Weather Resistance Performance of Backsheets with Various Structures

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Abstract. Backsheet is the key element to ensure the power generation of PV modules during their whole life cycle. To continually decrease the LCOE, backsheets of new structures are gradually applied. Currently, the evaluation of module product performance is mainly on the module scale, while the assessment of each single material is rare. This paper is aimed at the evaluation of each single backsheet’s reliability when applied in different climatic environments for the widely used new backsheet structures (BS1-BS5). Through comparative research, the backsheet based on thicker PET was found to have a better mechanical performance and BS3 exhibited good resistance performance in hot and humid condition, which could be attributed to the low water vapor transmission rate of the PO film.

1. Introduction
Polymer backsheet has been applied in the photovoltaic industry for more than 30 years [1]. Photovoltaic modules can mainly be divided into single glass modules and double glass modules according to the type of backplane material. A double-glass module utilizes glass to replace the polymeric backsheet, which can prevent moisture penetration from the back side and improves module reliability in hot and humid condition [2]. However, due to the limitation of the tempering technology of glass, tempered glass still needs to be thick, resulting in high weight of current double-glass modules. Moreover, the production yield of double glass modules is lower than that of the single glass ones, so the single glass module is still the mainstream in the market. The main encapsulating materials for single glass modules are glass, encapsulant and backsheet [3]. Among them, only glass and backsheet directly face the complex outdoor environment. Glass is an inorganic material, which is intrinsically weather resistant. However, backsheet is generally a polymer composite, thus its weather resistance becomes an important factor affecting the life of a photovoltaic module [4-8]. Photovoltaic backsheet materials have evolved in structure from TPT to KPK to KPF, etc. To further reduce the cost of photovoltaic electricity, new backsheet structures and materials are gradually being promoted and applied. It is generally understood that polyethylene terephthalate (PET) is less UV-resistant than Fluorine-containing resin, thus backsheets based on PET core layer must be embedded between two layers of Fluorine-containing film to ensure its UV-resistance [9]. Considering the progress in the material technology, new prescriptions or recipes have been developed, leading to longer lifetime of the PET core layer. The more weather resistant PET or the so-called strengthened PET, may become adequately strong to endure the harsh complex conditions during module operation for 25 years. Currently, backsheets are evaluated according to the IEC standards, but the evaluation tests are mainly performed on the module level [3-4,10]. Therefore, in this paper, the backsheet of
these new structures was studied on the single material level with the previously widely used backsheet structure to investigate the weatherability of these new developed recipes. For the complex climatic environment of outdoor applications, the aging test of ultraviolet as well as hot and humid environment was carried out separately. The mechanical properties of the backsheets before and after aging were measured. The obtained results will provide an important reference for the selection of backsheet materials in the PV industry.

2. Experimental Section
Five different backsheets were selected in this work. The backsheets of different structures were manufactured by different manufacturers. The backsheets were cut into 15mm strips, both for the horizontal and vertical directions. The initial tensile strength and elongation at break were tested, and then the samples were put into the pressure cooking box under 121°C, 100% RH. The backsheet samples were taken out after cooking for 24 h and 48 h, and tested for tensile strength and elongation at break. The longitudinal and lateral directions of each sample were tested separately. The UV test doses were 60 kWh and 120 kWh, respectively, and afterwards the tensile strength and elongation at break were tested in transverse direction (TD) and mechanical direction (MD), respectively.

3. Results and Discussion
The structure of the BS1 and BS2 backsheet is PVDF/PET/F-coating, BS3 is PVDF/PET/PO, BS4 is Tedlar/PET/F-coating, and BS5 is a PET single layer. The thicknesses of the five backsheets (BS1-BS5) are 280um, 290um, 290um, 280um and 220um. Among them, the thickness of PET in BS1 and BS2 is 250um, PET in BS3 and BS4 is 188um, and in BS5 is 220um. The five backsheets are made of PET. Due to the polyester structure, the ester groups in the molecular backbone are easily hydrolyzed in a high-humidity environment or under ultraviolet light, resulting in performance degradation.

To evaluate the weather resistance performance of the backsheet in hot and humid environment, the backsheet samples were placed in 121°C, 100% R.H. environment for high pressure cooking. Figure 1a is the tensile strength of MD before and after PCT, and Figure 1b is the tensile strength of TD before and after PCT. The initial performance of the tested backsheets was above 100MPa, and different backsheets showed some differences. The tensile strength of the backsheet with a thin PET thickness was lower. The tensile strength of 188um PET in MD was only 100MPa-120MPa, which could still meet the national standard. In terms of TD tensile strength, in addition to BS3 and BS4, the test results of BS2 were also lower, even about 15 MPa lower than the results after PCT 24h. This anomaly may due to the edge burrs caused during sample preparation. From the tensile strength after PCT24h and PCT48h, it could be noted the tensile strength of the backsheet gradually decreased with the prolonged aging time. After PCT 48h, the retention rates of the tensile strength in TD of BS1-BS5 backsheets were 74%, 84%, 80%, 74% and 86%, respectively, and the retention rates of the tensile strength in MD were 74%, 72%, 75%, 49% and 83%, respectively.

Figure 1. Tensile strength of different backsheets before and after PCT.

