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Materials Matter For Reliable Performance And Power Output Of Solar Panels

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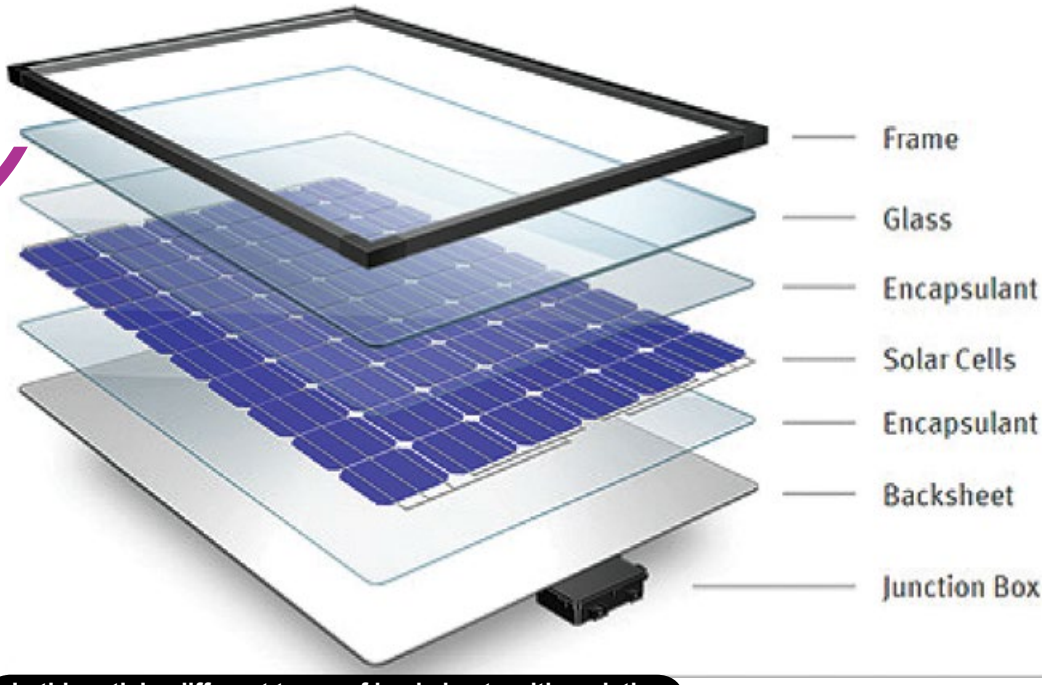
Solar Backsheets provide the first line of defense for solar cells & encapsulating materials, protecting them from environmental stresses while providing electrical insulation.

Solar cells collect the sun's energy and convert it into electricity. These cells are electronically connected to form solar panels that can provide enough electricity for products ranging from small radios to space satellites. Solar panel materials play a crucial role in protecting solar panels and enabling them to reliably produce power for their 25 year expected lifetime, even in harsh climatic conditions such as those in India.

What is a solar panel made of ?

Proven, reliable and rugged materials are required to protect solar panels from environmental damage and help enable safe and superior power output over their 25 year lifetime. In a typical solar panel, a multi layered backsheet is critical for the long term performance and safety of the panel. This component should be able to withstand extreme climatic conditions.



• In this article, different types of backsheets with variations in design, construction and materials will be examined.

Why are solar backsheets important?

Solar backsheets represent the outermost 'layer' of a paneland are a key contributor in ensuring the power output of the panel is sustained over the solar energy system's lifetime.They provide the first line of defense for solar cells and encapsulating materials, protecting them from environmental stresses while providing electrical insulation. A Backsheet related failure can result in breakdown of panels, premature power degradation and electrical safety hazards.

The impact can be significant, ranging from potential reputational issues for companies and their brands when panels do not perform as expected, to potentially large financial losses for system owners, to serious worker safety issues.

