Encapsulant based solution to Potential Induced Degradation of Photovoltaic Modules *

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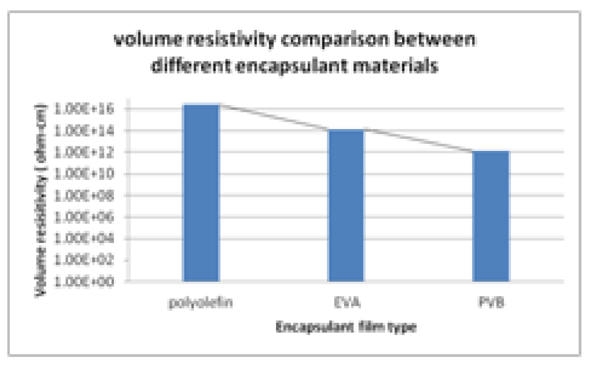
Introduction

In solar power installations, modules made of individual solar cells are connected in series to achieve desired supply voltage. The module frames are also grounded to prevent electrical shock hazards. The large potential created by this architecture between the ends and ground has been shown to cause small leakage currents across the insulators protecting the cells. This leakage current over time has been associated with reduced power output from the system. This phenomenon has been called potential induced degradation (PID). Accordingly, materials used as the insulators protecting the cells become extremely important in designing PID resistant modules. In this study, electrical properties of encapsulants (insulators) made from ethylene vinyl acetate (EVA) and polyolefins (ENLIGHT™) are evaluated and compared. Accelerated testing of PID on single and multiple cell modules made with different encapsulant films at elevated temperatures are related to the electrical properties of the films. ENLIGHT™ films show orders of magnitude higher volume resistivity compared to EVA films. It is also seen that the resistivity over broad temperature range is essential to minimize the effect of PID.

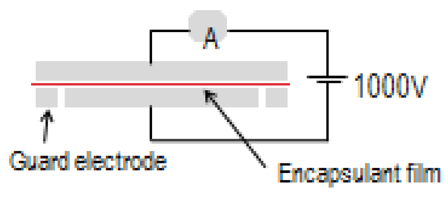
Electrical properties



Sample	Encapsulant Film Thickness (micron)	WVTR @ 38°C
ENLIGHT™ Polyolefin Encapsulant Film	457	3.3
EVA-based Encapsulant Film	457	34
PVB-based Encapsulant Film	457	84

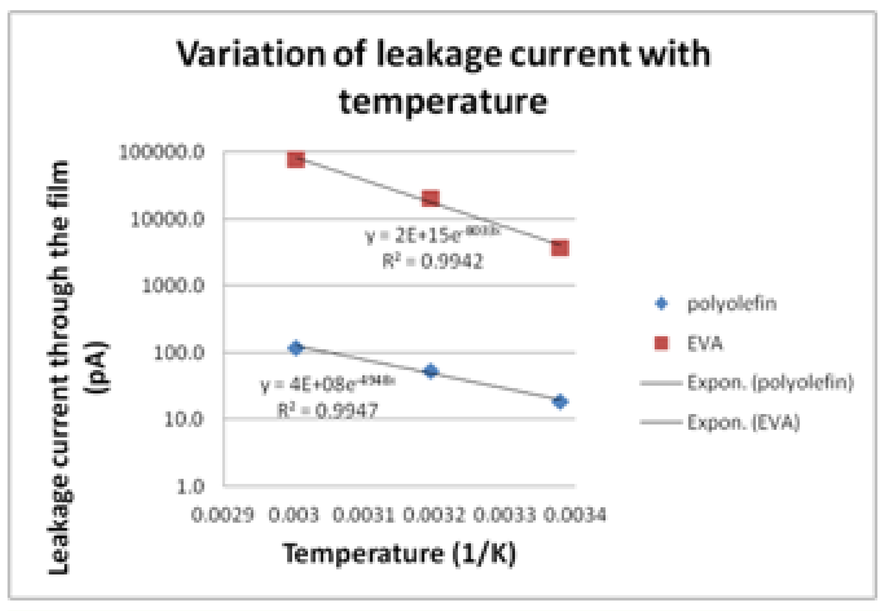
All WVTR units are in g/(m²/24 hrs) measured at 100% RH, average of two specimens.

