Role of Encapsulants in Improved Reliability of Photovoltaic Modules

Kumar Nanjundiah, John Naumovitz, Michael Biscoglio, Tom Burns

The Dow Chemical Company

1605 Joseph Drive, Midland, MI 48642, USA

Abstract

Recent efforts in crystalline silicon module technology have been focused on increasing life and reliability of PV modules to go along with improvements in cell efficiency. The reliability aspect has led to interest in polymeric materials used in module construction as well as BOS components. In this regard, polymer encapsulants play a key role in improving reliability by providing better environmental protection as well as electrical insulation.

In recent years, new materials have been introduced to replace EVA to overcome drawbacks of yellowing, acid generation and moderate electrical insulation. In this report, reliability analysis based on accelerated testing results will be provided comparing different encapsulant materials used in PV modules. Data showing the need for improved electrical insulation and better barrier performance to prevent phenomena like PID will also be presented.

Motivation and test methodology

1. Can encapsulants help increase life time of efficient power generation in PV modules?
2. Does choice of encapsulant and polymeric material properties matter ?

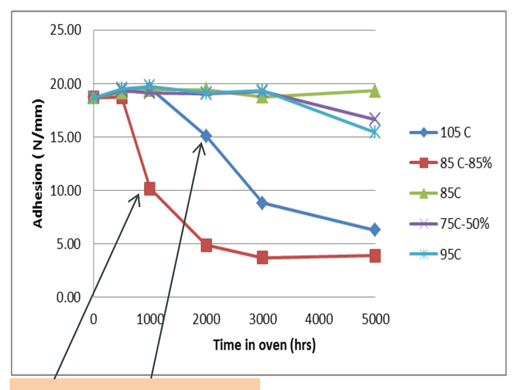
Ideal test: Field testing, Draw back – Long time period, can't be used to develop today's systems

Accelerated testing: Consider stressors as experienced in the field and watch out for unrealistic failure modes.