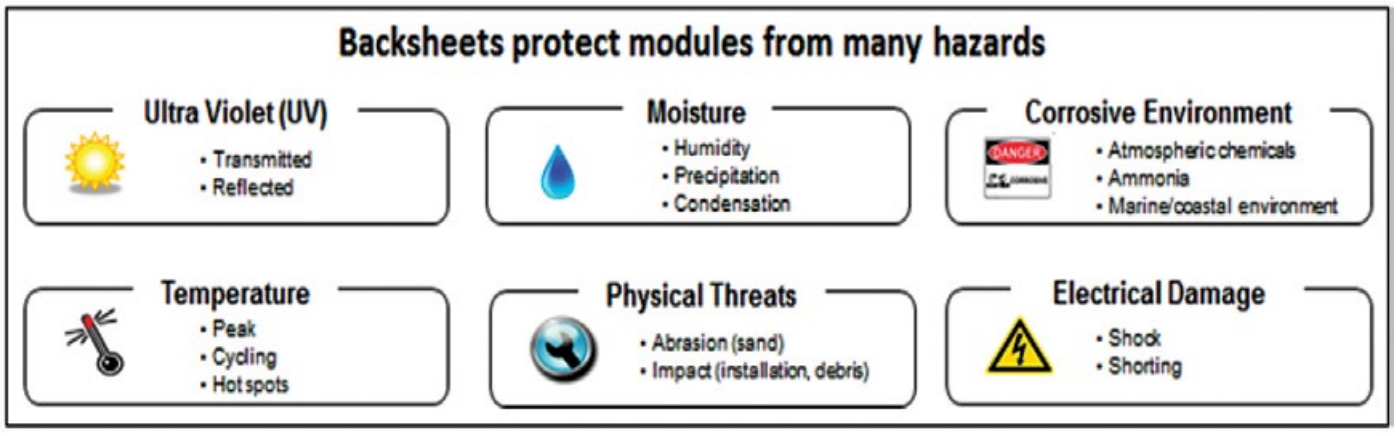


Figure 1: Solar backsheets protect panels from many hazards

What are backsheets made of ?

Backsheets today are made from a widening array of materials, not all of which are proven to perform reliably over the 25 year expected lifetime of solar panels. Developing an understanding of the types of materials and their durability is important to ensure safe and reliable system performance.

A backsheet used in a crystalline silicon solar panel is a laminate of polymer materials and typically consists of three layers as shown in figure 2. Each layer has a role to play in the features required in a backsheet and should possess unique properties to fulfill that role. The function and key properties of each of the three layers are summarized in table 1