PO films show two orders lower leakage current compared to EVA films



		ELECTRICAL	
Sample	Temp. Tested, C	Volume Resistivity (ohm cm)	Leakage Current (picoamp)
PO	23	2.64E+16	19
	40	9.47E+15	52
	60	4.12E+15	121
EVA	23	1.32E+14	3795
	40	2.48E+13	20243
	60	6.45E+12	77635

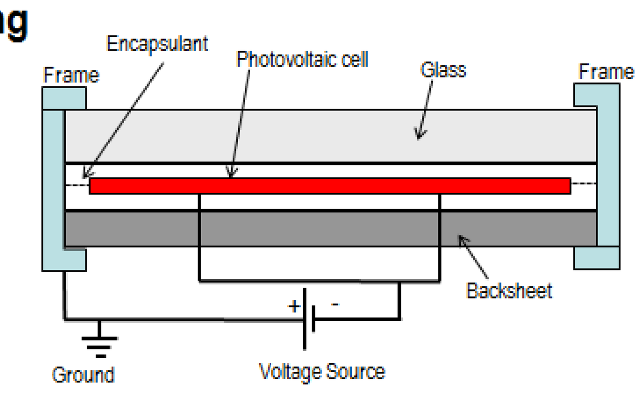
Arrhenius factor for Leakage Current



Arrhenius factor
EVA – 0.7 eV
Polyolefin – 0.42 eV

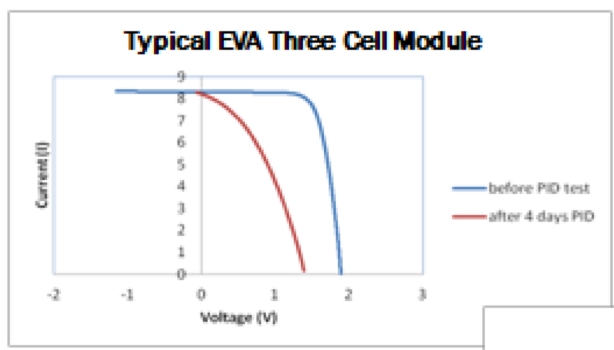
The slope is 1.5X higher for EVA suggesting EVA film is more prone to current leakage than PO film through the encapsulant with increase in temperature

PID Testing

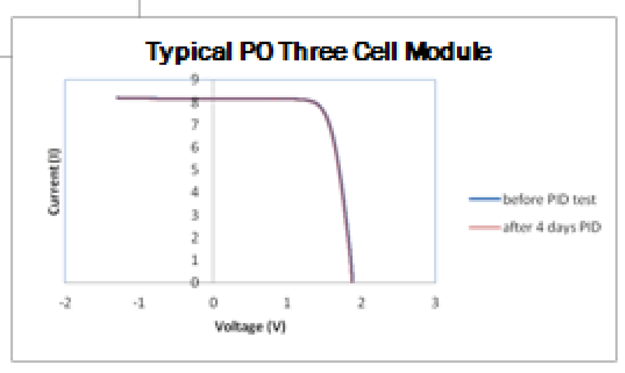


- Prepare single cell modules with MC 4 connectors and junction boxes
- Flash them to get baseline power, IV data and get electroluminescence image of the module
- Place them in the oven at 60C and 85% RH and apply -1000V to the cells with respect to the frame
- Age for 96 hours with voltage applied
- Flash the modules to check for loss of power and do EL measurements to look for failures.

