Next Generation Tedlar* PVF Film for Photovoltaic Module Backsheets

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Global Market Segment Leader Photovoltaics

DuPont Teflon® and Tedlar® Films

Outline

- Tedlar® PVF film for Backsheets
  - Properties of FluoroPolymers
  - Tedlar® PVF in Backsheets
  - PV2100: A new generation of backsheet films
  - UL Recognition Testing
  - The laminators perspective
- Tedlar® film Capacity Expansion
- DuPont Photovoltaic Solutions (DPVS)

DuPont Pioneered Fluoropolymer Technology

Since the discovery of PTFE, DuPont has led the world in fluoropolymer technology.

Most fluoropolymers have been DuPont inventions.

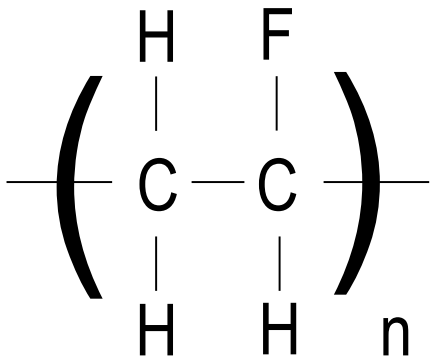
DuPont is the world's largest and most diversified supplier of fluoropolymer products

Roy Plunkett discovers p-tetrafluoroethylene in 1938

Properties of Fluoropolymer Films

- UV Resistant
- Moisture Resistant
- Chemically Resistant
- Tough
- Wide Processing Temperature Range
- Good Electrical Properties
- Easily Cleaned
- Low Refractive Index
- Highly Transparent
- Flame Resistant

Tedlar® PVF Film



- Simplest Fluoropolymer
- Easy to pigment
- Adherable
- Available in thicknesses from 12.5 to 100 microns
- Available in a wide range of colors

Typical Tedlar® Film Properties

	PV2001
Density, cc/cm^3	1.38 - 1.72
Tear strength, initial, kJ/m	129 - 196
Tensile modulus, MPa	44 - 110
Ultimate elongation, %	115 - 250
Continuous use temperature, °C	-70 – 107
Water vapor permeability, g/m^2-day	24.5
Dielectric strength, short term dc, kV/µ	0.15 – 0.19
UL 94 Flame Class	HB
UL 746B RTI, Electrical, °C	140
UL 746B RTI, Mechanical (Impact Str), °C	120, 125

adapted from Ebnesajjad and Snow, Kirk-Othmer Encylcopedia of Chemical Technology, 4th Ed

Photovoltaic Module Backsheets

Function

- Physical protection: puncture and abrasion resistance
- Moisture protection: minimize moisture vapor ingress
- Electrical insulation: isolate the cells and connections from the environment
- Long term protection: UV stable and moisture stable over the life of the module, protects the P layer
- Color: provide the color that helps the modules blend into environment.
- More power: can improve efficiency through internal reflection

Tedlar® PVF film is the material of choice for TPT™ backsheets

- Readly available in a variety of film types, especially pigmented
- Durable, weatherable, and strong

DuPont Tedlar® Offerings for PV Backsheets

DuPont supplies PVF films to companies globally for conversion into PV backsheet laminates

PV2001

- 37.5 micron white PVF film… The most often used "T" in TPT™

TCC15BL3

- 37.5 micron black PVF film used where a dark color is desired for aesthetic purposes

