Acceleration factors for damp-heat and HAST with high voltage stress

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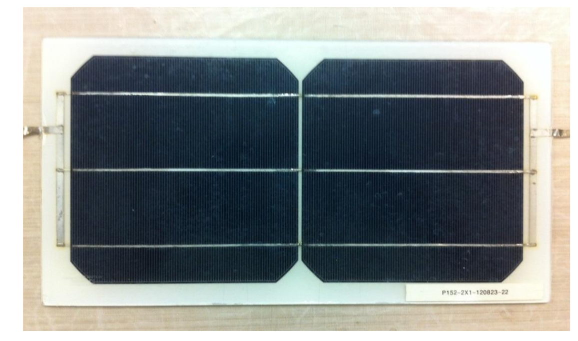
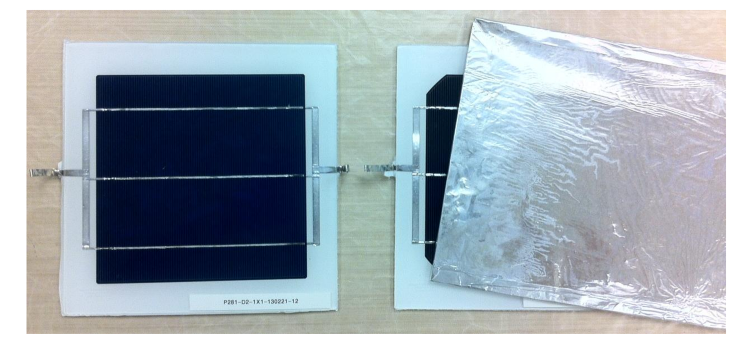
Introduction

Damp heat (DH) testing can take up to 4000 hours before failure. HAST can accelerate degradation 10-20x over DH, speeding screening tests and product development. Here, we determine the acceleration factor (AF) and show that the failure modes in DH and HAST are similar for common glass module constructions. We also look at potential induced degradation (PID) in both DH and HAST conditions and determine the failure modes and AF's.

Module construction

Module construction was made with representative industry standard materials (SnPb ribbon, EVA encapsulant, low iron glass and TPE backsheet). The commercially available multi-crystalline and mono-crystalline cells were from a tier 1 manufacturer with nameplate efficiencies of 19% and 17.6%, respectively. Mini-modules for DH and HAST testing were a 1x2 construction and mini-modules for PID-DH and PID-HAST testing were a 1x1 construction. In PID-DH and PID-HAST, a sheet of aluminum foil pressed against the front glass was used for the grounding.

