Product Introduction

DuPont™ Tedlar® Frontsheet Offers Ideal Protection for Lightweight Photovoltaic Modules

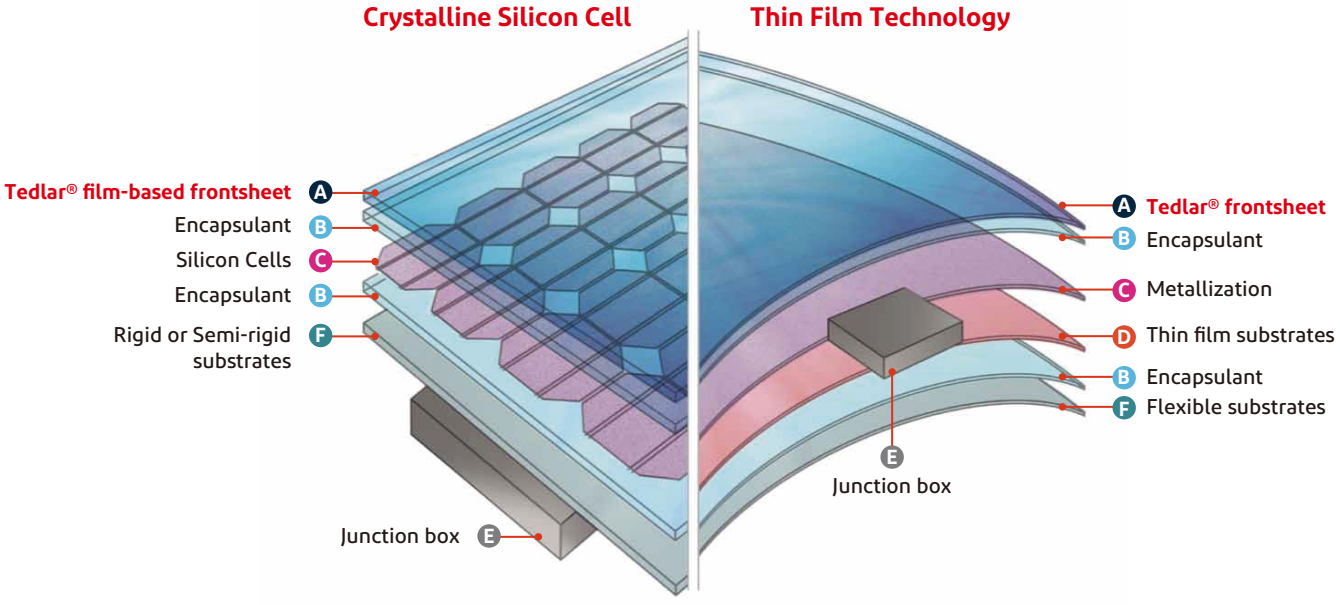
Photovoltaic Application

The weight of photovoltaic (PV) modules is a big challenge in some applications. Numerous commercial buildings and auxiliary structures are designed with little to no spare structural capacity. Vehicle efficiency is directly tied to weight. Lightweight modules may address this challenge by reducing weight, enabling PV elements to be installed or retrofitted at low cost for parking roofs, building Integrated PV (BIPV), and vehicle integrated PV (VIPV).

The main challenge for lightweight PV modules is replacing the glass frontsheet while maintaining mechanical stability and weatherability. For crystalline silicon cells, polymer frontsheets have been implemented to provide protection for supporting lattices like glass-fiber reinforced polymer (GFRP) structures. For thin film technologies like copper indium gallium selenide (CIGS), flexible substrates and polymer frontsheets have been applied as durable insulation (See illustration in Figure 1).

Why Tedlar® frontsheet?

DuPont™ Tedlar® film is an ideal solution for protective frontsheet of solar modules due to its unique balance of durability, UV resistance, high level of light transmittance, lasting UV protection, mechanical toughness, abrasion resistance, chemical resistance, good adhesion to encapsulant, easy cleaning, light weight and flexibility. Transparent Tedlar® films have been used for decades in protecting graphics and signage and photovoltaic backsheets. Building on years of successful performance, the new transparent Tedlar® TFS15BM3 film is designed to provide the highest level of outdoor stability and protection, offering a preferred and technologically advanced alternative to traditional glass.



A. Frontsheet materials: with high light transmittance, DuPont™ Tedlar® frontsheet offer excellent UV resistance, outstanding weatherability and exceptional mechanical strength and durability against cracking.