TUT10BL3

- 25 micron clear UV absorbing film used when transparent backsheets are desired

Introducing the PV2100 series of Tedlar® Films for Backsheets…

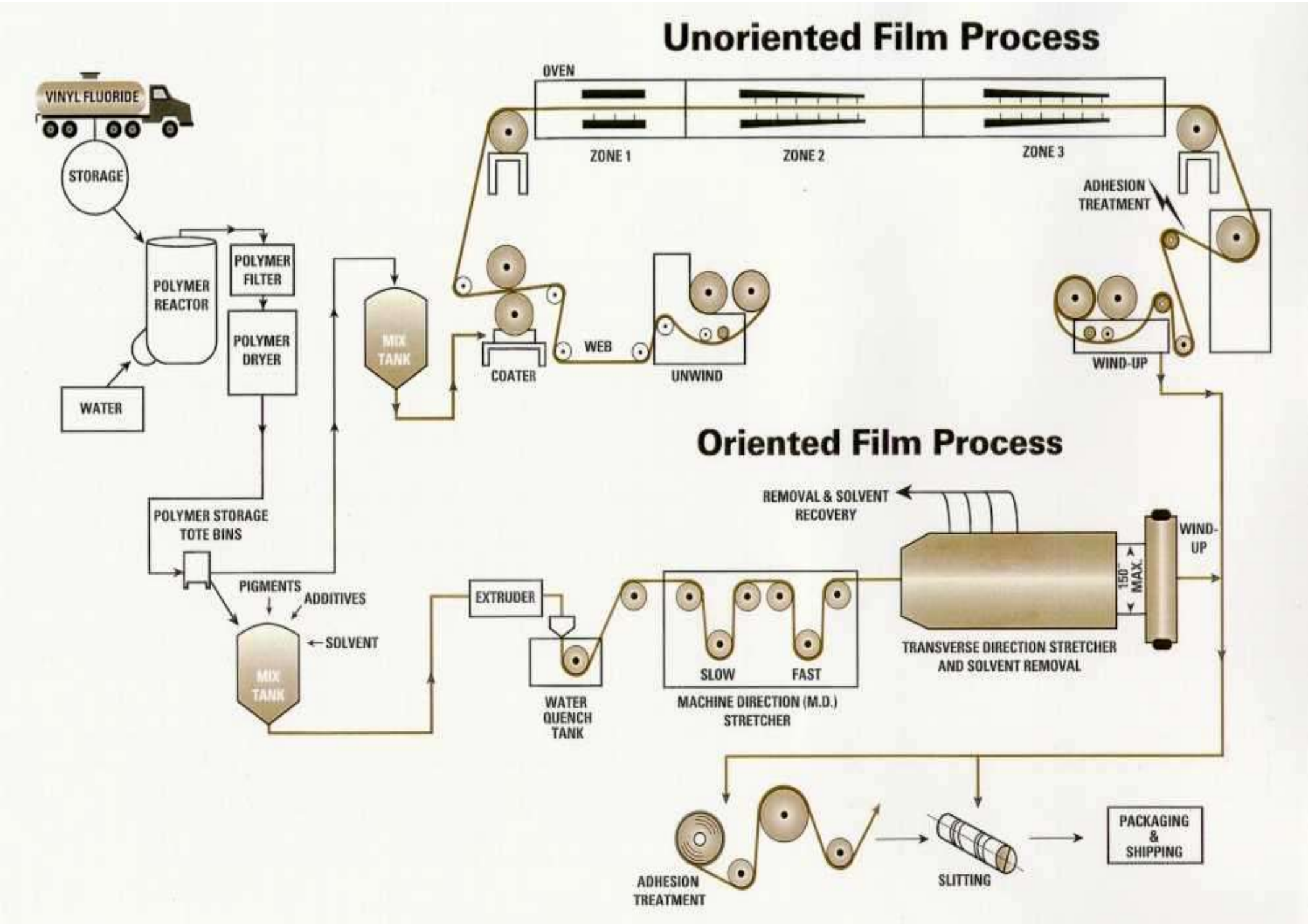
PV2111: A New Tedlar® Film for Backsheets

PV2111, the first member of the PV2100 family, has all of the properties that have made Tedlar® films the standard in PV backsheets :