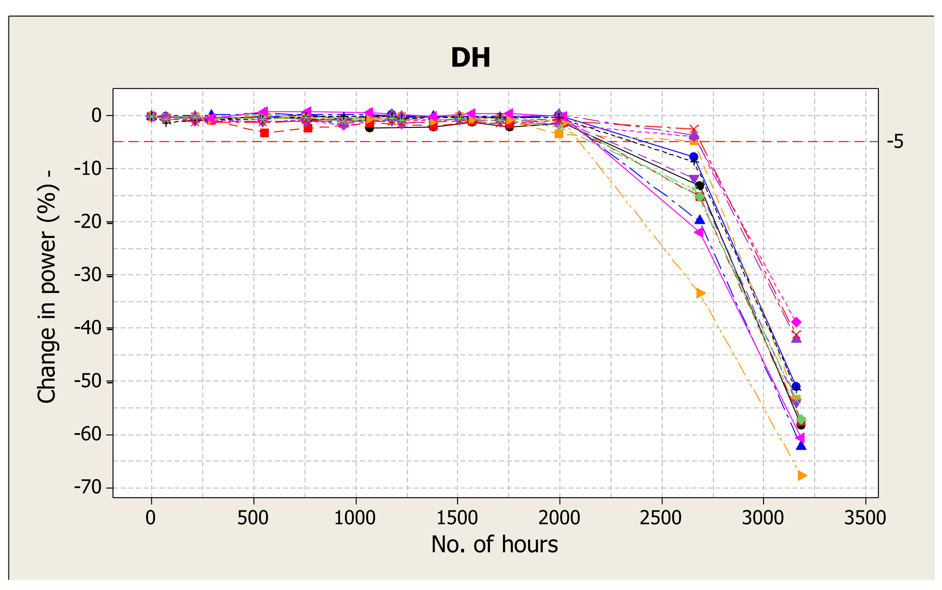


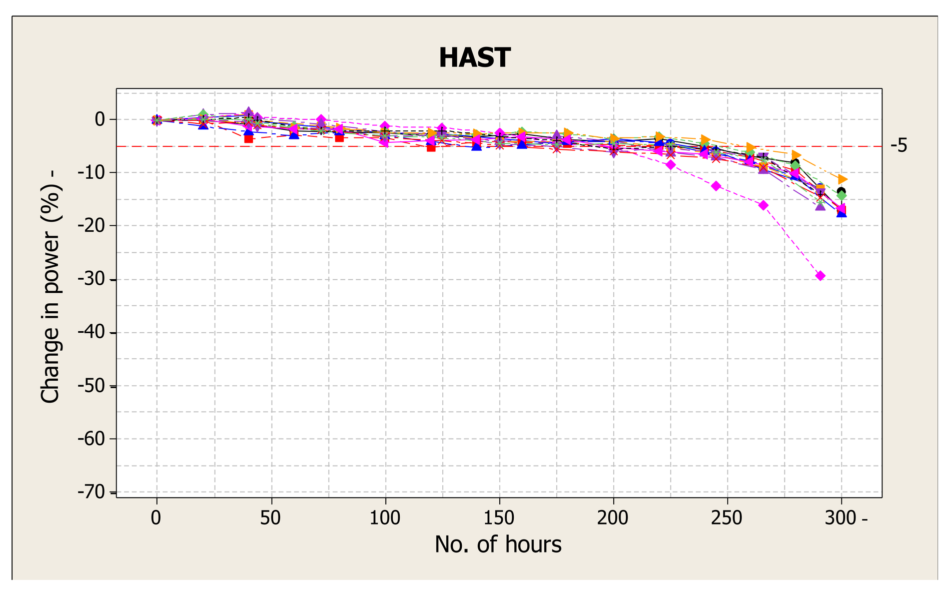


DAMP-HEAT (DH), HAST

Efficiency degradation:

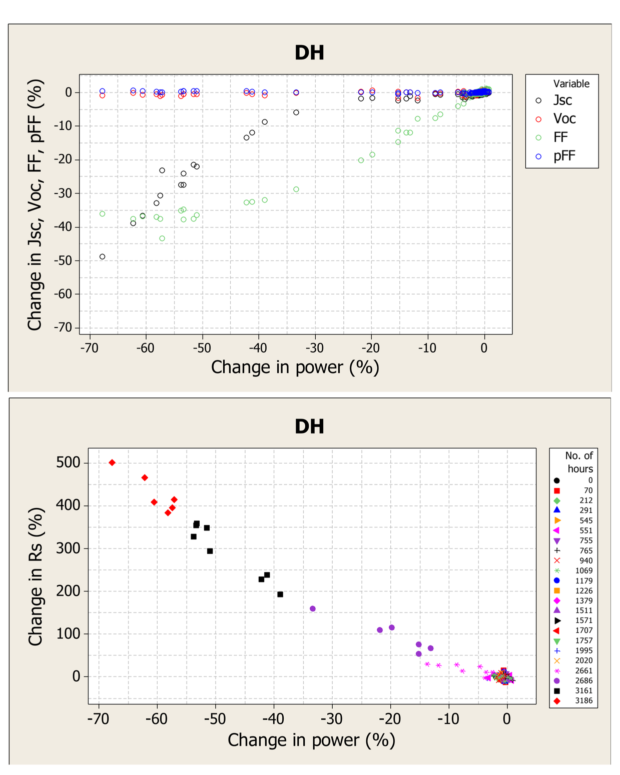
For quality control purposes, multiple groups of modules with identical construction are run through DH (85C/85%RH) and HAST (120C/100%RH) with periodic testing. The time to failure (TTF), taken as the time of 5% loss in power, for DH modules was ~2400 hours and for HAST ~210 hours, giving an acceleration factor of approximately 11.