Figure 1. Illustrations of typical lightweight photovoltaic module structure

Long Lasting and Field Proven

Transparent Tedlar® films have been used for decades in graphics and signage applications to protect substrates from harsh environmental conditions. The free-standing transparent film was exposed for ten years in south Florida and showed no degradation in transmission, haze, or color over ten years of exposure.

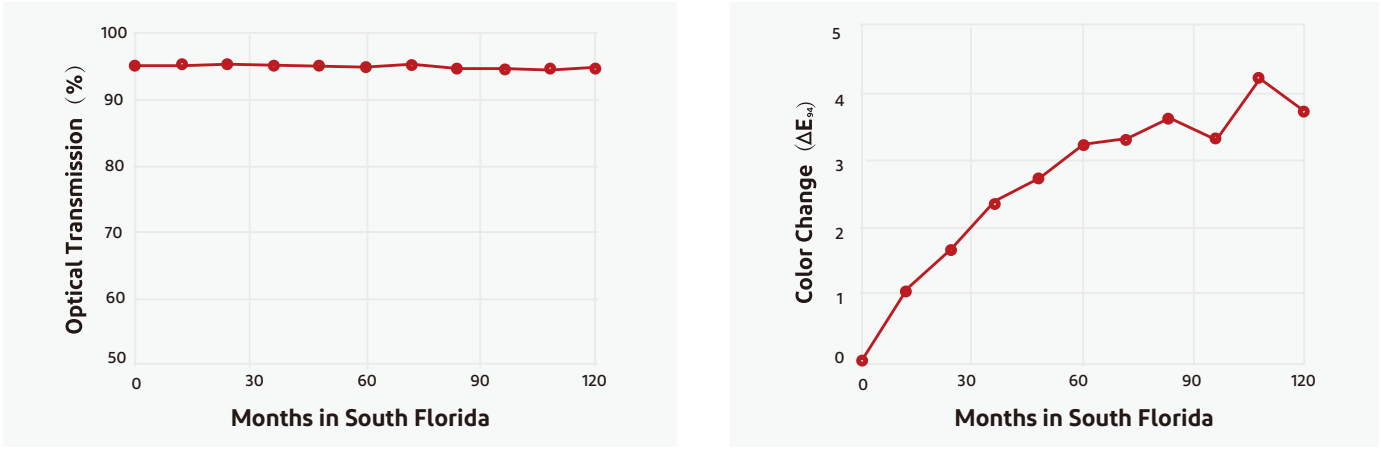


Figure 2. Retention of optical properties for Tedlar® clear films during 10 years exposure in south Florida (45° orientation, south facing).

More recently, this transparent Tedlar® film was reformulated to substantially increase its ability to survive in harsh environments outdoors for the front side of photovoltaic modules. This new film represents the highest level of performance in Tedlar® transparent films. A sequential test incorporating broad-spectrum Xenon Arc light, thermal and dark cycles, and water spray (described by ASTM D7869) was used to simulate the full range on environmental conditions on the front side of a photovoltaic module. The film survived for 20,000 hours (911 kWh/m² of UV light from 290 to 400 nm) with good mechanical property retention, high transparency, and good UV screening (Figure 3).

