# Degradation of Backsheets for Crystalline Photovoltaic Modules under Damp Heat

Dajung Kim<sup>1</sup>, Won-Sik Hong<sup>1</sup>, and Chulmin Oh<sup>1\*</sup>

<sup>1</sup> Robust Components and System Research Center, Korea Electronics Technology Institute 25 Saenari-ro, Bundang, Seongnam, Gyeonggi, 463-816, South Korea Phone: +82-31-789-7291 E-mail: cmoh@keti.re.kr

# Abstract

The reliability of crystalline silicon photovoltaic module is determined not only by the efficiency loss of silicon cells but also by the degradation of other components (EVA, ribbon, glass, and backsheet). In those components, backsheet is designed to protect the inner silicon cell of the PV module from external stresses as well as act an electric insulator. In our study, we investigated the degradation of different types of backsheets under several damp heat conditions (95° C/85 % R.H., 85 °C/85 % R.H.). During the damp heat, the tensile test was carried out to find mechanical degradation of backsheets. Molecular weight of PET in backsheets was measured by gel permeation chromatography (GPC) to understand the intrinsic mechanism of degradation in backsheet. By finding the correlation between tensile strength and molecular weight of bakchseet, our results can open an opportunity to improve the reliability of backsheet.

## 1. Introduction

As the efficiency of crystalline PV module comes to approximately the theoretical value, the development of a crystalline PV module has driven to cost reduction as well as long-term reliability. The long-term reliability of a crystalline PV module can be achieved by understanding the degradation mechanism of each components which compose a crystalline PV module. In those components, the glass and polymeric backsheet are exposed to outside field to protect the inner silicon cell of the PV module from external stresses such as an electric insulator [1, 2]. In particular, the backsheet material is more vulnerable to external environment than the glass because it is designed by multilayer of polymeric materials, such as polyethylene terephthalate (PET), polyvinyl fluoride (PVF), and polyvinylidene fluoride (PVDF) [3, 4]. In our study, damp heat test was carried out to accelerate the field condition with various types of backsheet. We investigate the mechanical property of backsheet materials under damp heat exposure to find the degradation of backsheet materials. We also analyze the change of molecular weight under damp heat test to understand intrinsic mechanism of degradation in backsheet materials. Therefore, we reveal the correlation between mechanical property and molecular weight of backsheet materials, suggesting the key factor to improve the reliability of backsheet materials.

# 2. Experiment

Three types of backsheets were used as shown in Fig. 1. Although the core layer of backsheet is same material as PET for all types of backsheets, the peripheral layer exposed directly to the harsh external environment, is different; laminated PVDF film, coated fluorine, and laminated PET film.



Fig. 1 Three types of backsheets used in our experiment; (a) PVDF laminated backsheet, (b) fluorine coated backsheet, and PET laminated backsheet.

Damp heat test was carried out under the different conditions for 85 °C/85 % R.H. and 95 °C/85 % R.H. until the specimens were broken by itself in handling. Tensile strength of specimens was measured every specific interval for each conditions with tensile speed of 1 mm/s to investigate the mechanical degradation behavior of backsheet materials. After tensile test, the factures of each specimen were observed by optical microscope to find the fracture site. The molecular weight of PET layer in backsheet materials was scrutinized by gel permeation chromatography (GPC) at specified time for each conditions to identify the polymeric degradation of PET layer.

## 3. Results

Fig. 2 shows the change of tensile strength of backsheet materials for each test conditions. During damp heat, the tensile strength of backsheet laminated PET film is higher than that of others. This result comes from superior water resistance of PET film than PVDF film and fluorine materials [5, 6]. However, in all specimens, the tensile strength of backsheet decreases slightly until 2000 h in the condition of 85 °C/85 % R.H., while the tensile strength drops significantly after passing 600 h in the condition of 95 °C/85 % R.H.