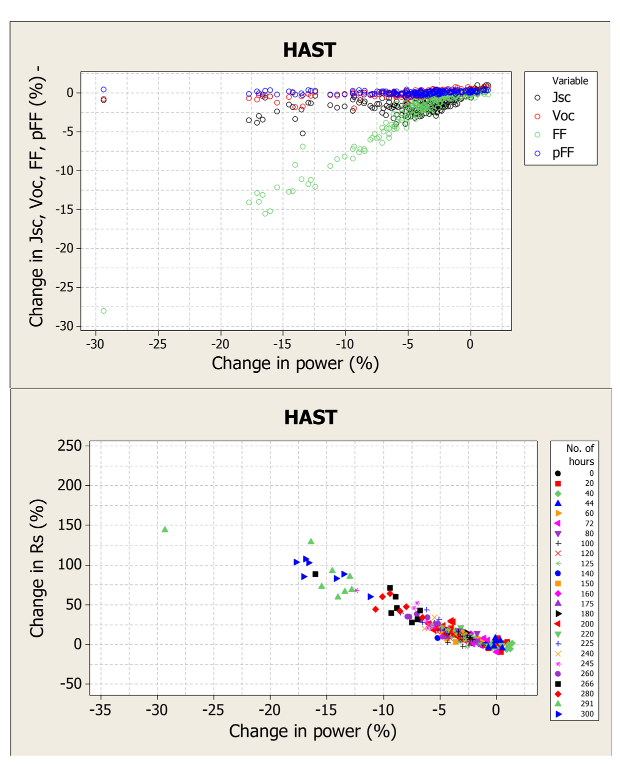


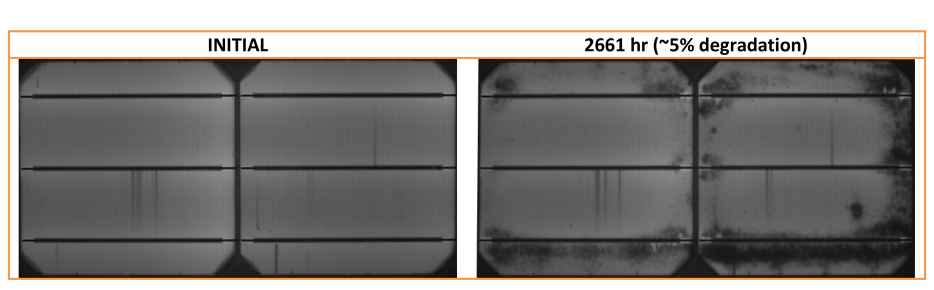


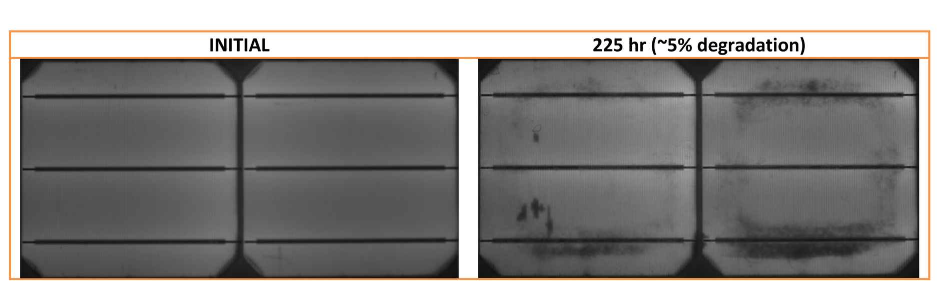
Failure modes

The predominant failure mode observed in both HAST and DH was an increase in series resistance (Rs) leading to a drop in fill factor (FF) and eventually a loss in current (Jsc). Similar signatures for both tests are also visible in electroluminescence images shown below. The mechanism is likely corrosion from acetic acid and moisture which eventually leads to an increase in contact resistance between the front grid and emitter.[1,2]





