that cause the charge transfer during high-voltage loading are imprinted during the salt-mist preconditioning phase.

Panel 5

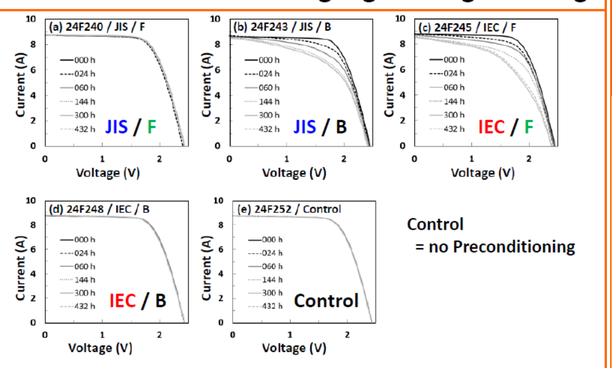
Transferred Charges – Power Loss Correlation



The total amount of transferred charge does not directly correspond to the reduction of output power.

Panel 6

Illuminated I-V Curves during High-Voltage Loading

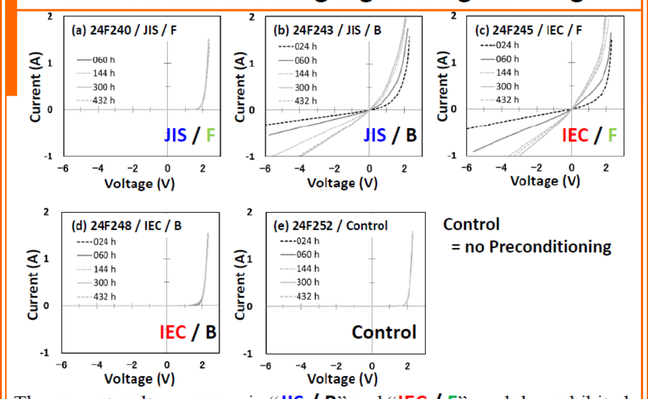


Control = no Preconditioning

In the "**JIS**/**B**" and "**IEC**/**F**" modules, FF decreased from approx. 69% to 52-54%, depending on the duration of loading, however FF remained at 69% in other modules.

Panel 7

Dark I-V Curves during High-Voltage Loading

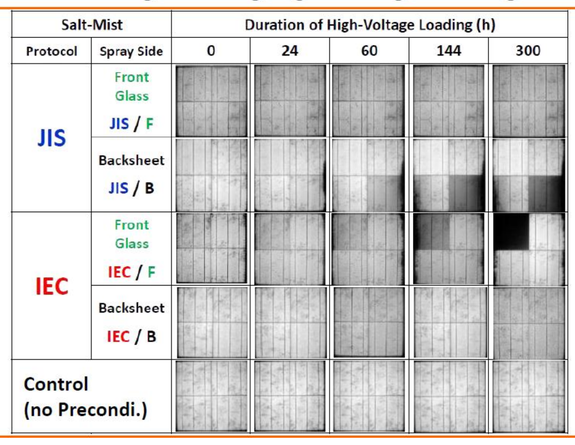


Control = no Preconditioning

The current-voltage curves in "**JIS / B**" and "**IEC / F**" modules exhibited ohmic behavior with a reduction of shunt resistance.