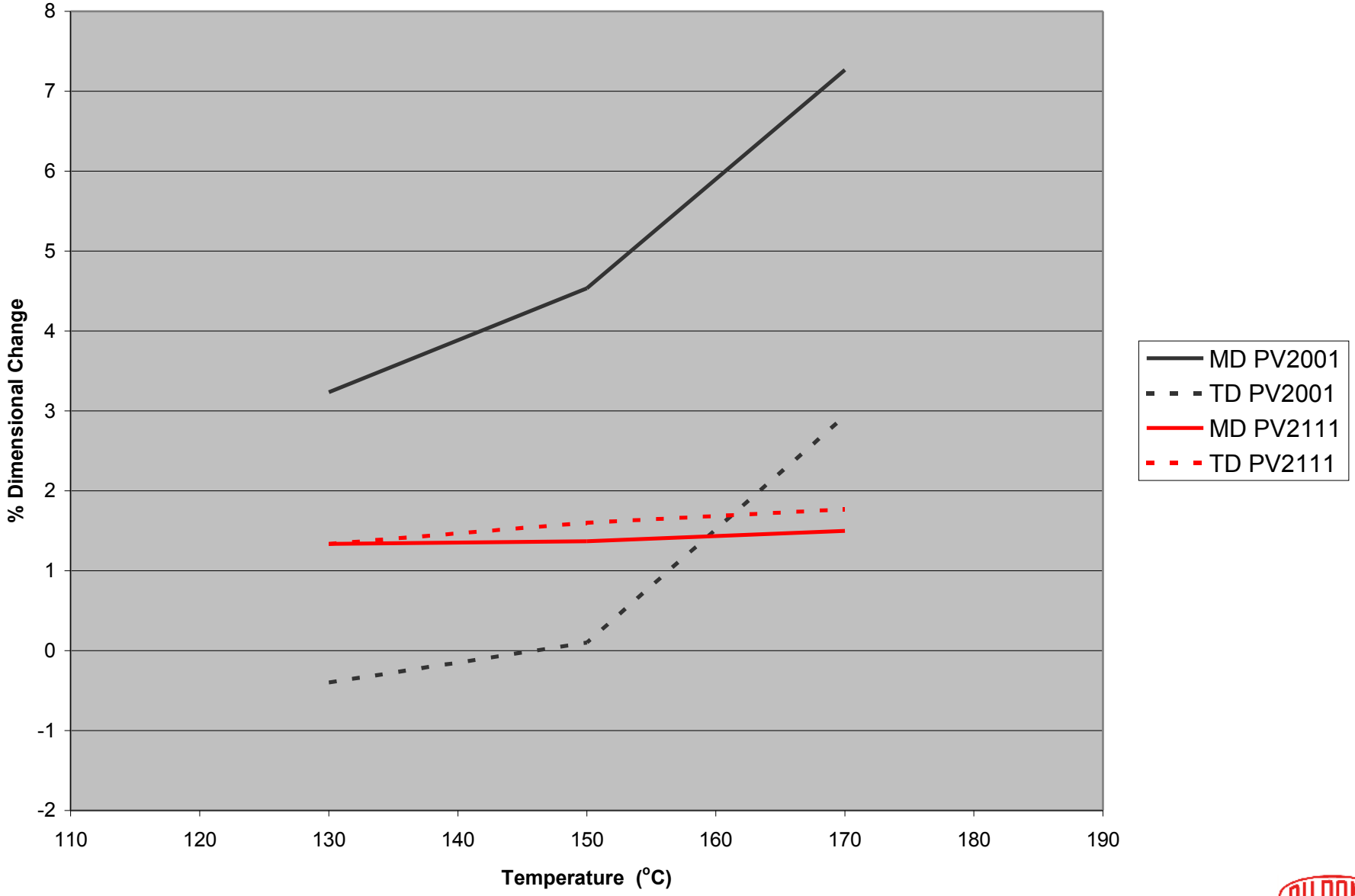
- Made from the same basic PVF polymer as PV2001
- Unaffected by extreme temperature and humidity
- Excellent adhesion to EVA encapsulants
- Good electrical, physical and barrier properties