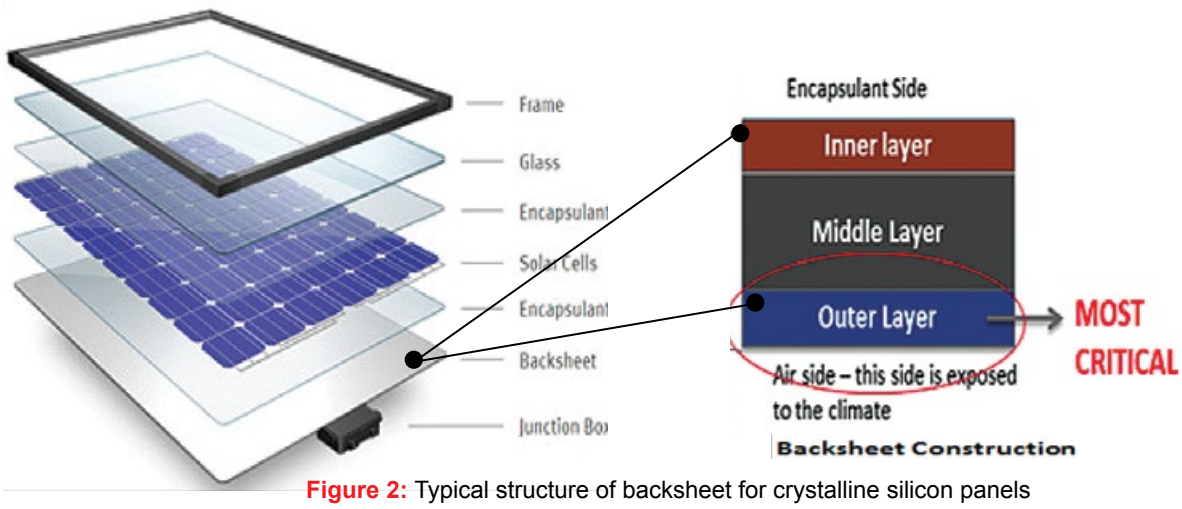


Figure 2: Typical structure of backsheet for crystalline silicon panels

Table 1 : Function of material layers in the solar backsheet

Layer	Function	Key Properties	Typical Material
Inner Layer	Used to promote adhesion between backsheet and encapsulant. Protects the backsheet core from UV light from the front side.	Good adhesion with panel encapsulant UV resistant (to withstand UV radiation penetrating the front side through gap between the cells)	Polyvinyl fluoride (PVF) films, such as DuPont™ Tedlar® PVF film, provide highest durability and reliability. Alternate materials include polyvinylidene fluoride (PVDF),Fluoroethylene-Alkyl Vinyl Ether (FEVE), ethylene vinyl acetate (EVA), polyethylene, polyolefin
Middle Layer	Critical for electrical insulation properties of the backsheet Provides mechanical strength and rigidity to the backsheet	Thick enough to provide required electrical insulation Also determines water vapor transmission rate	Polyethylene terephthalate (PET or polyester) is used in almost all backsheets
Outer Layer	Most critical layer in the backsheet laminate as it is directly exposed to climate in the field Protects middle layer from environmental stresses, which otherwise degrades very quickly and loses its properties when exposed to outdoor conditions	UV and weather resistant Abrasion resistant (sand abrasion)	Polyvinyl fluoride (PVF) films, such as Tedlar®PVF film provide highest durability and reliability. Alternate materials include PVDF, FEVE, UVresistant polyester (UVPET), tetrafluoroethylene - hexafluoropropylene - vinylidene fluoride (THV), Polyamide (PA)

Properties of a Backsheet

Key properties of a backsheet are specified below in Table 2. A backsheet should be able to retain these properties over a panel's 25 year expected lifetime (or longer) in the service environment.

Table 2 : Key properties of backsheet

Key Property	Importance	Remarks
Thickness [microns (µm)]	• Thickness of middle PET layer greatly impacts electrical insulation. As thickness increases, electrical insulationvalue increases and water vapor transmission rate value decreases • Outer layer should be thick enough to withstand cut and abrasion	Recommended thickness: • Total thickness: >300µmis recommended • PET thickness > 200 µm • Outer layer thickness ≥25 µm
Adhesion strength with panel encapsulant [Newton per centimeter(N/cm)]	• Determines the adhesion strength between the backsheet's inner layer and panel's encapsulant • Inner layer selection is critical for adhesion strength	>40 N/cm has become industry standard
Interlayer adhesion strenght (N/cm)	• Determines adhesion strength between backsheet's layers, i.e. between inner layer and middle layer, and between middle layer and outer layer • Backsheet manufacturer's process and adhesive used to laminate backsheet layer are critical for inner layer adhesion	>5 N/cm has become industry standard
Partial Discharge Voltage [VoltageDirect Current(VDC)]	• Determines electrical insulation of the backsheet • Depends on the total thickness of the backsheet	• Should be >1000 VDC for installations in India (max. system voltage is 1000 V)

Table 2 : Key properties of backsheet

Water vapor transmission rate(WVTR)[in grams per square meter per dayg/ (m2x day)]	• Determines ability of the backsheet to stop water from transmitting through it • Typically tested at 38°C, 90% Relative Humidity (RH). Increasing test temperature or humidity or both will increase WVTR value. Thus, test conditions should be taken into consideration • Depends on the thickness of polyester middle layer	• Typical range is 1-3 g/(m2 x day)
Tensile & Elongation	•Determine mechanical properties of the backsheet •Deterioration of these properties can lead to cracking of the backsheet	Recommended values are: **Tensile Strength-** • 100 megapascals(MD)*and 80 megapascals (TD)* Elongation- • 100% (MD) and 80% (TD)
Dimensional stability (shrinkage percentage)	• Determines the extent to which backsheet can shrink in the presence of temperature • Tested at 150°C for 30 mins • Critical for high temperature conditions and to prevent wrinkles during panel manufacturing (during lamination process, temperature typically reaches above 150°C)	**<1.5%** is recommended

*** MD – machine direction; TD – transverse direction (polymer orientation)**

Types of backsheets available

Some backsheets supplied in the market contain outer layer materials which have less than 5 years of operational history. Considering the criticality of outer layer material in the backsheet structure, it is important to develop an understanding of different types of backsheets based on the outer layer materials.