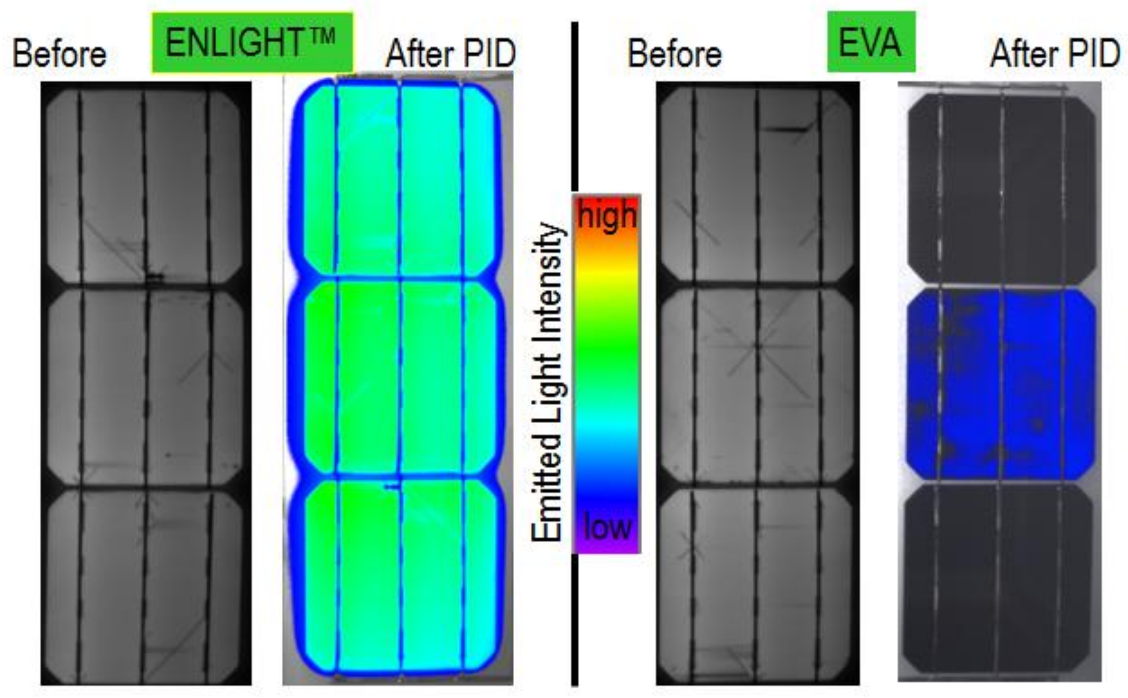
PID Test Results



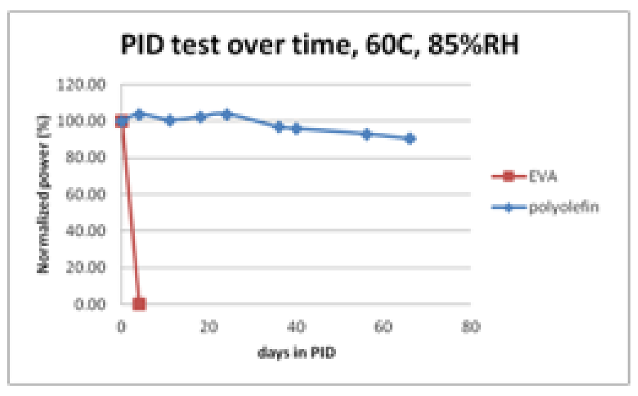
Module	Power loss after PID
EVA based	> 60%
PO based	< 1%



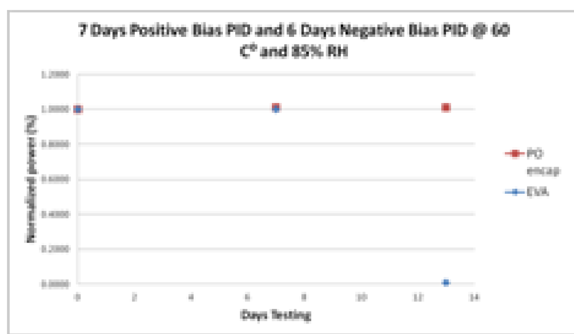
Electroluminescence Measurements

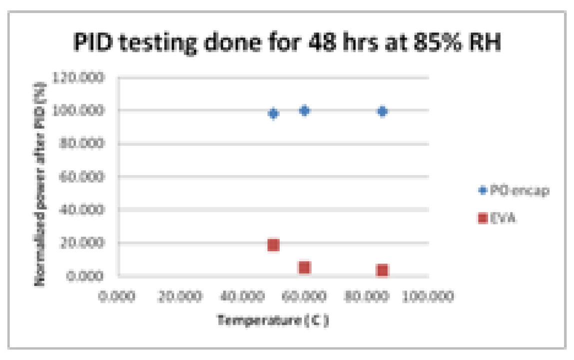


PID continued..