- Temperature
- Humidity
- Voltage
- Harmful radiation

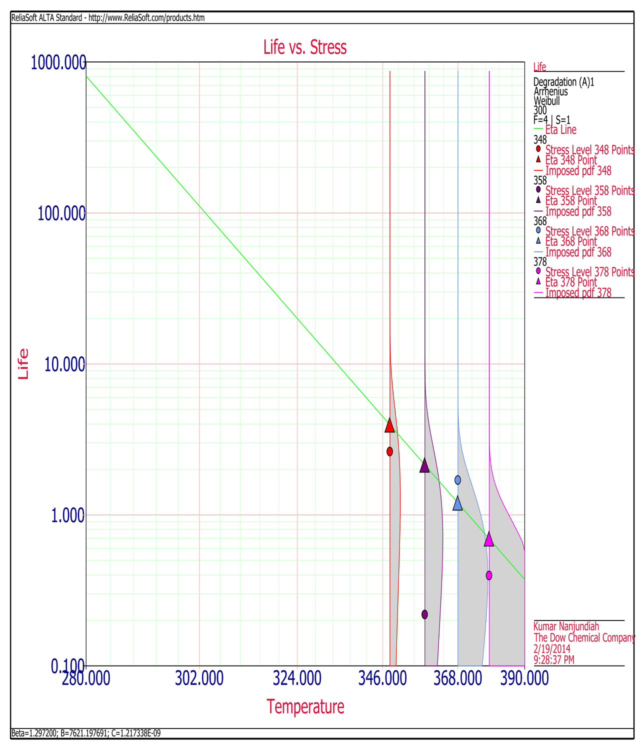
Combinations are closer to reality

Adhesion data and model

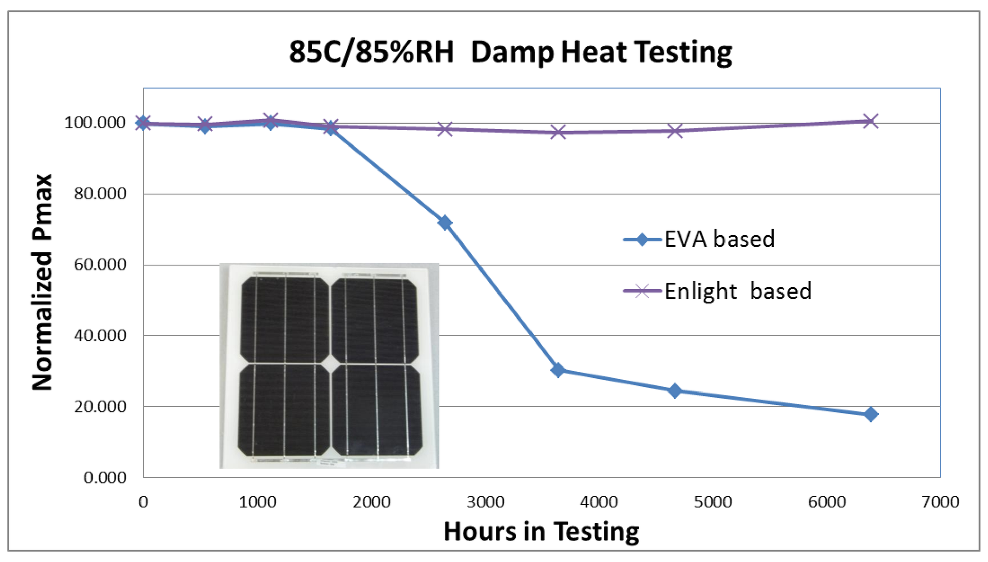


Backsheet brittle

Critical degradation – 10 N/mm
Use temp – 45C
Mean Life = 28.8 Year
Acceleration Factor = 44.9



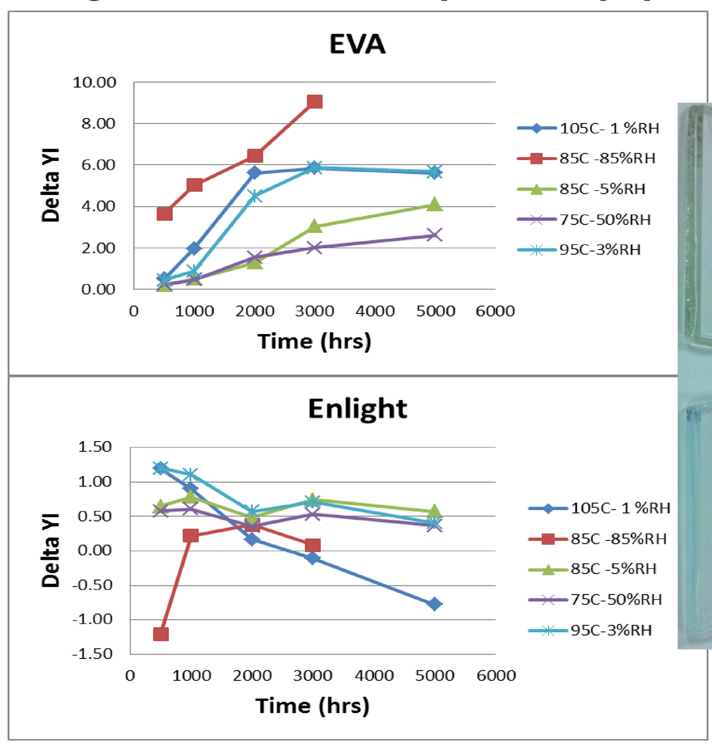
Degradation of power in DH



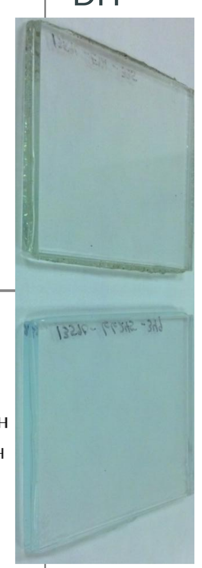
Data average of 3 four cell crystalline silicon modules

Testing at conditions of 75C/50%, 85C/5%, 95C/3%, 85C/85%, 105C/1% temperature and humidity respectively to develop a model for Enlight™ remains unfinished since all modules have retained power close to initial values with 5000hrs of testing

Change in color of encapsulant (YI)



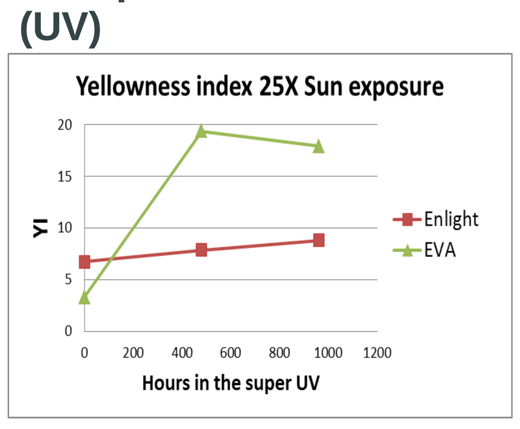
Measured on Glass /Encapsulant / Glass in DH