In addition, PV2111 has

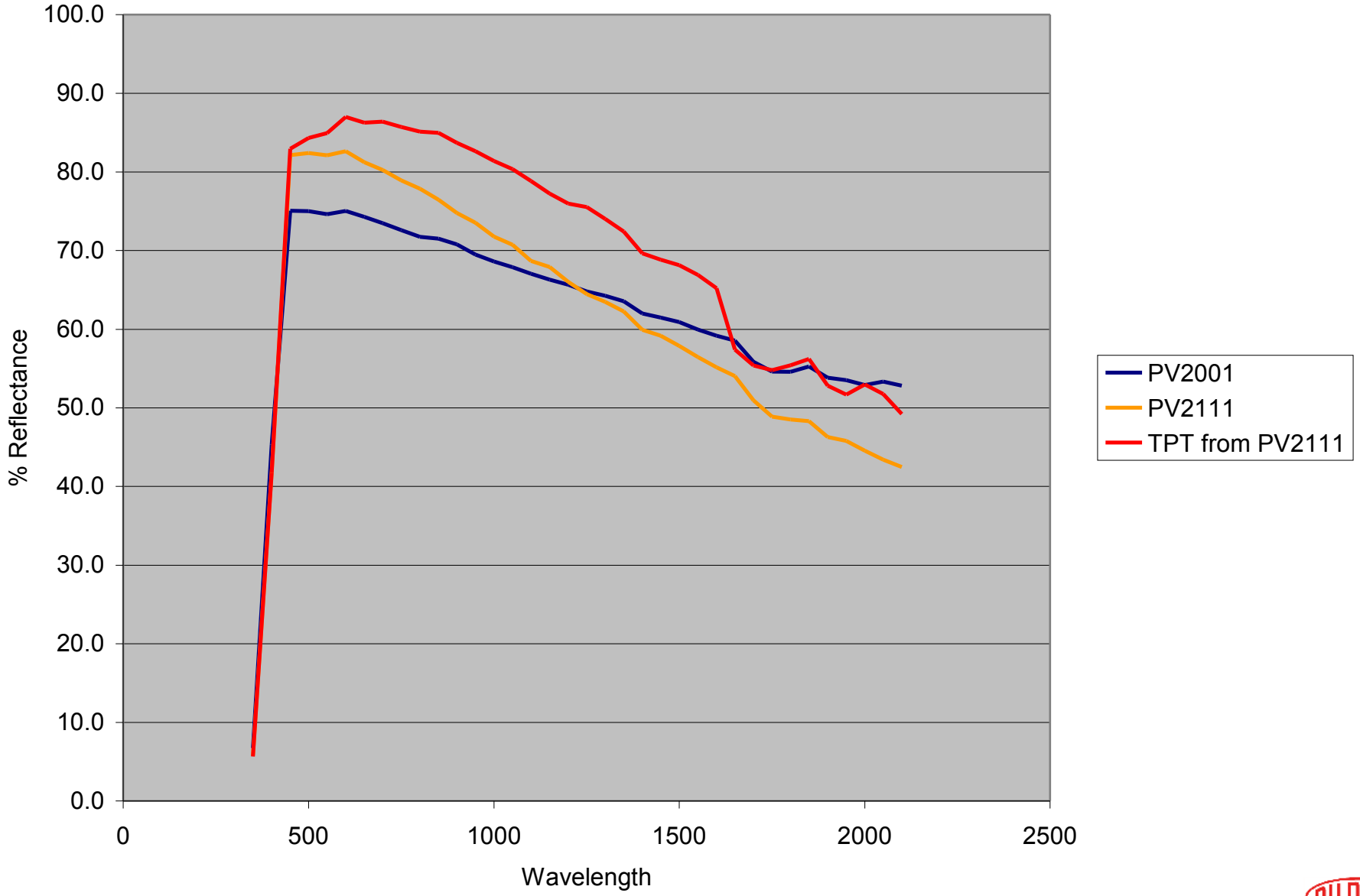
- Better dimensional stability than PV2001… Low shrinkage that is *balanced* at module laminating temperatures leading to virtually wrinkle free modules.
- Over 15% higher solar reflectivity for added power in modules that take advantage of backsheet reflectance