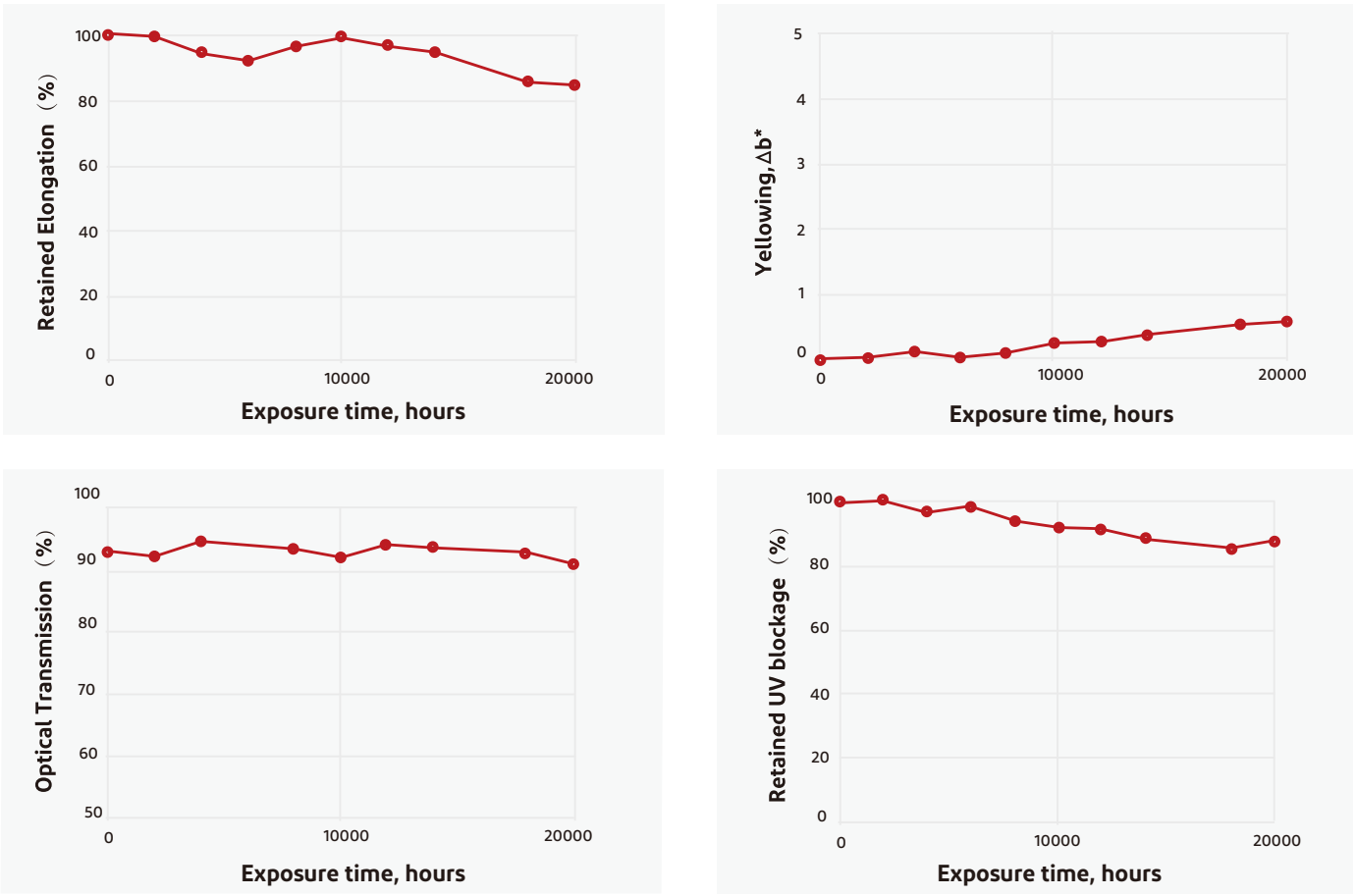


Figure 3. Retention of elongation, yellowness, light transmittance, and UV blocking ability of DuPont™ Tedlar® front sheet film (TFS15BM3) after 20,000 hours (911 kWh/m² of UV light from 290-400 nm) of Xenon Arc exposure (ASTM D7869).

Enhance Longevity of Frontsheet Substrates

The Tedlar® film absorbs UV light and provides protection to the underlying substrates, enabling composite frontsheets with a combination of outstanding weathering properties and electrical insulation at reasonable cost. Previously, transparent Tedlar® film has been successfully laminated to fiberglass panels for architecture applications, where it has substantially improved panel life in humid and corrosive environments with high ultraviolet light.

Composite frontsheets made with Tedlar® film have extraordinary resistance to environmental factors that otherwise damage materials. Often, this frontsheet is constructed with an outer layer of Tedlar® and an inner layer of PET. In Figure 4, the composite Tedlar® frontsheet (TFS15BM3) laminate with UV-stabilized transparent PET sheet retains its transmission and mechanical properties after 12,000 hours of an accelerated weathering test that combines exposure of UV light, dark, water spray, and condensation (ASTM D7869). In Figure 5, the same composite Tedlar® frontsheet is tested in continuous Xenon Arc light at elevated temperatures (IEC 62788-7-2, Method A3), and in Figure 6 using a UVA fluorescent light source (ASTM G154, UVA-340 fluorescent bulb, 1.2 W/m²-nm @ 340 nm, 70 °C BPT) for 14,000 or 12,000 hours. In both tests, the optical and mechanical properties of the composite frontsheet are preserved. This extreme level of testing demonstrates the suitability for use on the front side of the photovoltaic module where intense light and weather provide high stress to materials.