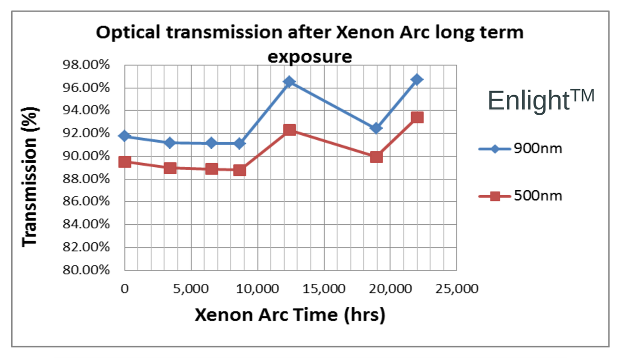


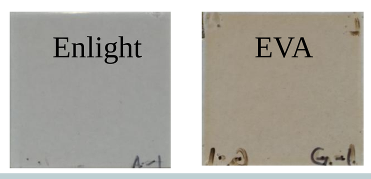
change in color with ageing

NO change in color with ageing

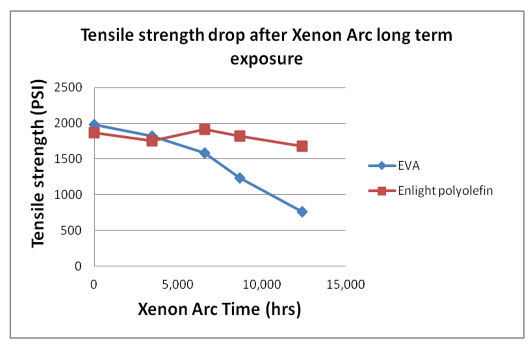
Encapsulant film tensile and degradation (UV)



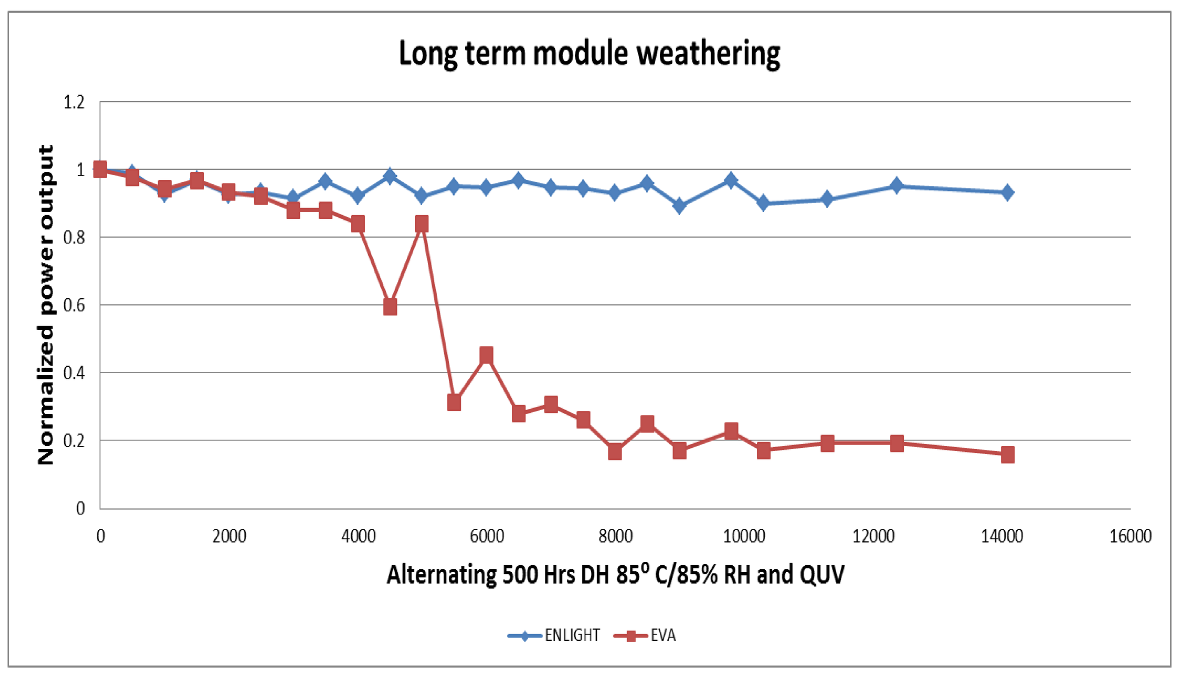




Super accelerated UV exposure shows yellowness increase for EVA compared to Enlight™



