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URL: https://www.sciencedirect.com/science/article/pii/B9781455778850000028

Surface Preparation of Thermoplastics, Thermosets, and Elastomers

Sina Ebnesajjad, in Handbook of Adhesives and Surface Preparation, 2011

7.2.32 Polyvinyl Fluoride

Du Pont has three types of Tedlar® film, Type A, with one side treated for bonding; Type B, with both sides bondable; and Type S, which is untreated and is used as a release film (www2.dupont.com).[21] Type B is used in laminating to metals, plastics, wood, and other materials; it requires no further surface preparation for adhesive bonding. The methods for preparing the untreated film for adhesive bonding are similar to those of polyolefins and fluoropolymers (see Chapter 6).

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URL: https://www.sciencedirect.com/science/article/pii/B9781437744613100070

Manufacturing of crystalline silicon solar PV modules

Rabindra Satpathy, Venkateswarlu Pamuru, in Solar PV Power, 2021

Materials used for inner layer

The polyvinyl fluoride (PVF) film called Tedlar as well as Kynar (PVDF), polyvinylidene fluoride (PVDF), fluoroethylene and vinyl ether copolymer (FEVE) coatings, PET, fluorine skin, polyolefin, ethylene, and the E-layer are the materials used as the inner layer for back sheet design.

Typically, the E-layer is made of low melting adhesives such as polyethylene or ethylene vinyl acetate. Both are thermoplastic materials, thus deforming and softening during heat exposure. This is problematic on two fronts: during vacuum lamination and during the lifetime in high-temperature installations. During the vacuum lamination process, typically conducted at 140–160°C under vacuum, the E-layer melts, pushing ribbon wires toward and in direct contact with the inner core PET layer. This reduces the electrical insulation characteristics of the back sheet. In addition, these olefin-based layers may yellow under UV exposure and have been reported to crack, pulverize, and disintegrate. This exposes the inner core films to a damaging UV light, thus marginalizing the safety and reliability of the PV module itself.

The major back sheet configurations in today's market are manifold (TPT, TPE, TPC, KPK, KPE, KPf, KPx, PPE, CPC, AOE, and OOO). The abbreviations are explained as T—Tedlar (PVF film); P—PET film; K—Kynar (PVDF film); C—Coating of fluoropolymer; E—Polyethylene or EVA layer; f—Fluorine skin; A—Polyamide; and O—Polyolefin.

Earlier back sheet designs of the inner and outer layers that were extensively used were with Tedlar, a PVF material and the trademark of Dupont. Tedlar was synonymously called back sheet. After 2007, due to the sudden growth of solar PV systems, the demand increased for Tedlar, and Dupont was not able to supply the requirements of solar module manufacturers. To meet the growing demands and to reduce the price of the back sheet, the R&D efforts took place in two ways: fluoropolymer-based back sheets and nonfluoropolymer-based back sheets. PVF and PVDF are fluoropolymer-based materials with fluorine content that are kept as the outer layer of the back sheet. The core material is PET, which cannot withstand UV light and becomes brittle if exposed to light.

The most common back sheet defects found by the researchers were:

Prolonged exposure of the back sheet to UV light, high temperatures, and environmental stresses cause the back sheet to undergo discoloration. This is an early indicator of serious mechanical integrity issues, including delamination and cracking. Yellowing can compromise the back sheet's electrical insulating properties.

Macrocracks in the back sheet's outer layer and outer layer separation from the back sheet structure are called abrasion and delamination. The abrasion and delamination defects will lead to safety issues because they represent severe degradation of the back sheet's protective feature and expose the inner PET core layer to the elements.

Delamination and bubbling: Cracks in the outer layers of the back sheet responsible for delamination and bubbling. The defect has the potential to expose the core back sheet layers and compromise the structural integrity. Delamination can also result from hot spots (a bubble caused by the separation of the back sheet or encapsulant layers) or increased series resistance.

The back sheet serves as a moisture barrier and provides the necessary environmental protection. Hence, the lifetime of the back sheet under certain operating conditions directly impacts the performance and lifetime of the PV module. However, these materials gradually degrade and lose their performance due to environmental stresses, including high temperature, humidity, and UV radiation. Based on the results from observing a field-aged PV module, the cracking of the PET and delamination between polyvinyl fluoride (PVF) or polyvinylidene fluoride (PVDF) and polyethylene teraphthalate (PET) are commonly observed failure modes that also represent catastrophic failure. These failure modes can reduce the performance of the PV module and shorten its lifetime. Moreover, cracking of the back sheet, which is caused by a decrease in the tensile strength, results in the penetration of a large amount of moisture. It is the most catastrophic failure mode among the reported failure modes of the back sheet because the cracking of the back sheet allows both water vapor and liquid ingress into the PV module. It can significantly impact the performance and reliability of the PV module. Thus, the prediction of degradation patterns and the lifetime for the back sheet are critical to ensure that the PV module maintains its performance throughout its lifetime. Fig. 5.12 shows the chemical structures of different back sheet materials.