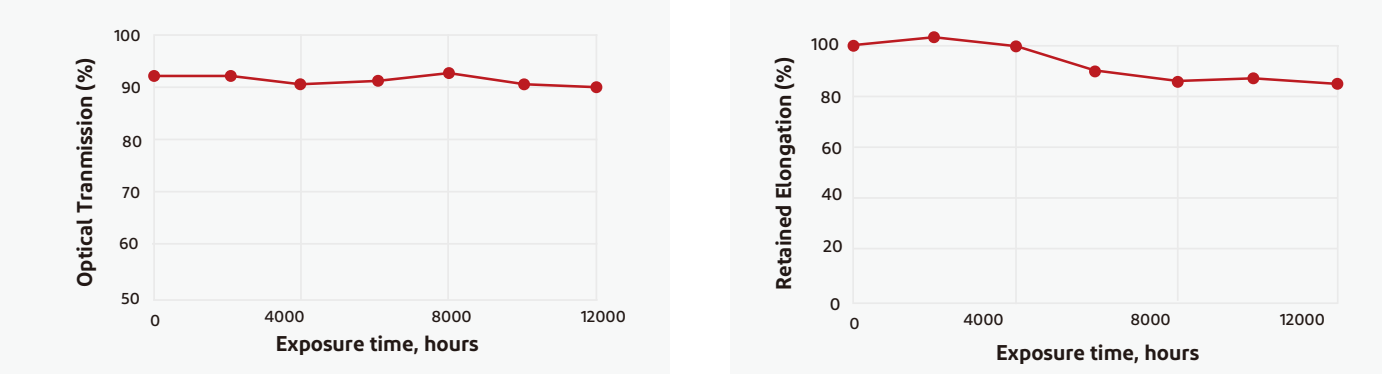


Figure 4. Retention of light transmission and mechanical properties of Tedlar® frontsheet (TFS15BM3) laminate with UV-stabilized transparent PET sheet after 12,000 hours (547 kWh/m² of UV light from 295-400 nm) of Xenon Arc exposure following ASTM D7869.

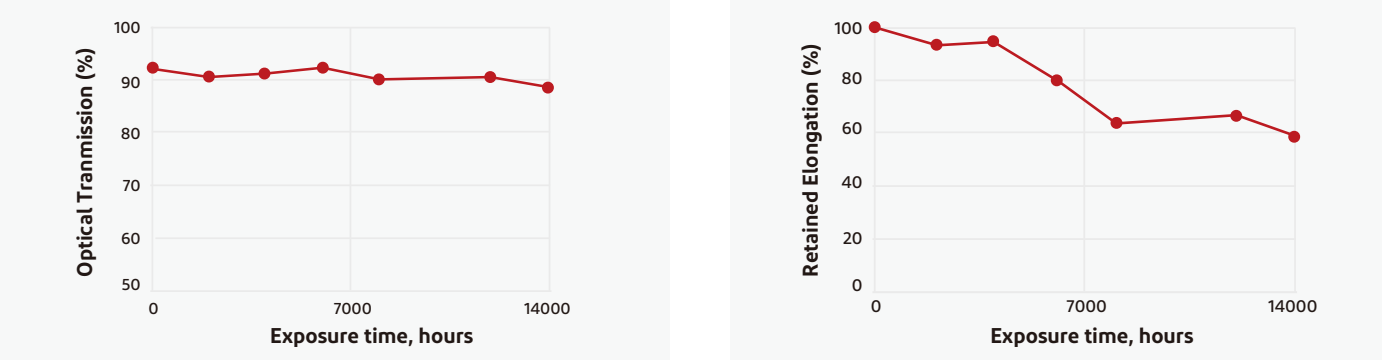


Figure 5. Retention of light transmission and mechanical properties of Tedlar® frontsheet (TFS15BM3) laminate with UV-stabilized transparent PET sheet after 14,000 hours (1120 kWh/m2 of UV light from 295-400 nm) of Xenon Arc exposure following IEC 62788-7-2, Method A3 (Xenon Arc, 0.8 W/m2-nm @ 340 nm, 90 °C BPT, 20% R.H.).