Unoriented Film Process
OVEN
ZONE 1
ZONE 2
ZONE 3
VINYL FLUORIDE
STORAGE
POLYMER REACTOR
POLYMER FILTER
POLYMER DRYER
WATER
MIX TANK
COATER
WEB
UNWIND
ADHESION TREATMENT
WIND-UP
Oriented Film Process
POLYMER STORAGE TOTE BINS
PIGMENTS
ADDITIVES
SOLVENT
MIX TANK
EXTRUDER
WATER QUENCH TANK
SLOW
FAST
MACHINE DIRECTION (M.D.) STRETCHER
REMOVAL & SOLVENT RECOVERY
150" MAX.
TRANSVERSE DIRECTION STRETCHER AND SOLVENT REMOVAL
WIND-UP
ADHESION TREATMENT
SLITTING
PACKAGING & SHIPPING

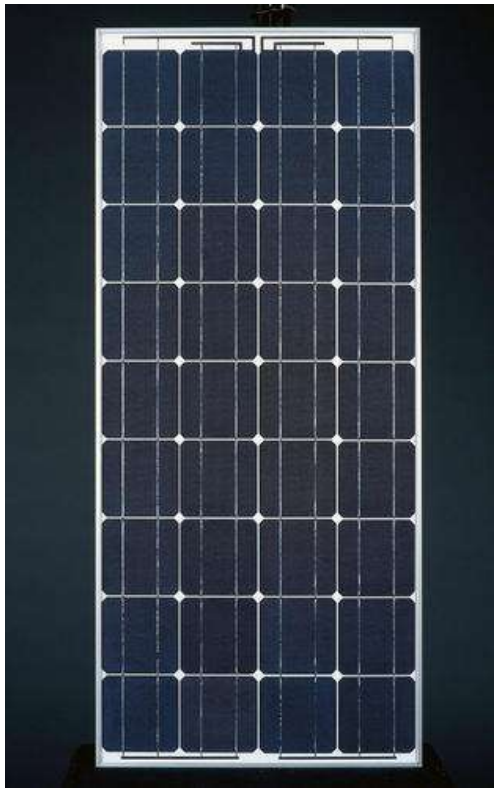
Dimensional Stability of Tedlar® Films



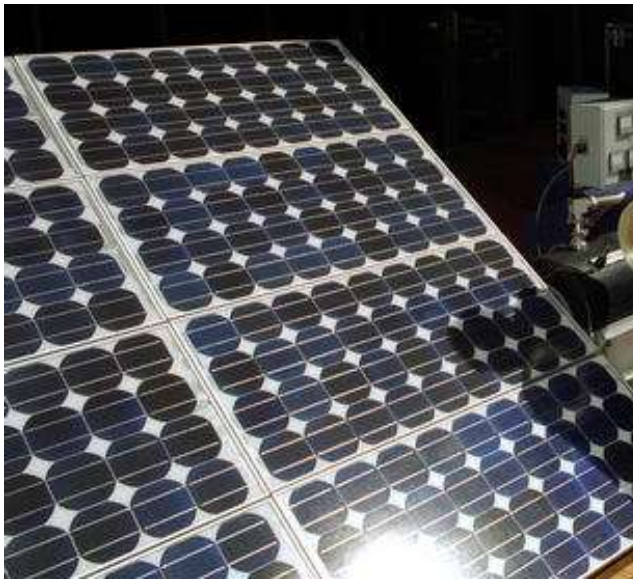
Reflectance of Tedlar® Films and Backsheet



Module Design and Backsheet Reflectivity



Backsheet Reflectivity has least effect here… little exposed backsheet



Backsheet Reflectivity has more effect here… more exposed backsheet

Backsheet Reflectivity has most effect here… large areas of exposed backsheet

Photos from the DOE/NREL Photographic Information Exchange

Comparison of PV2001 and PV2111

Property	Method	PV2001	PV2111
Thickness, micron	Caliper	37	25
Elongation at Break (%)	ASTM D882	140	35
Tensile Strength (kpsi)	ASTM D882	10	5.2
Tensile Strength (MPa)	ASTM D882	69	36
Tear Strength (kN/m)	Graves	129	213
60° Gloss	Gardner	6	74
Total Solar Reflectance (%)	ASTM E424	69	74[a]
Dielectric strength (V/mil)	ASTM D150	3000	3000

[a] As TPT™, Reflectance increases to 80%

Underwriters Laboratories Recognition Testing of Tedlar® Photovoltaic Film Offerings