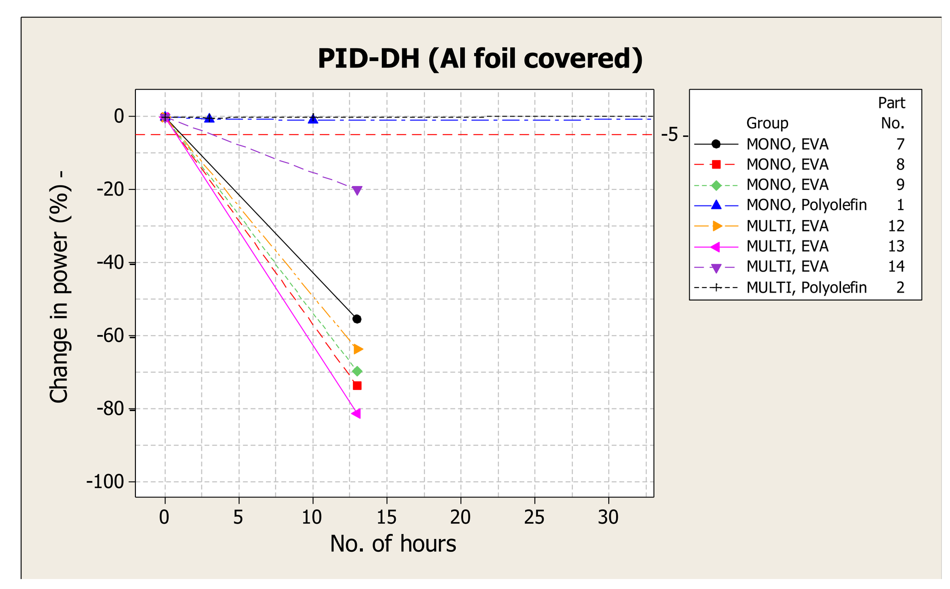


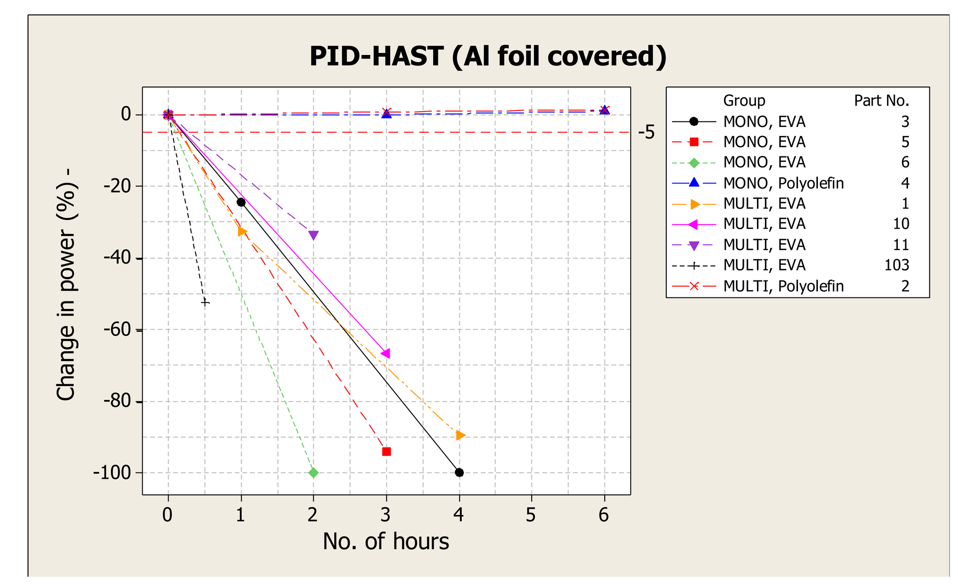


PID-DH, PID-HAST

Efficiency degradation:

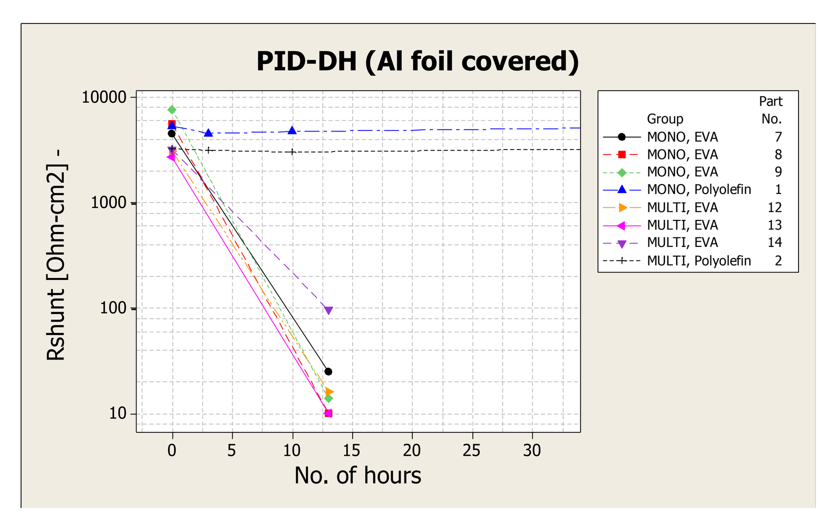
Potential induced degradation (PID) testing was performed in both DH (85C/85%RH) and HAST (120C/100%RH) conditions. In both cases, voltage biasing (-1kV) was performed with the front surface covered in Al foil in order to accelerate the test and reduce the dependence on the glass front surface conductivity which differs significantly between the two chamber conditions. In all cases with EVA, failure was quite rapid and TTF was determined by extrapolating back to a 5% power loss. Parts with polyolefin encapsulant were also tested and showed no degradation (up to 300hrs PID-DH and 7 hrs PID-HAST)

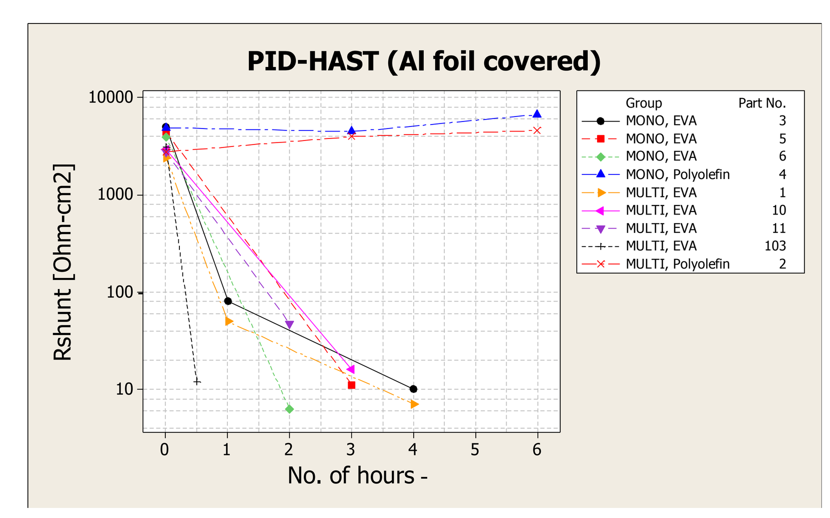


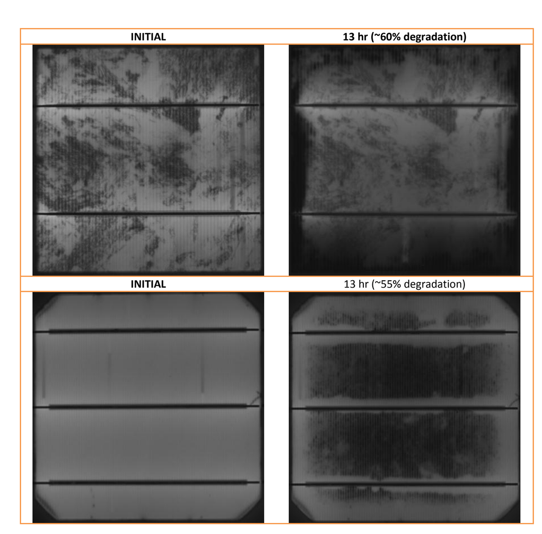


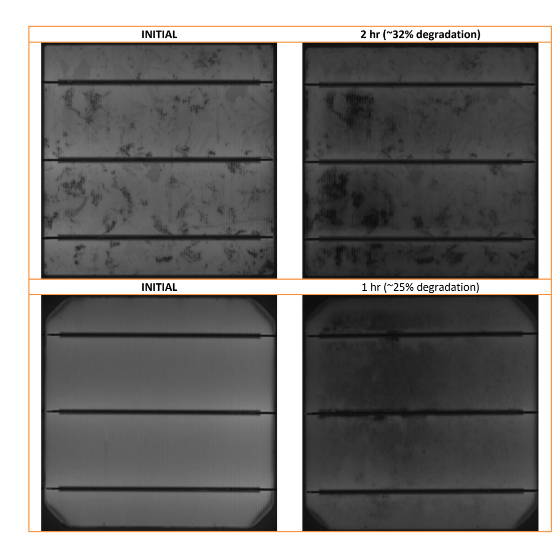
Failure modes

The predominant failure mode observed in both PID-HAST and PID-DH was a decrease in shunt resistance (Rshunt) leading to a drop in fill factor (FF). In both cases, electroluminescence images, shown below for representative samples, show the dark spotting of shunted areas typical of PID.