PID testing over 2 months shows ~10% power drop for Polyolefin with EVA based modules showing >90% power drop in 4 days





PID continued..

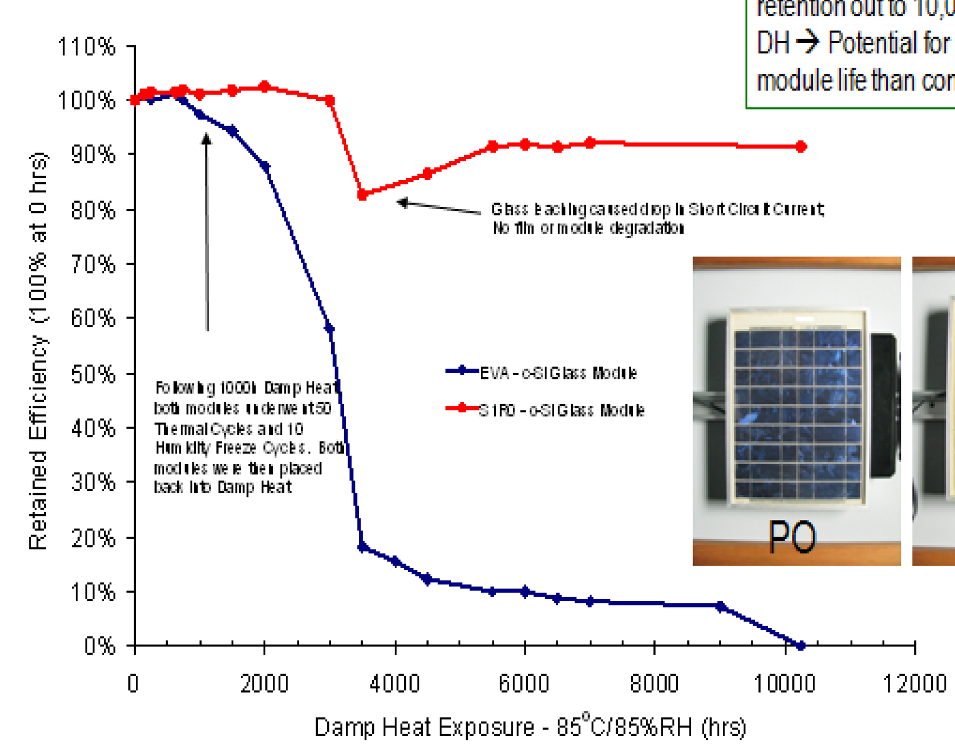
Even with PID resistant cells – severe conditions can lead to power drop

Encapsulant film	7 days under water @RT	85C, under water, 7 days	85 C, dry, 7 days
ENLIGHT™ PO	-0.9%	-0.7%	-1.8%
EVA	-2.3%	12.0%	7.5%