Long term power with alternating QUV and DH

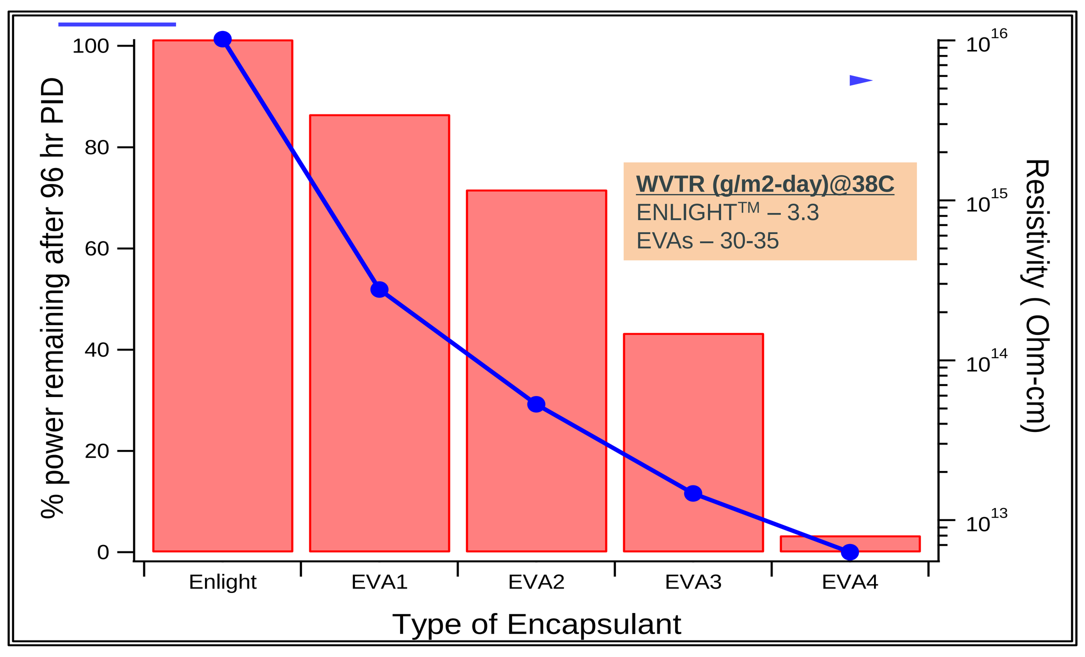


Images of backsheet after DH

Fresh 2000hrs 4000hrs

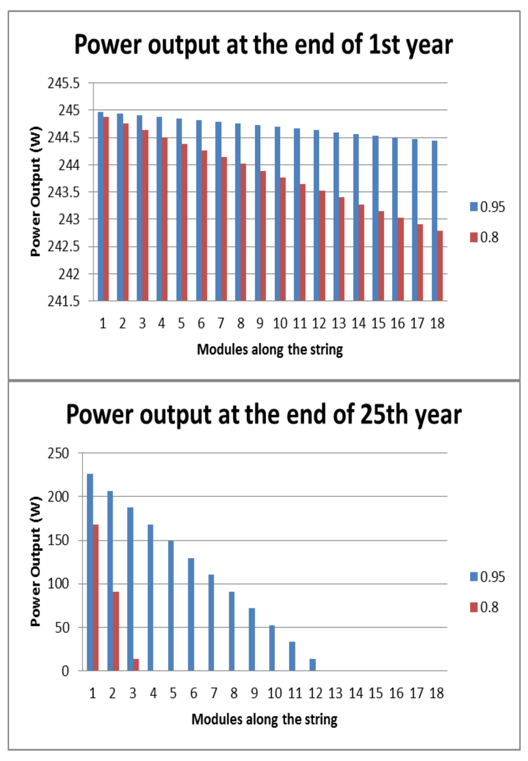
- The power after 14,000 hrs of DH is still above 90%
- The backsheet seems to be completely destroyed.
- With new encapsulants having electrical performance and WVTR comparable to backsheets - calls to question function of backsheets in PV modules

