Prevention of Potential-Induced Degradation with Ionomer film by Reducing Sodium-ion Accumulation in PV Modules

Jane Kapur[1], Katherine Stika[1], Craig Westphal[1], Sergiu C. Pop[2], Ralf Schulze[2], Xiaoguang Wang[3], Beihai Yuan[3], Andreas Meisel[4]

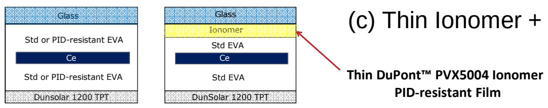
[1]E. I. DuPont de Nemours & Co., Inc., Wilmington, DE, USA
[2]Yingli Green Energy Americas, San Francisco, CA, USA
[3]Yingli Group Co., Ltd., Baoding, China
[4]DuPont Silicon Valley Technology Center, Sunnyvale, CA, USA

1. Abstract

- Transformerless (TL) inverters have increased efficiency compared to traditional ones. However, the voltage in systems using TL inverters can reach 1500 Vdc. → This increases demand for modules with PID-resistive properties.
- We evaluate an Ionomer-based encapsulant and compare it against two traditional types of encapsulant materials, standard EVA and PID-resistant EVA
- The severe PID degradation seen in EVA can be fully suppressed by inserting a 100 µm ionomer layer between the front glass and EVA. Additional accelerated aging tests according to extended IEC61215 protocol were passed.
- Analysis of PID exposed mini-modules show significantly higher sodium accumulation near the solar cell surface for the std EVA than for the ionomer.
- Preliminary data for a "one-encapsulant" solution shows PID suppression.

2. Methodology

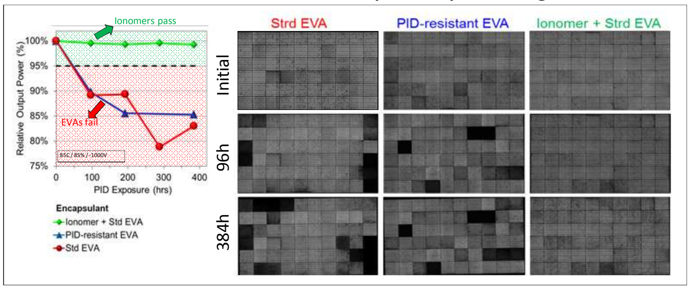
- Three encapsulants: (a) Std EVA (b) "PID-resistant" EVA (c) Thin Ionomer + Std EVA



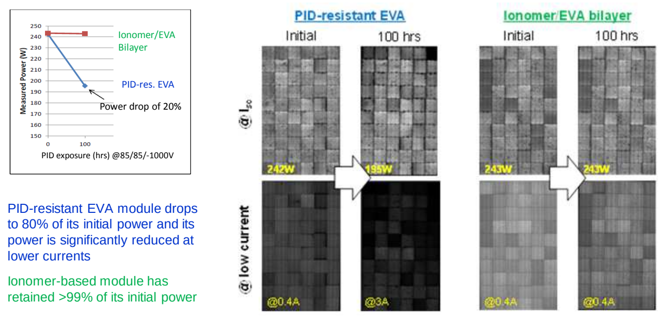
- PID sensitive 1st quality commercial 17.6% efficiency solar cells
- DH, TC, and TCHF Exposure on 6x10 cell modules
- PID Exposure: – 6x10 cell modules: 60 or 85C / 85%RH / -1000V / 0-96-384h

3. Ionomer Film prevents PID

DuPont Photovoltaic Solutions (DPVS) Testing Lab

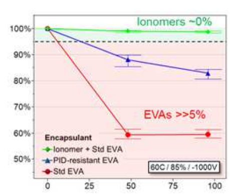


DNV-GL (independent lab) validates above results

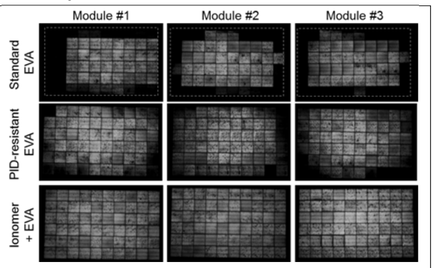


- PID-resistant EVA module drops to 80% of its initial power and its power is significantly reduced at lower currents
- Ionomer-based module has retained >99% of its initial power

Yingli Research Lab (China) confirms the results

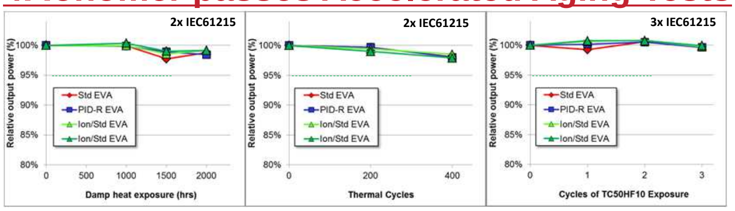


Comparison of relative output power for different encapsulants in 2nd set of nine full-size modules after PID exposure at 60°C / 85% / -1000V of 96 hours. All modules had similar BOM to the set above (with specially built PID-prone cells) and were built at the Yingli production facility in Baoding, China.