The molecular weight of PET was significantly reduced after degradation, which was manifested by a significant decrease in the elongation at break. Figure 2 shows the change in elongation at break of the backsheet before and after the PCT test. The initial elongation at break of each backsheet exhibited obvious variation. Generally, backsheet based on thicker PET had a higher elongation at break, but all
samples were above 100%. After PCT for 48h, the retention rates of elongation at break in TD of BS1-BS5 backsheets were 50%, 22%, 56%, 46% and 57%, respectively, and the retention rates of elongation at break in MD of BS1-BS5 backsheets were 21.1%, 5.3%, 58.6%, 63.9% and 43.2%, respectively. Among them, the elongation at break of BS2 backsheet exhibited the largest degradation. After PCT 48h, the elongation at break in MD and TD was reduced to 7.4% and 18.9%, respectively. These results demonstrated that BS2 was obviously embrittled and had a high risk of cracking after outdoor aging. BS3, in which polyolefin was employed as the inner layer, showed good retention of elongation at break both in TD and MD, and exhibited good resistance performance in hot and humid condition, which could be attributed to the low water vapor transmission rate of the PO film.

![Figure 2](image1.png)

Figure 2. Elongation at break of different backsheets before and after PCT.

To evaluate the weatherability under outdoor UV radiation, the backsheet samples were placed in a simulated ultraviolet environment for irradiation. The irradiation dose was set at 60 kWh and 120 kWh, taking into account the amount of irradiation backsheet may receive during outdoor operation. Figure 3a and 3b shows the tensile strength before and after UV in MD and TD, respectively. As can be seen, the tensile strength of the backsheet gradually decreased with the prolongation of UV aging. After 120kWh irradiation, the retention rates of tensile strength in TD of BS1-BS5 backsheets were 81%, 102%, 89%, 84% and 97%, respectively, and those in MD were 84%, 69%, 73%, 53% and 95%, respectively. The absolute values of the tensile strength of each backsheet were all over 80 MPa.

![Figure 3](image2.png)

Figure 3. Tensile strength of different backsheets before and after UV.

Figure 4 shows the change in elongation at break of backsheets before and after UV irradiation. After 120 kWh UV irradiation, the retention rates of elongation at break in TD of BS1-BS5 were 55%, 95%, 56%, 69% and 71%, respectively, and those in MD were 35%, 36%, 49%, 67% and 64%, respectively. The elongation at break of various backsheets was all above 50%, indicating good UV resistant performance of the backsheets.
4. Conclusion
Backsheet is the key element to ensure the power generation of PV modules during their whole life cycle. The evaluation of module products is currently assessment of the overall module performance, while the assessment of each material is rare. This paper focused on the evaluation of the backsheet’s reliability when applied in different climatic environments for the widely used new backsheet structures (BS1-BS5). The obtained results demonstrated that the backsheet based on thicker PET had a better mechanical performance and backsheet with a PO layer exhibited good resistance performance in hot and humid condition, which could be attributed to its low water vapor transmission rate.

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References
[1] K. J. Geretschläger, G. M. Wallner, J. Fischer, Structure and basic properties of photovoltaic module backsheets, Solar Energy Materials & Solar Cells, 144 (2016), 451-456.
[2] F. Kraemer, S. Wiese, Assessment of long term reliability of photovoltaic glass-glass modules vs. glass-back sheet modules subjected to temperature cycles by FE-analysis, Microelectronics Reliability, 55 (2015), 716-721.
[3] W. Qi, Research on the effect of encapsulation material on anti-PID performance of 1500 V solar module, Optik - International Journal for Light and Electron Optics, 202 (2020), 163540.
[4] F. Liu, L. Jiang, S. Yang, Ultra-violet degradation behavior of polymeric backsheets for photovoltaic modules, Solar Energy, 108 (2014), 88-100.
[5] Y. Kobayashi, H. Morita, K. Mori and A. Masuda, Investigation of UV and hygrothermal stress on back side of rack-mounted photovoltaic modules, Renewable Energy Focus, 29 (2019), 107-113.
[6] W. Luo, Y. S. Khoo, S. Ramakrishna, et al. A comparative life-cycle assessment of photovoltaic electricity generation in Singapore by multicrystalline silicon technologies, Solar Energy Materials and Solar Cells, 174 (2018), 157-162.
[7] O. O. Ogbomoa, E. H. Amalub, N. N. Ekerea, P. O. Olagbegic, A review of photovoltaic module technologies for increased performance in tropical climate, Renewable and Sustainable Energy Reviews, 75 (2017), 1225-1238.
[8] J. Tanesab, D. Parlevliet, J. Whale, T. Urmee, Seasonal effect of dust on the degradation of PV modules performance deployed in different climate areas, Renewable Energy, 111 (2017), 105-115.
[9] Y. Lyu, J H Kim, X Gu, Developing methodology for service life prediction of PV materials: Quantitative effects of light intensity and wavelength on discoloration of a glass/EVA/PPE laminate, Solar Energy, 174 (2018), 515-526.
[10] G. Makrides, M. Theristis, J. Bratcher, J. Pratt, G. E. Georgiou, Five-year performance and reliability analysis of monocrystalline photovoltaic modules with different backsheets materials, Solar Energy, 171 (2018), 491-499.