

DuPont Frontsheet Materials

DUPONT™ TEFLON® FILMS

Lightweight, Durable, Flexible Films Offer Greater Power Output



Photovoltaic Application

DuPont™ Teflon® ETFE and FEP fluoropolymer films are rugged, clear thermoplastics that can be used as a substitute for glass in the frontsheet of photovoltaic modules. Teflon® films deliver a very high level of light transmittance in the operating frequency range of the solar cells which provides high power. These films are flexible, lighter and less fragile than glass and show very little degradation over time. They offer excellent durability, mechanical stability and reliability.

DuPont™ Teflon® films are used to make solar panels for portable applications and grid-connected systems.

Why Teflon® Fluoropolymer Films?

- Flexibility
- Excellent weathering performance
- UV resistance
- Tear strength
- Chemical resistance
- Dielectric properties

DuPont™ Teflon® fluoropolymer films are ideal as protective frontsheets for solar modules because they have a unique balance of properties. They are flexible, lightweight, durable, easier to clean, and have superior power output. Teflon® films have proven performance in both solar thermal and photovoltaic (PV) applications, offering a preferred, technologically advanced alternative to traditional glass.

Lightweight, Safer and Easy to Handle

A Teflon® film frontsheet on a typical 1600 mm x 800 mm module weighs less than 150 grams. The same glass frontsheet would weigh more than 10 kg. Not only is Teflon® lightweight, it is also flexible and unbreakable. As a result, corners will not chip, making it easier to install, and it is safer to handle than glass, with no sharp edges.

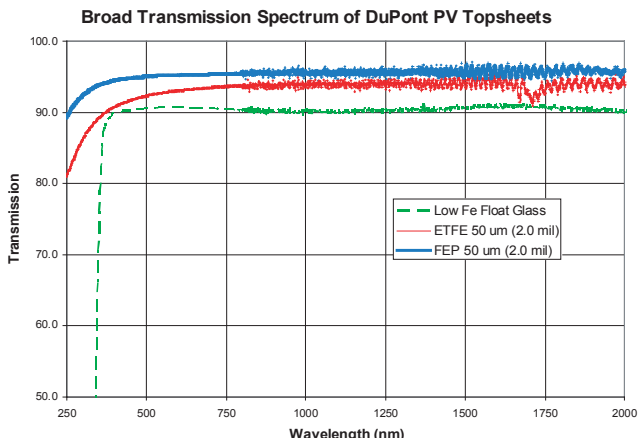
UL Recognition

In addition, Teflon® fluoropolymer resins are recognized by Underwriters Laboratories for meeting rigorous V-0 flammability classification safety standards and will help prevent flame propagation in the event of a fire. Teflon® FEP has a slower flame spread and lower heat of combustion versus ETFE, which makes it an even more attractive material in terms of flammability.



energy for a
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Figure 1. Light transmission of DuPont™ Teflon® Films



Increased Power

Due to their lower refractive indices, Teflon® films transmit light better than glass used in PV modules. Higher light transmittance means increased photons are absorbed by the solar cells and more power is produced. Teflon® FEP is the highest transmissive frontsheet used in PV today.

In **Figure 1**, comparison data is shown on the light transmission of glass versus two different types of DuPont™ Teflon® fluoropolymer films, Teflon® ETFE and Teflon® FEP. Low Fe float glass, which is commonly used in solar modules, has less transmission than Teflon® ETFE, and Teflon® FEP is 2% more transmissive than ETFE.

In **Figure 2**, comparison data is shown on the power output of solar modules using the two different types of Teflon® fluoropolymer film as frontsheets. The modules covered using Teflon® FEP film show on average 5% more power output than those covered with Teflon® ETFE, which is commonly used in flexible solar modules.

Long Lasting

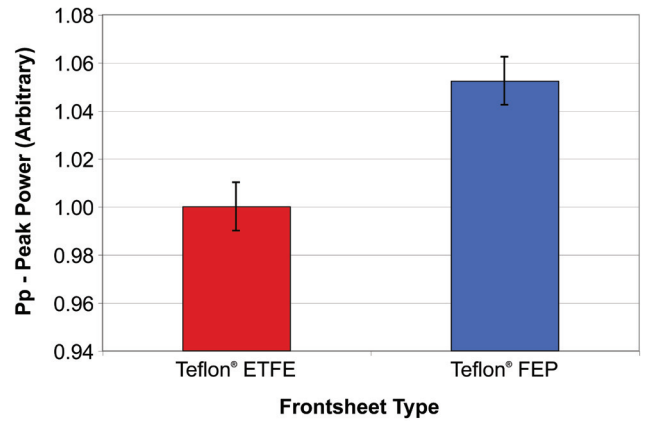
Teflon® fluoropolymer films will last for years without degradation. In **Figure 3**, a study by the Institut für Solartechnik SPF shows the solar transmission of DuPont™ Teflon® FEP compared with low Fe float glass over 20 years of outdoor exposure. Not only does the DuPont film perform better with a higher transmittance, it also performs better over an extended period of time to deliver increased power output vs. glass, hence improving long term cost efficiency. **Table 1** shows retention of tensile and elongation properties after various Florida, USA exposure times. Both Teflon® FEP and ETFE 50 µm films show satisfactory performance after 15 years.