Fig. 2 The variation of tensile strengths for backsheet materials in both conditions of (a) 85  $^{\circ}$ C/85  $^{\circ}$  R.H. and (b) 95  $^{\circ}$ C/85  $^{\circ}$  R.H.

After tensile test for specimens passed 1000 h at 95  $^{\circ}$ C /85  $^{\circ}$  R.H., The fracture crack was mainly observed in PET film of backsheet as shown in Fig. 3. In rupture stage, the PET film in backsheet materials are cracked, resulting in brittle fracture. It is caused by an increase of crystallization in PET film during damp heat. The internal cracks inside PET film of backsheet were also observed in Fig. 3(b) as the result of crystallization in PET film.



Fig. 3 After 1000 h in the condition of 95 °C/85 % R.H., crosssectional optical micrographs of facture of PET films in (a) PVDF laminated backsheet, (b) fluorine coated backsheet, and (c) PET laminated backsheet.

To clarify the degradation mechanism of PET film of backsheet, the molecular weight of PET film was measured by using GPC analyzer at specified interval time in the condition of 95 °C/85 % R.H. The molecular weight of polymer is one of key parameters, determining physical properties such as stiffness, strength and toughness [7, 8]. During the damp heat, molecular weight of PET films decrease in all specimens, matching well with the drop of tensile strength as shown in Fig. 2. It is known that the relation between tensile strength and molecular weight of polymer can be approximately by the proportional relation [9, 10].

A decrease of tensile strength of backsheet materials can be plotted as function of molecular weight of PET film with specific time as shown in Fig. 2. The tensile strength of backsheet materials isn't changed considerably with decreasing the molecular weight of PET film. However, after passing a specified region ( $6000 \sim 8000$  molecular weight), the tensile strength of backsheet materials drops sharply compared to a slight reduction of the molecular weight of PET film. In other words, during damp heat, the mechanical durability of backsheet materials can be kept before the molecular weight of PET film decreases to the transient molecular weight region.



Fig. 4 A drop of tensile strength as a function of molecular weight of three kinds of backsheet materials during damp heat in the condition of 95  $^{\circ}C/85 \%$  R.H.

#### 4. Conclusions

We can demonstrate the degradation of backsheet materials by investigating tensile strength and molecular weight. The tensile strength of backsheet materials decreases during the damp heat test, although backsheet laminated PET film is superior to others. After damp heat test, we also reveal that the brittle fracture is occurred in PET film which is a core layer in backsheet material. By analyzing the molecular weight of PET film, the decrease of the molecular weight of PET film is correlated with that of tensile strength of backsheet materials. In addition, regardless of backsheet materials, the mechanical degradation in backsheet can be occurred significantly after the molecular weight of PET drops below specified region. Based on our results, we can realize the reliable backsheet materials by finding the key parameters for assuring long-term reliability of backsheet materials.

#### Acknowledgements

This work was supported by the New & Renewable Energy Program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) Grant funded by the Korea Government Ministry of Knowledge Economy (20133030011150).

### References

- [1] Dan Wu et al., Prog. Photovolt : Res. Appl. 22 (2014) 796.
- [2] W. Gambogi et al., 26th European Photovoltaic Solar Energy Conference and Exhibition (2011) 3325.
- [3] G. Oreski, G.M. Wallner, Solar Energy 79 (2005) 612.
- [4] Klaus J. et al., 26th European Photovoltaic Solar Energy Conference and Exhibition (2012) 3499.
- [5] G.D. Barber et al., 29th IEEE PVSC-Conference (2002) 1541.
- [6] Cornelia Peike et al., International Scholarly Research Network (ISRN) Renewable Energy (2012) 5.
- [7] WILLIAM McMAHON et al, Journal of Chemical & Engineering Data 4 (1959) 57.
- [8] L. J. Fetters et al., Macromolecules 27 (1994) 4639.
- [9] D.F. Farrar, R.K. Gillson, Biomaterials 23 (2002) 3905.
- [10 Paul J. Flory, J. Am. Chem. Soc. 67 (1945) 2048.