DSCI 3512-451 Project 3

Accelerated Aging of PV Module Backsheet

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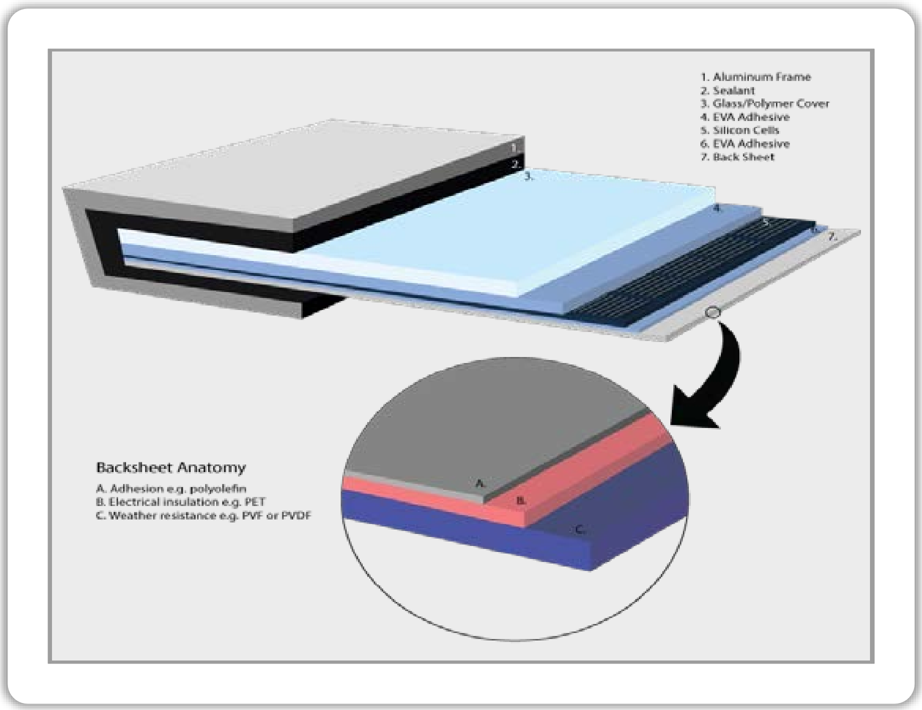
Introduction and Background

PV modules are required to survive in different types of environments, and the backsheets of PV module play an important role in protecting the PV module from outside weathering effects. The backsheet also can protect human being from electric shock. However, various environmental factors, such as UV radiation, humidity and temperature, induce degradation process of PV module backsheet. In order to enhance the performance and reliability of a PV module, it is necessary to study the degradation of PV backsheet. Oreski and Wallner give some good background information on this topic in their paper[1]

The backsheet of PV module usually consists of three layers of polymer (Fig. 1). The fluoropolymers such as polyvinylidene fluoride (PVDF) and polyvinyl fluoride (PVF) acts as a protection against weathering influences and are used as outer layer (facing the sun). Polyesters such as polyethylene terephthalate (PET) provides mechanism strength and dielectric protection are used as core layer. As for inner layer, the polymers are selected either same with the outer layer and the backsheet forms a symmetric structure, or ethylene vinyl acetate (EVA) to increase adhesion with encapsulate layer of PV module.



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[1] [1] G. Oreski and G. M. Wallner, "Aging mechanisms of polymeric films for PV encapsulation," *Solar Energy*, vol. 79, no. 6, pp. 612–617, Dec. 2005.

Fig.1 Diagram of backsheet structure of a PV module.

The indoor accelerating tests are designed to study the degradation behavior of backsheet exposes to high-intensity condition without waiting long time to observe the degradations.

Experiment Design

The PV backsheet coupons are laminated with glass, encapsulant layer, and five types of commonly used backsheet: PVDF/PET/EVA (sampleID: sa31001), fluoro-coated backsheet/PET/EVA (sampleID: sa31002), PET/PET/EVA (sampleID: sa31003), PVF/PET/EVA (sampleID: sa31004), polyamide (PA)/PA/PA (sampleID: sa31005).

These five types of backsheet coupons are exposed to three different conditions: Damp heat, xenon arc #1 and xenon arc #2. The details of three conditions are listed in Table 1. Xenon arc radiation was selected among the six major light sources used in the industry (carbon arc, xenon arc, fluorescent UV lamps, metal halide, indoor actinic source, mercury lamp) because it is the closest to natural daylight. Damp Heat was also selected because it is widely recognized as a standard test for PV backsheets in the industry (one of the criteria to meet to be IEC 61215 approved).

Table 1. Description of three types of exposure conditions

Exposure	**Irradiation (W/m^2)**	**Chamber Temp. (°C)**	**Black Panel Temp. (°C)**	**Relative humidity**	**Comment**	**Durations (hrs)**
Xenon Arc #1	0.8	65	90	20%	100% light, no water spray	4000
Xenon Arc #2	0.8	65	95	20%	102 minutes light, 18 minutes waterspray	4000
Damp Heat	/	65	/	85%	/	1500

For all three exposures, non-destructive evaluations are conducted at selected pull times. In addition, one coupon of each backsheet type (among coupons used for non-destructive evaluations) is retained at selected pull times as a reference and for deeper investigation and analysis. The different selected schedules are summarized in Table 2. The xenon arc #2 exposure has not been finished yet (3000 hrs).

Table 2. Summary of the selected pull times for evaluations and retains for each exposure and backsheet type

		Steps/Exposure time							
		step 00	step 01	step 02	step 03	step 04	step 05	step 06	step 07
Exposure		0hrs	500hrs	1000hrs	1500hrs	2000hrs	2500hrs	3000hrs	4000hrs
Xenon Arc #1 and #2	Non-destructive evaluations	●	●	●	●	●	●	●	●
	Coupon retained	●		●		●		●	●
Damp Heat	Non-destructive evaluations	●	●	●	●				
	Coupon retained	●	●	●	●				

Characterization Methods

At every step, optical evaluations including yellowness index and gloss are conducted on all coupons.

The yellowness index (YI) is a single value that present the color of polymer surface. It is well-known that polymers degrade and become yellow due to light or chemical exposure. The YI is used to act as a degradation indicator of polymers.

The gloss is a measurement of how much light reflects from the sample surface. And the glossmeter measures the reflectance light at three different angles: 20, 60 and 85 degrees. The more smooth of the surface, the larger the gloss value. The polymers are presumed to become more and more course during degradation process. In this project, we choose gloss measured at 60 degree as degradation response.

Project Requirement

1. Visualize the YI and gloss of one of the samples over time, what trends do you notice?
2. How do YI and gloss relate to the material degradation?
3. Develop degradation models
   (1) Develop a linear model for each material with exposure to each condition.
   (2) For each exposure, plot the data and linear model for all the materials on one plot.
   (3) Discuss the differences you notice between the data and the models.
   (4) For each exposure describe which material performs the best and worst, explain your conclusions.
   (5) Do any of the models appear non-linear? If so, try and improve their fit with a power transformation or a piecewise linear model.
4. For each of the 5 backsheet materials, use Hyperspec and plot the FTIR spectra of each backsheet at the beginning and at the end of each of the 3 exposure type. Discuss what peak changes you note. You may want to normalize the two spectra so their peak amplitudes match for most of the peaks.
5. Explain which backsheet you feel is the best overall performer based on this data set

Useful R packages:

ggplot2, tidyverse, dplyr, segmented, MASS, lme4, segmented