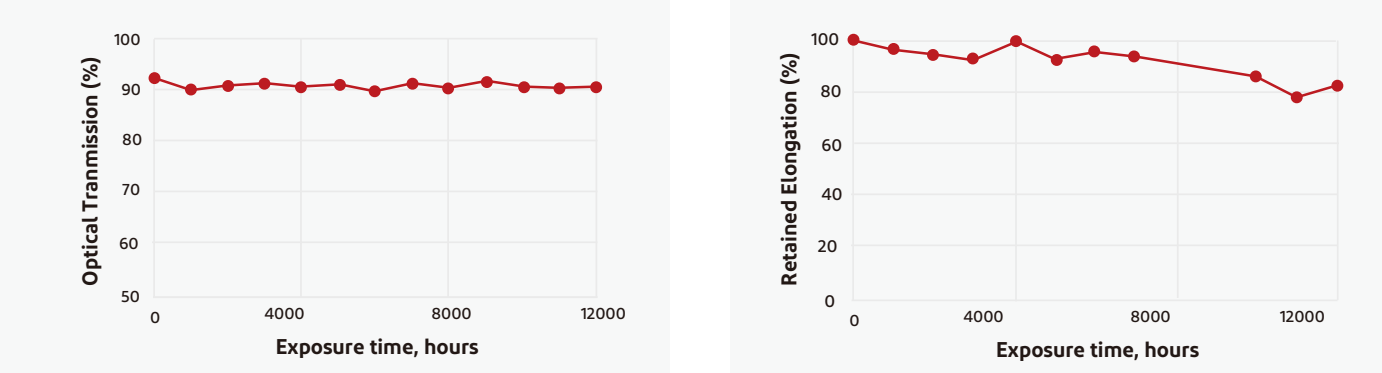


Figure 6. Retention of light transmission and mechanical properties of Tedlar® frontsheet (TFS15BM3) laminate with UV-stabilized transparent PET sheet after 12,000 hours (780 kWh/m² of UV light from 295-400 nm) of fluorescent UVA exposure following ASTM G154 (UVA-340 fluorescent bulb, 1.2 W/m²-nm @ 340 nm, 70 °C BPT).

Lightweight, Easy to Install and Maintain

A Tedlar® film frontsheet on a typical 1m*2m module weighs less than 130 grams, while a glass frontsheet would weigh more than 10 kg. It is also flexible and resistant to chipping, making it easier to install and safer to handle than glass.

The fluorocarbon nature of Tedlar® film is the basis for the film's outstanding durability and resistance to a variety of solvents and harsh chemicals (Table 1). Tedlar® film stands up well to atmospheric pollutants and resists acid rain attack and mildew. Most airborne dirt does not adhere to Tedlar® film; if soiling does occur, rainwater or a commercial cleaner can be used to restore the surface to its original appearance.

Tedlar® film improves the cleanability of frontsheet as it is fluoropolymer and contains no plasticizers. Additives in uncoated frontsheet can migrate to the surface of the module and collect dirt after field aging, making cleaning difficult.

Tedlar® frontsheet is an oriented film, which has high tensile strength and good abrasion resistance.

Table 1. Chemical Resistance of Tedlar® Frontsheet – TFS15BM3 Film

Chemical (1 week immersion)	Appearance	Color, ΔE*	UV Spectrum
10% HCl in water	Normal	0.06	No change
10% H_2SO_4 in water	Normal	0.07	No change
10% NaOH in water	Normal	0.08	No change
Isopropanol	Normal	0.1	No change
Window cleaner	Normal	--	No change

Other Key Properties

- **Adhesion to EVA Encapsulants:** Tedlar® films are surface treated using a proprietary treatment process, leading to superior adhesion to EVA.
- **Dielectric Properties:** excellent dielectric strength helps make these films effective insulators.
- **Mechanical Properties:** good mechanical strength and abrasion resistance
- **Chemical Properties:** Tedlar® PVF film has excellent resistance to chemicals, solvents, and stains. At ordinary temperatures, the film is not affected by many classes of common solvents, including hydrocarbons and chlorinated solvents.

See Table 2 for important physical properties of DuPont™ Tedlar® frontsheet.

Table 2. Physical Properties of Tedlar® Frontsheet – TFS15BM3 Film

Measured Properties	Test Method	Unit	Value
Unit Weight	DuPont Method	$g \cdot m^{-2}$	51–57
Gauge Variation	DuPont Method	%	≤17.5
Tensile Strength MD/TD	ASTM D882	MPa (ksi)	≥55 (8.0)
Elongation at break MD/TD	ASTM D882	%	≥95
Gloss 60°	ASTM D523	–	40–45
Shrinkage TD @ 170°C	ASTM D1204	%	0.0–5.0
Adhesion Strength (both sides)	Heat Seal Peel	pass/fail	pass
Visual	Continuous Inspection	pass/fail	pass

CLEAR Tedlar®

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