- Use of UL Recognized Components In PV Modules Is Critical to Global Product Acceptance

- DuPont Supports the UL Concept of Recognized Components in PV
  - Helps Ensure Long Term Module Performance and Reliability
  - Decreases Product Test Cost and Time to Market Release

- DuPont/UL Recognition Testing
  - Started in November of 2006 and Is Ongoing
  - Deals with Fire Resistance, Electrical, UV and Thermal Characterization
  - Complies with the Provisions of the IEC 61730 Safety Standard and the Next Generation of the UL Photovoltaic Safety Standard
  - Completes Characterization of the PV2001 Product and Provides Data on New PV2111 Offering

Tedlar® Film Comparison in Underwriters Laboratories Recognition Tests

TEST METHOD	PVF PV2000	PVF PV2100
Identification	Complete	Complete
Flame Classification	HB	HB
Flame Spread Index (Radiant Panel)	0.6	0.5
UV Exposure	PASS	PASS
Hot Wire Ignition (HWI) PLC	4	3
High Current Arc Ignition (HAI) PLC	4	4
Comparative Tracking Index (CTI) PLC	0	0
Inclined Plane Tracking Rating (IPT) PLC	IP	IP
RelativeTemperature Index (RTI)	125 C	IP

Performance Level Category (PLC) 0 = Best
IP = Testing In Progress

The laminators perspective

New Gen-Tedlar® - PV 2111 → Akasol® PTL HR

History *we look back on almost 4 years of testing and approvals*

start of internal tests: early 2004

first public announcement: 2nd workshop „Photovoltaic Module Technic“ ;
TÜV Rheinland, Cologne; Germany
December 1st and 2nd , 2005
session V: materials and components:
„Flexible Base materials and Special Laminates“ by K. Brust

first response on quality: “yellowing” after damp-heat test
Du Pont adjusted formulation to “cast” technology in 2006

2nd response since 2007: excellent bonding to EVA; good damp-heat behaviour: no yellowing

November 2007: more than 100 customers have received sample rolls and sheets

forecast 2008: major share of PV 2111 compared with PV2001/TWH

KREMPEL GROUP KREMPEL JSI AAF

New Gen-Tedlar® - PV 2111 → Akasol® PTL HR

Advantages – from the view as TPT™ backsheet manufacturer

+ thermal dimensional stability of PV 2111 is closer to the low shrink quality of PET-films;
this results in less thermal stress between PVF and PET in TPT™

+ better homogenity of pure PVF film due to no orientation process in film production;

+ excellent bonding to encapsulation polymer films (> 8 N/mm);

+ 2000h damp heat test (85% rh, 85°C) without failures

Disadvantages – are mainly given for the TPT™-production

- lower tensile strength, thinner film increases problem of film tearing during lamination of PET to PVF.

- low availability in 2nd half of 2007 and Q1/2008

PV 2111 and PV 2112 are approved by ISOVOLTA AG for Icosolar® 3469 as backsheet material

Photovoltaics

Tedlar® Films for Backsheets:
Summary

Tedlar® Films have demonstrated over 20 year performance in PV backsheets.

Tedlar® Films are unaffected by harsh testing conditions and long term exposure conditions.

Tedlar® Films can be tailored to specific colors:

- Clear
- White
- Black
- Custom Colors

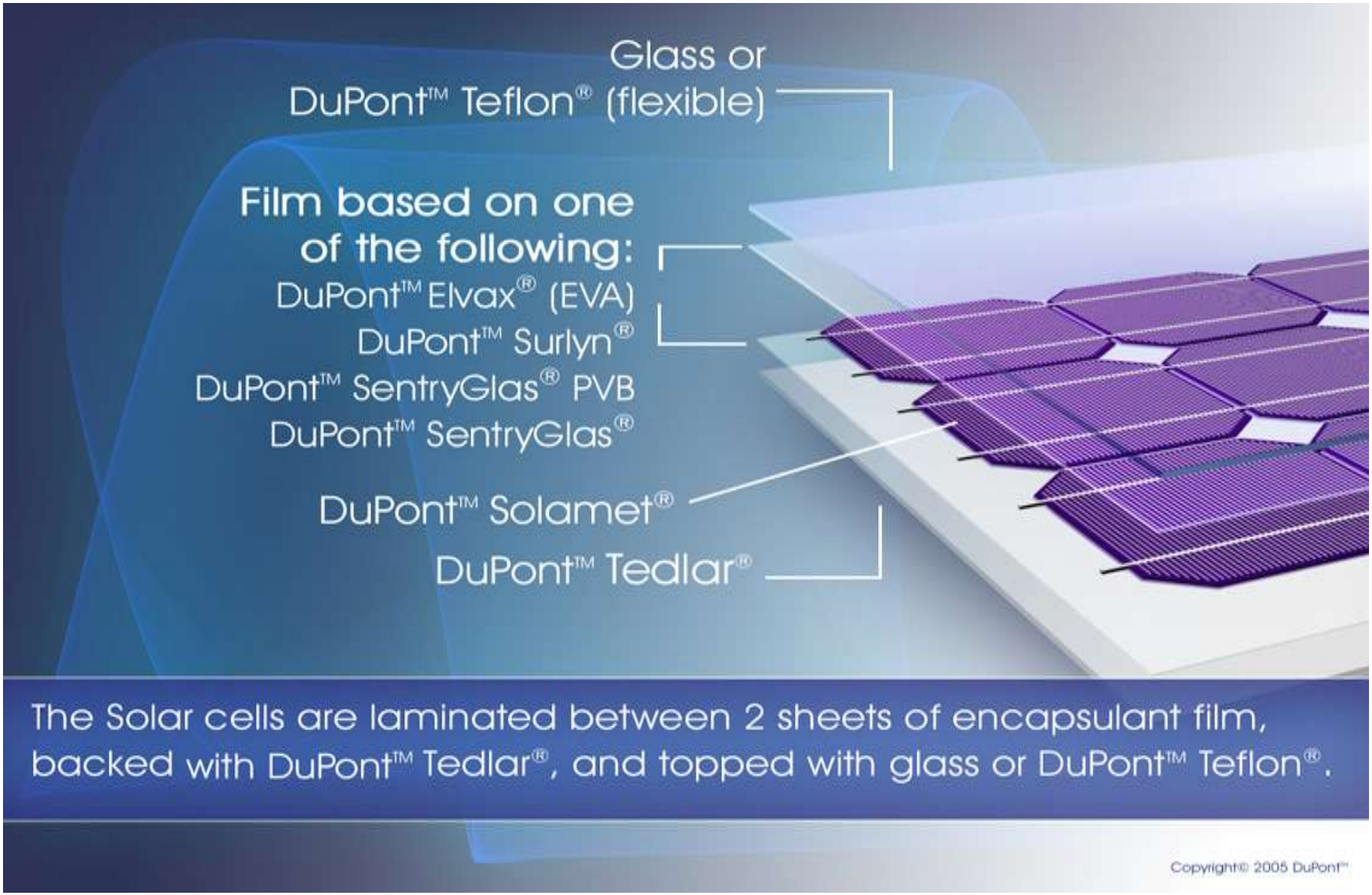
PV2100 Series represent a new generation of films designed for dimensional stability at lamination temperatures for wrinkle free backsheets

PV2111, the first member of the PV2100 family, is a white, highly reflective film.

New polymer plant started up

Tedlar ® Film Capacity expansions

Since 2002 through increased staffing, plant ream-outs, 6-sigma projects and new polymer and film lines coming on stream, we will have increased our capacity by 2009 with **300%.**


Glass or
DuPont™ Teflon® (flexible)
Film based on one
of the following:
DuPont™ Elvax® (EVA)
DuPont™ Surlyn®
DuPont™ SentryGlas® PVB
DuPont™ SentryGlas®
DuPont™ Solamet®
DuPont™ Tedlar®
The Solar cells are laminated between 2 sheets of encapsulant film,
backed with DuPont™ Tedlar®, and topped with glass or DuPont™ Teflon®.
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