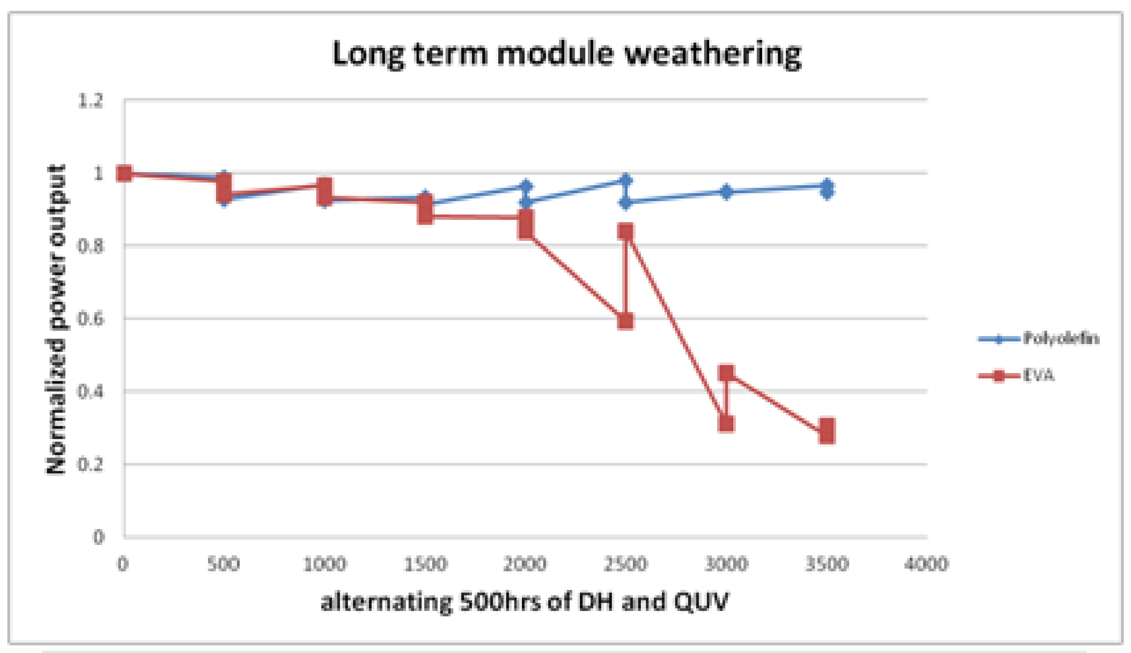
Negative sign means power gain compared to before PID test

Extended Module Reliability Data

PO module still shows 90% power retention out to 10,000 h DH → Potential for much longer module life than conventional EVA

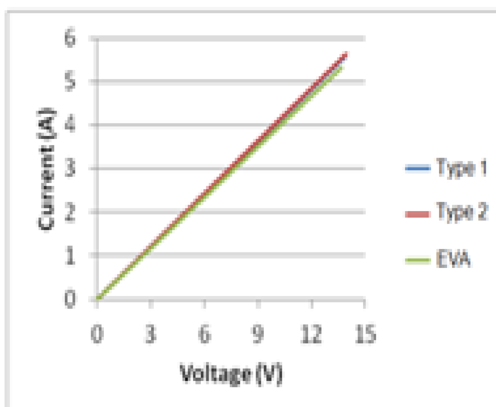


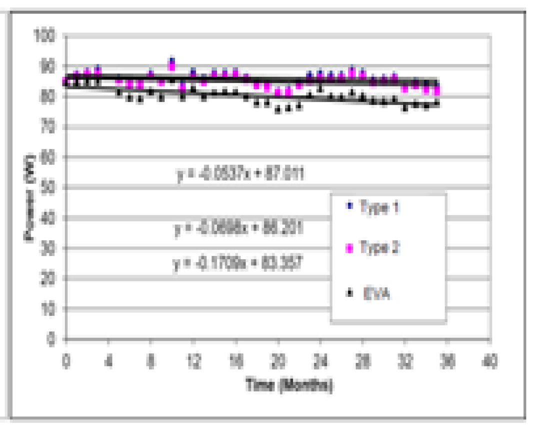
Exposure to QUV and Damp Heat testing



PO based module retains power during alternative cycling of damp heat and UV exposure over 7000hrs of total exposure

Long-term Durability of Modules with Dow Encapsulant films





Module type →	Dow Prototype 1	Dow Prototype 2	EVA
Degradation Rate (%/ year)	0.74	0.97	2.46

The power of EVA modules drop 2X compared to the PO film modules

Summary

- PID has been shown to be a significant issue in crystalline silicon modules in the field
- There have been solutions suggested to the solve the issue by changing the coating on solar cells or changing the grounding configuration
- In this work, we present an approach by using polyolefin based encapsulant in place of EVA which does not lead to any change in the type of cells used or the installation process
- It was found that electrical insulation resistance and lower water vapor transmission are required to prevent ion migration and PID
- The ENLIGHT™ Polyolefin encapsulant film provides two orders higher volume resistivity and one order lower water vapor transmission rate which in turns helps modules resist PID.