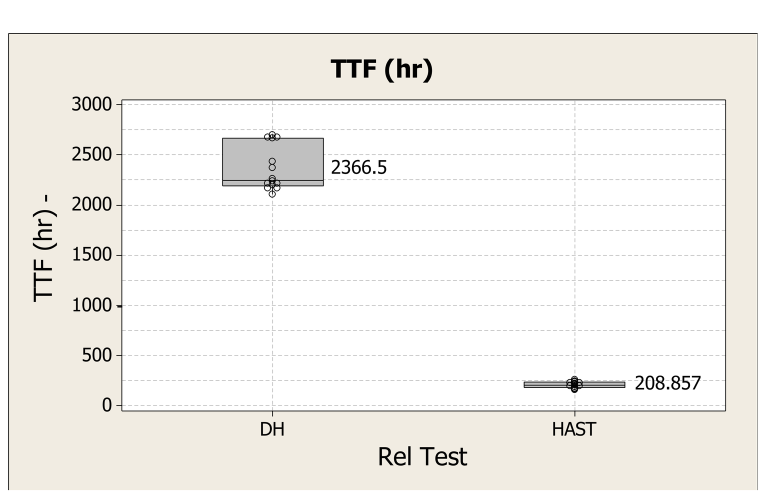






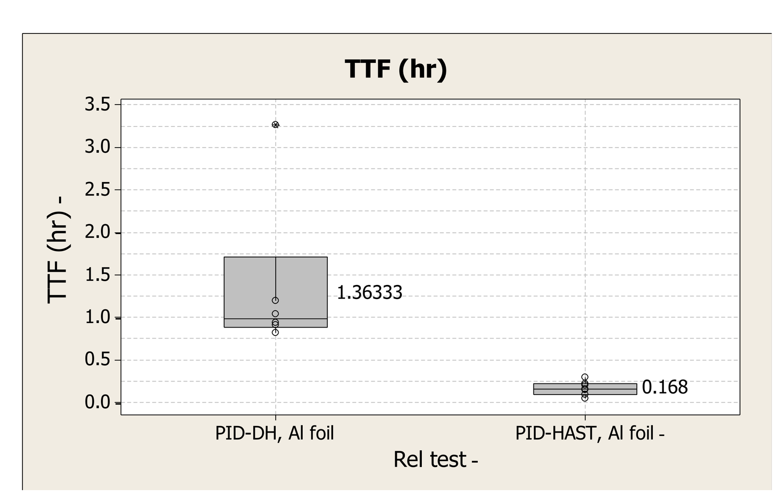


Acceleration factors



$$AF = \frac{MTTF_{DH}}{MTTF_{HAST}} = 11$$

Acceleration factors



$$AF = \frac{MTTF_{PID-DH}}{MTTF_{PID-HAST}} = 8$$

The acceleration factors (AF) here are simply computed as the ratio of the mean time to failure (MTTF) for the two tests. In the case of the PID tests, parts failed too rapidly to capture a measurement near a 5% power loss, and therefor there is significant uncertainty determining the TTF. Clearly, however, there is a significant acceleration of the dominant degradation mechanism.

Conclusions

We have shown that the dominant failure mechanisms for both damp heat and high voltage stress in damp heat can be accelerated by approximately an order of magnitude under HAST conditions. It should be underscored that these findings are only for conventional modules with conventional cells.

References

1. Ketola, Barry, and Ann Norris. "Degradation Mechanism Investigation of Extended Damp Heat Aged PV Modules."
2. Hacke, Peter, et al. "Test-to-failure of crystalline silicon modules." *35th IEEE PVSC* (2010): 244-250.