Improved PID by using Enlight™



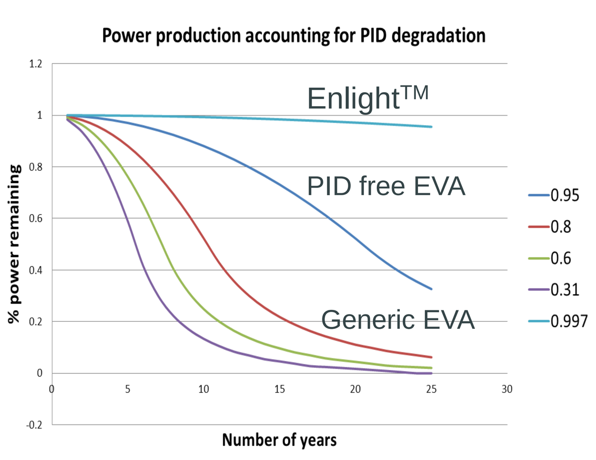
Power remaining after 96hrs at 85^{0}C, 85% RH, -1000V bias

Analysis based on NREL field study

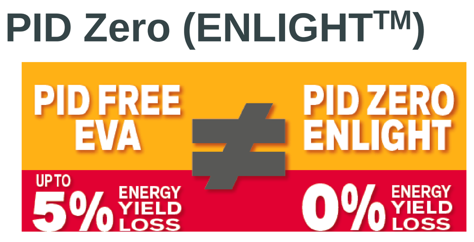


- 245 W module –string model based on module test data (considering linear power drop with voltage bias)
- NREL lab to field correlation based on single modules tested @ 60C/85% RH, 96hrs, in lab ~ 4.7yr in field
- Power retention over time measured, shows a 1-(b*t^2) dependence

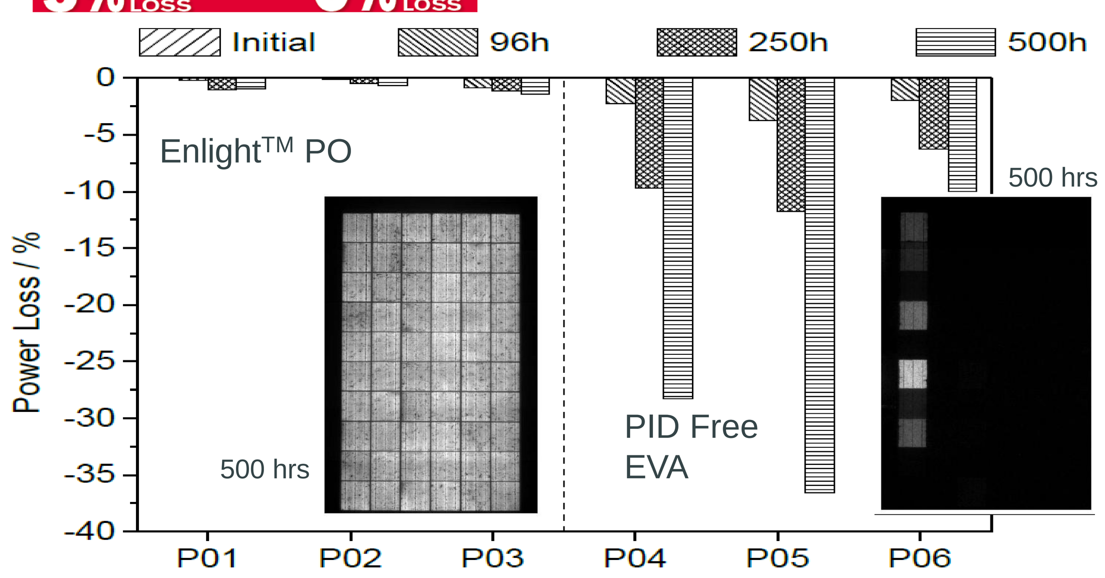
Peter Hacke et.al, IEEE conference 2012



PID Zero (ENLIGHT™)



- * 3rd Party validated by Fraunhofer CSP
- (85^{o}C/85%rh/-1000V/500hours)
- PID susceptible cells
- Enlight – 0.3% Power loss
- PID free EVA – 35% Power loss



Summary

- Accelerated testing studies were conducted with individual stressors and combination of stressors to evaluate the role of encapsulants in durability of crystalline silicon PV modules. Results suggest new encapsulant materials can increase the durability of modules and provide longer life times
- New encapsulant formulations show excellent UV stability
- Modules with polyolefin encapsulant performs with > 90% efficiency under combination of UV and DH after 14,000hrs of ageing
- Analysis based on NREL field studies suggest <0.5% degradation due to PID in accelerated testing necessary to achieve >90% efficiency at the end of 25 years
- It is shown that with proper choice of encapsulant a PID zero solution is possible