Backsheet selection should be based on its field performance and history of outdoor exposure, and not on initial test values.

Table 3 : summarizes the types of outer layer protective materials for solar backsheets.

Table 3 : Introduction to outer layer protective materials of backsheets

Outer Layer	Typical Structure(s)	Characteristic
Protective Material	Inner Middle Outer	
DuPont™ Tedlar® polyvinyl fluoride (PVF) film	Tedlar® PVF PET Tedlar® PVF ELayer PET Tedlar® PVF	• Tedlar® / Polyester / Tedlar® structures, referred to as TPT backsheets are the established standard solar backsheets which have been used widely in solar panels since the 1980s, with over 30 years of proven performance. Many solar installations globally made using panels with Tedlar® PVF film-based backsheets are still performing well today. • Tedlar® / Polyester / E layer, referred to as TPE backsheets have Tedlar® film as the outer layer only. These backsheets have been widely used since 1990s. E-layer is typically a UV resistant, adhesive based copolymer, such as EVA, polyolefin, or polyethylene.

Table 3 : Introduction to outer layer protective materials of backsheets

Outer Layer	Typical Structure(s)	Characteristic
PVDF FILM	PVDF PET PVDF ELayer PET PVDF	• PVDF based backsheets are available in two configurations – double sided (outer and inner layer made of PVDF materials) and single sided (only outer layer has PVDF material) • PVDF is a relatively new material for solar backsheets and thus has very limited long term field experience • Most of the PVDF materials used for solar backsheets contain 20-30% acrylic additives such aspoly(methyl methacrylate)(PMMA) • There are several makers of PVDF films and the composition and performance of these vary by suppliers • PVDF films have poor mechanical properties which lead to increased brittleness and cracking in the field.
FEVE Coating	ELayer PET FEVE Coating	• FEVE is a copolymer of vinyl ether / ester and vinyl di-fluoride, and contains isocyanate to support chemical crosslinking. It's a fluorinated polyurethane material • FEVE based backsheets are quite new to the solar industry • Unlike Tedlar® and PVDF (films), FEVE is a coating based product and has challenges due to lower thickness (compared to film) which results in poor abrasion resistance (critical for desert areas). With age, FEVE coating can become brittle which increases the probability of cracking and delamination
PET / MODIFIED PET	E Layer PET PET / Modified PET	• PET is a non-fluorinated material which was first used in 1990s by Japanese manufacturers for top roof panels. Though PET backsheets have been in use for quite some time, multiple issues of yellowing and cracking resulting in power loss in the system have been reported from the field. • Modified versions of PET (such as UV and Hydrolysis resistant PET) have been introduced in the past 3-4 years. However, the issues of cracking and yellowing exist with improved versions as well.
POLYAMIDE (PA)	PA PA PA	• Polyamide is a non-fluorinated material that was introduced about 3-4 years ago, and thus is not proven to performin outdoor conditions • PA based backsheets have exhibited issues such as cracks and delamination

Issues such as yellowing, cracks, and delamination in backsheets can negatively impact the performance and safety of solar energy systems.

Tedlar® PVF film-based backsheets have now been in the field for more than 30 years in different climates all over the world. They have been field-proven in India and have demonstrated critical, long-life panel performance, protecting the system and enabling stronger returns on system investments. Other backsheets including HPET, PVDF, and FEVE coatings are relatively new in the solar industry and do not have sufficient field experience. Therefore they contain some degree of risk of failure in the field.

By using proven materials for solar panels, company reputations and customers can be protected from expensive system failures and safety issues.

This article is part of an educational series on solar backsheets. More on backsheet field issues and accelerated testing will be addressed in following articles.