Available Products

Films are supplied in roll form, and continuous lengths allow for easy roll-to-roll processing. Widths are available up to 1524 mm (63 inches) to fit a wide variety of module sizes, and thicknesses are available from 13µm to 127µm (0.5 to 5.0 mils).

Code	Polymer	Thickness
PV3121	FEP	2 mil
PV3131	FEP	3 mil
PV3151	FEP	5 mil
PV3221	ETFE	2 mil
PV3251	ETFE	5 mil

Figure 2. Power output of DuPont™ Teflon® Films

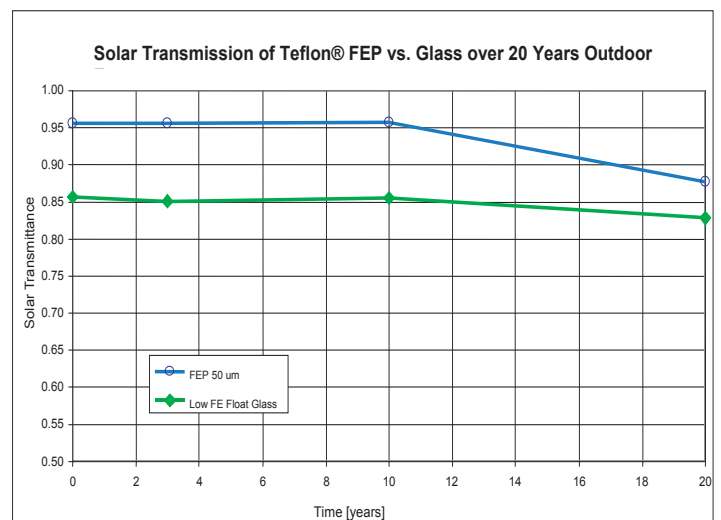


Other Key Properties

- **Adhesion to EVA Encapsulants:** Teflon® ETFE fluoropolymer 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 dimensional stability have proven to last even after 20 years of Florida exposure.
- **Moisture Permeability:** Both Teflon® ETFE and FEP provide effective protection against moisture. Teflon® FEP provides 5 times more moisture barrier than Teflon® ETFE.
- **Cleanability:** The lower surface energy of Teflon® films also means they are harder to soil, and easier to clean.

See **Table 2** for a comparison of these and other important physical properties of DuPont™ Teflon® FEP and ETFE fluoropolymer films.

Figure 3. Solar transmission of DuPont™ Teflon® FEP vs float glass over 20 year outdoor exposure



data courtesy of the Institut für Solartechnik SPF, Rapperswil, Switzerland

Table 1: Florida Outdoor Exposures

Polymer	Film Thickness (µm)	Years of Exposure	Tensile Strength (MPa)		Break Elongation (%)		Tensile Strength Retention (%)		Break Elongation Retention (%)	
			MD	TD	MD	TD	MD	TD	MD	TD
FEP	50	0	21.4	18.6	270	290	100%	100%	100%	100%
FEP	50	5	20	13.8	365	310	93%	74%	135%	107%
FEP	50	7	20	16.6	290	300	93%	89%	107%	103%
FEP	50	10	18.6	16.6	145	221	87%	89%	54%	76%
FEP	50	15	19.4	15.4	200	190	91%	83%	74%	66%
ETFE	50	0	61	63.5	418	440	100%	100%	100%	100%
ETFE	50	15	57.6	59.5	364	370	94%	94%	87%	84%

Table 2: Product Attributes of Teflon® ETFE and FEP Film

Product Attribute	Test Method	Test Item	ETFE	FEP
Refractive Index			1.40	1.34
Moisture Permeability	ASTM F372 at 100°F 90% RH in g/m ² /day	50 micron (2 mil)	7.8	1.5
Flammability		UL 94 (resin)	V-0	V-0
	ASTM D-2863	Limiting Oxygen Index	30%	95%
	ASTM D-635	Horizontal rate of burning	10 mm; >5 sec	5 mm; >5 sec
	ASTM D-2015	Heat of combustion Btu/lb K cal/kg	6200 3441	2200 1221
Adhesion to EVA	Instron	Mode of failure	No EVA adhesion failure; film breaks	No EVA adhesion failure; film breaks
Continuous Operating Temperature	°C	Resin	150 °C	205 °C
Dielectric Strength		0.25 mm	64 kV/mm	71-79 kV/mm
		3.18 mm	15 kV/mm	20-21 kV/mm

For more information about Teflon® or other DuPont Photovoltaic Solutions:

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