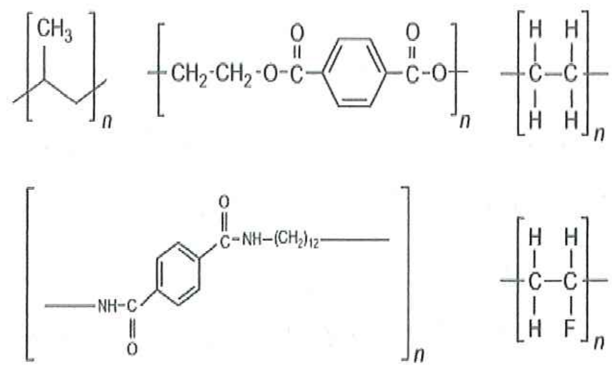

Fig. 5.12. The chemical structures of back sheet materials; (A) PP, (B) PET, (C) PVF, (D) PA, and (E) PVDF.

The degrading mechanisms can be prevented most effectively by an intact polymeric back sheet that forms an outer layer of solar panels and that is expected to provide protection for photovoltaic modules over the expected service life.

PET molecule contains a large number of ester groups in the main chain. It has good affinity with water, so, even a trace amount of water will lead to the degradation of the molecular main chain. PET aging properties change in hot and humid environments. The aging process is affected by three factors: the degree of crystallinity, water plasticization, and hydrolysis. These factors appear at different environments and play a leading role in different stages of performance of PET. The degree of crystallization is a dominant factor for early aging of the material. It increases the Young's modulus and maximizes the tensile stress, causing the material to become brittle, reducing the impact strength. The water plasticization become a factor for the increase of material toughness causing the hydrolysis reaction to start. The hydrolysis reaction breaks the chains of PET macromolecules, and the molecular weight decreases, thereby causing the destruction of the mechanical properties. The temperature rise significantly accelerates the above-described processes. Water and heat cause reduction of physical and mechanical properties of PET material. In addition, UV radiation may cause the reduction of molecular weight of the PET, and so, the strength and elongation of PET are greatly decreased. UV radiation increases the degree of crystallinity causing the material to become brittle. Table 5.4 shows different configurations of the back sheet with different combinations of tri layers. PET with modifications is used as a core layer for almost all types of back sheets.

Table 5.4. Different configurations of the back sheet.

Back sheet structure	Tedlar (PVF)/PET/Tedlar (PVF)	Kynar (PVDF)/PET/Kynar (PVDF)	Kynar (PVDF)/PET/Other Polymer film	Tedlar (PVF)/PET/Poly
	TPT	KPK	KPX	TPE
Air side layer	Tedlar	Kynar	Kynar	Tedlar
Core layer	PET	PET	PET	PET
Cell side layer	Tedlar	Kynar	Polymer film	Polyethylene

	Kynar (PVDF)/PET/polyethelyne	Kynar (PVDF)/PET/fluorine skin	Tedlar (PVF)/PET/coating	Tedlar (PVF)/PE polymer
	KPE	KPf	TPC	TPX
Air side layer	Kynar	Kynar	Tedlar	Tedlar
Core layer	PET	PET	PET	PET
Cell side layer	Polyethylene	Fluorine Skin	Coating	Polymer

	PET/PET/polyethylene	Coating/PET/coating	Polyamide/polyolefin/polyethy
	PPE	CPC	AOE
Air side layer	PET	Coating	Polyamide
Core layer	PET	PET	Polyolefin
Cell side layer	Polyethylene	Coating	Polyethylene

Table 5.5 gives the typical properties of a back sheet material.

Table 5.5. Typical properties of a back sheet material.

Sr. no.	Properties	Standard followed	Value	Unit
1	Interlayer peel strength	ASTM D1876	> 5	N/cm
2	Peel strength with encapsulant	Relevant ASTM	> 75	N/cm
3	Breakdown voltage	ASTM A-149	69.34	kV
4	Partial discharge	IEC 60664-1/IEC 61730	1500	VDC
5	Water vapor permeability	ASTM F1249 (38°C, 90% RH)	1.71	g/m^2/day
6	Damp heat exposure	IEC 61215 (85°C/85% RH)	1000	h
7	Maximum system voltage	IEC 61730-2; IEC 60664-1	1000	V
8	Thickness (total laminate)	ASTM D1593	320	μm
9	Tensile strength	ASTM D882	> 100	N/mm^2
10	Shrinkage	ASTM D1204	> 1.5	%

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Fluoropolymers

Laurence W. McKeen, in Permeability Properties of Plastics and Elastomers (Fourth Edition), 2017

11.7 Polyvinyl Fluoride

Polyvinyl fluoride (PVF) is a homopolymer of vinyl fluoride. The molecular structure of PVF is shown in Fig. 11.23.

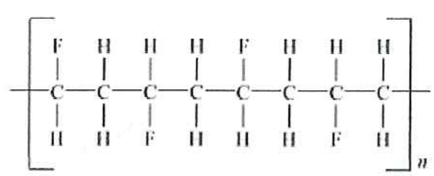

Figure 11.23. Structure of polyvinyl fluoride (PVF).