Lifetime and Degradation Science of PERC Technology: Simultaneous optimization of lifetime, efficiency, cost
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PERC Cells & Degradation

PERC (passivated emitter rear cell) solar cell technology is an upgrade from standard AL-HIF solar cells which increases efficiency by using an aluminum oxide (AlOx) passivation layer to improve the transformation of solar energy into electric energy.

Technology Summary

We will advance our BAPVC-funded development of multivariate predictive network modeling of degradation data by combining with process variables and throughput time to optimise cost/efficiency/lifetime of PERC cells. We will utilize sample variants in processing, experiences in conventional solar cells and macroscopic and microscopic semiconductor physics characterization schemes to develop rapid insights into fast lifetime testing, degradation mechanisms vs process conditions, and throughput time in fabrication by partnering with DuPont PV Solutions and The University of Connecticut. Data analytics developing multi-scale network models to indicate the quantitative impact of these variables on the device outcomes and simultaneously optimize while meeting efficiency, CapEx and lifetime goals of 20%, $0.25/Wa and 40 years, respectively.

Network modeling for predictive degradation

Data in: optimization out

- sgSEM network modeling tool predicts lifetime behavior of PV modules using multivariable analytics.
- Expansion of this development to incorporate more device physics, material characterization, and process variables so as to optimize cost and lifetime performance using multiscale sgSEM of next generation passivated emitter rear cell (PERC) solar cells.

Project Outline

Task 1: We will obtain cells and mini-modules from PVUS with varying passivation materials schemes inclu ding candidates of anodized SiOx and variants of AlOx processing, all deposited by PECDY.

Task 2: Samples will be characterized by Current-Voltage (I-V), Electroluminescence(EL), Quantum Efficiency(QE), and Photoluminescence(PL) at CWRU, select samples will be sent to UConn and CCRY for Atomic Microscopy (AFM) and Time-Resolved Photoluminescence (TRPL) and admittance spectrometry, respectively.

Task 3: Samples will be exposed to several multifactor accelerated aging conditions and the real world in Cleveland, Ohio at the SDLE Research Center a “SunFarm” instrumented outdoor test facility.

Task 4: Repeat the characterization outlined in Task 2 stepwise in time to discern the performance over time. Return samples will be sent to partners for careful spectroscopic and microscopic characterization. Apply sgSEM methodology to develop quantitative network models from macroscopic to microscopic variables, optimize processing for lifetime performance and efficiency and cost.

Exposures & signs of degradation

- Busbar corrosion
- Gridline delamination
- Aluminum pitting
- Rear side corrosion

Bare cell exposures:
- Acetic Acid: concentration comparable to degraded module
- Cyclic QUV: alternating heat+UV and condensing humidity
- Preliminary bare cell experiments revealed different types of degradation for acetic acid and QUV exposures, depicted above, associated with various power loss modes (series resistance, etc.).

Bare Cell Characterization

- Time-series data over exposure steps including:
  - Current-voltage curve tracing (I-V)
  - External quantum efficiency (EQE)
  - Electroluminescence imaging (EL)
  - Ti re resolved photoluminescence (TRPL)
  - Photoconductive atomic force microscopy (p-c-AFM)

Bare cell acetic acid corrosion

- 2.5 M aqueous acetic acid (concentration in a degraded module)
- 4-hour exposure steps
- Power decrease tracks with fit factor (increased series resistance), consistent with contact corrosion.

Bare cell degradation in cyclic QUV

- ASTM G154 protocol:
  - 8 hr. 1.5 W/m² UV 70°C
  - 4-hr condensation 50°C
- 1 week exposure steps
- Power loss tracks with open circuit voltage and short circuit current, consistent with LID.

Mini-module Design

- Bare cells and mini-modules of types: Al-BSF, AlOx-PERC
- Mini-module design allows for stepwise testing of individual cells as well as full module tracking during exposure

Mini-module Characterization

- In-situ mini-module level current-voltage curve tracing (I-V)
- Stepwise cell level current-voltage curve tracing
- Capacitance-voltage profiling (C-V)
- Deep level transient spectroscopy (DLTS) - extended to mini-modules
- Electroluminescence imaging (EL)
- Photoconductive atomic force microscopy (p-c-AFM)

References