EL for different encapsulants in 2nd set of full-size modules after PID exposure at 60°C / 85% / -1000V of 96 hours. The dashed line indicates the module edge.

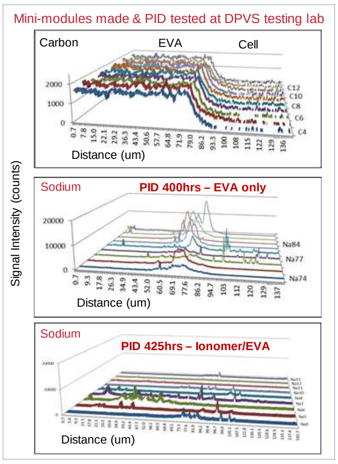
4. Ionomer passes Accelerated Aging Tests



5. Minimizing Na^+ accumulation prevents PID

Na Ion Migration Profile Measured Using LA-ICP-MS in a PV Module

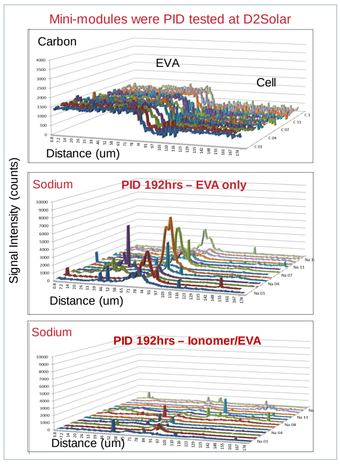
Laser Ablation – Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS): A laser beam is focused and scanned across the sample surface of the module's cross-section, generating particles from the top 5-20 µm of the sample surface. The particles are introduced into a high temperature Argon plasma, which serves as a ionization source. The resulting elemental ions are analyzed by a mass spectrometer. Modules were exposed to extended PID conditions of 60C/85%RH/-1000V/foil.

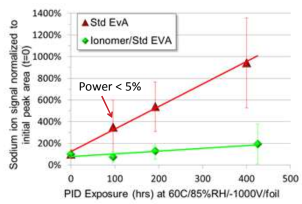


Uniform Carbon transition from EVA to Cell at various locations

Na-ion Line Scans across EVA only module cross-section; Statistical difference before and after PID exposure is significant at 96, 192, 400h

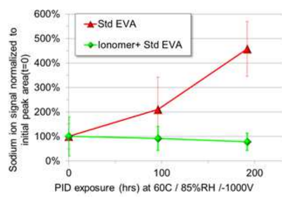
Line scans across ionomer/EVA module cross-section; No statistical difference before and after PID exposure at 96, 192, 425h





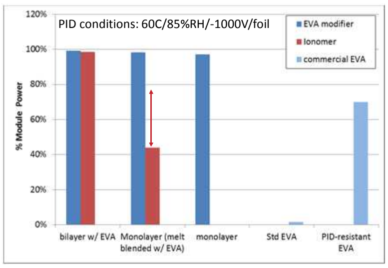
Sodium Increases Linearly

- Na accumulation increases with exposure to PID test
- Accumulation is much faster for EVA than for ionomer-based module



6. Next Gen "One Encapsulant"

An EVA modifier was tested in mini-modules as a bilayer (EVA modifier/EVA construction) and as a melt blend with EVA; both types of encapsulant have excellent transmission and suppress PID. The modified EVA encapsulant has passed 192h of PID exposure, while the ionomer/EVA melt blends do not suppress PID as well. Further research and module testing is needed.



7. Conclusions

- Thin ionomer between a Standard EVA and front glass suppresses any PID degradation
- 'PID-resistant' EVA cannot prevent PID degradation
- Sodium ion accumulation at cell surface was demonstrated for EVA-based encapsulant
- Ionomer-based encapsulant effectively prevents accumulation of the sodium ions
- Preliminary research shows a promising candidate for a "one-encapsulant" solution to PID

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