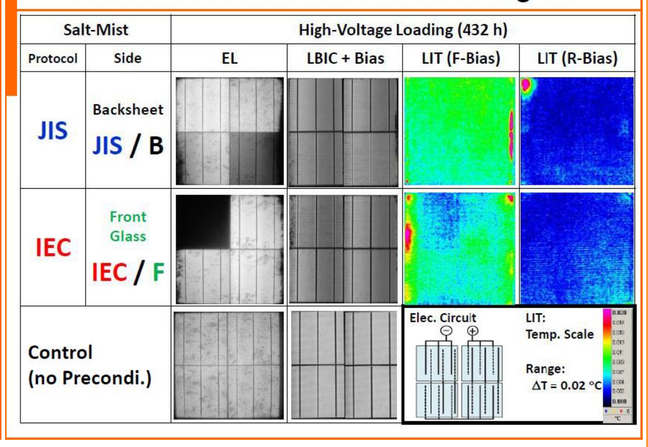
Panel 8

EL Images during High-Voltage Loading



Panel 9

Detection of Severe Rsh-Decreased Regions

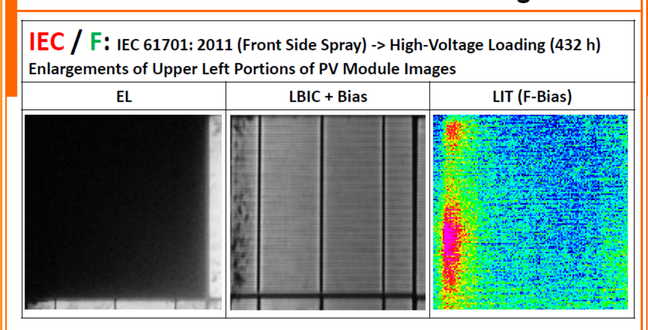


Panel 10

Detection of Severe Rsh-Decreased Regions

IEC / F: IEC 61701: 2011 (Front Side Spray) -> High-Voltage Loading (432 h)

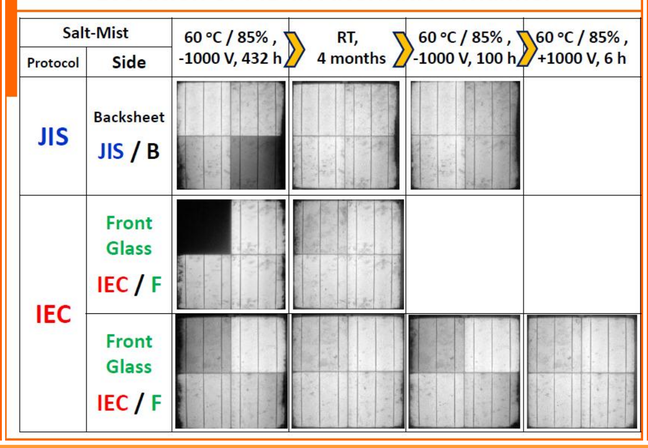
Enlargements of Upper Left Portions of PV Module Images



The punctate spots were identified only near the sides of "**JIS**/**B**" and "**IEC**/**F**" modules that lie in parallel with the bus-bar, and at the corners of the PV module, but not at the sides that are oriented perpendicular to the bus-bar.

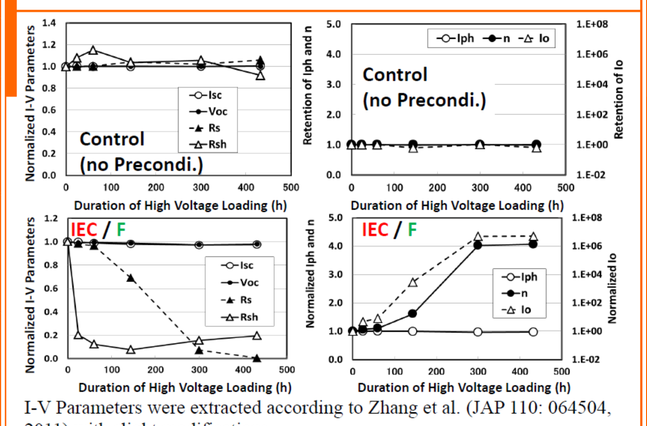
Panel 11

Evolution of PID in Alternation Manner



Panel 12

Extracted I-V Parameters from Illuminated I-V Curves



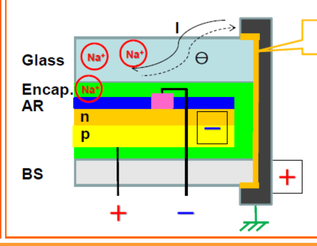
I-V Parameters were extracted according to Zhang et al. (JAP 110: 064504, 2011) with slight modifications.

Panel 13

Degradation Order

IEC / B : Wet Leakage Current Test: nearly NG
> **JIS / B** >= **IEC / F**
> **JIS / F**

IEC > JIS ➔ Na ions penetration: not through Edge-Slit, because sprayed duration / amount of salt-mist are JIS > IEC.



Back side > Front side ➔ Penetration of Na Ions through Backsheet ?

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