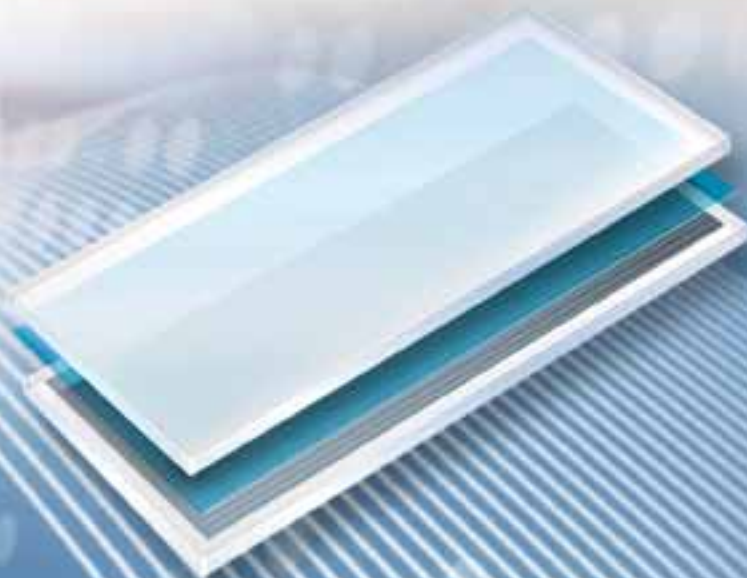


kuraray


PHOTOVOLTAIC MODULE ENCAPSULATION

FORWARD-LOOKING MODULE TECHNOLOGY
WITH PVB FILM



PRODUCT INFORMATION

TROSIFOL[®]



**SOLAR MODULE
ENCAPSULATION.
GET CLOSER.**

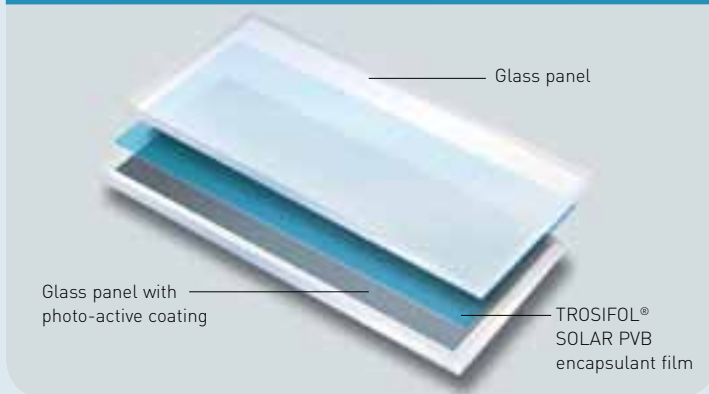
A NEW DIMENSION IN SOLAR MODULE MANUFACTURING

TROSIFOL® polyvinyl butyral (PVB) film is a product with decades of successful use in the production of laminated safety glass for architectural and automotive applications. Recent years have seen a sharp rise in the quality and manufacturing efficiency required of photovoltaic (PV) modules and in the importance of high-grade encapsulation materials for the solar cells in the modules. TROSIFOL® has responded to this by becoming the first supplier to develop new and innovative PVB based encapsulants – TROSIFOL® SOLAR.

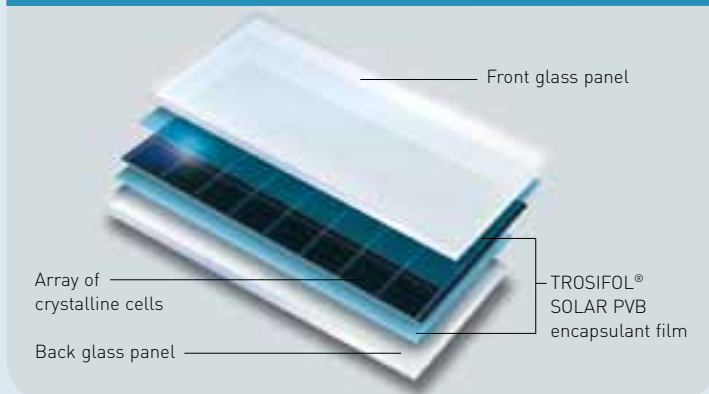
TROSIFOL® SOLAR can be processed both in vacuum laminators and in the two-stage process used successfully for laminated safety glass. This can take place either in a vacuum de-airing process (for modules with crystalline cells) or a roll lamination process (nip-roll process for thin-film modules) with subsequent autoclaving at elevated pressure and temperature.

TROSIFOL® is certified to ISO/TS 16949:2002, DIN EN ISO 9001:2008, DIN EN ISO 14001:2005 (environmental management systems) and BS OHSAS 18001:2007 for occupational safety & health management systems.

PV MODULE – THIN FILM TECHNOLOGY



PV MODULE – CRYSTALLINE TECHNOLOGY



ADVANTAGES OF TROSIFOL® SOLAR

- Non-crosslinking thermoplastic
- Excellent adhesive properties on glass, solar cells, metals and other plastics
- Outstanding optical transparency
- High bond durability
- Excellent resistance to heat, UV-light and environmental influences
- Very high compatibility with module components
- Reproducible lamination behaviour in all conventional lamination processes
- Significant energy savings in logistics chain (no need for cooling of film)
- Certified according to IEC 61646:2008 and IEC 61215:2005
- Can be stored and processed up to 4 years after manufacture



★ 2010

Development of TROSIFOL® SOLAR 2G

★ 2009

Market launch of TROSIFOL® SOLAR ULTRA WHITE (encapsulation + reflexion)



★ 2007

Start of production of TROSIFOL® SOLAR R40 at the first a-Si thin-film module turnkey production plants

★ 2006

First series use of TROSIFOL® SOLAR in thin-film modules

★ 2005

Launch of TROSIFOL® SOLAR, a special product line for PV applications

★ 2000

Launch of a sound-insulating PVB film for architectural glazing – TROSIFOL® SOUND CONTROL

★ 1982

AEG Solar embarks on the series production of modules with TROSIFOL®



★ 1980s

TROSIFOL® starts production of the first jumbo product line (3.21 m wide)

★ 1968

Development of the PE interleaf for PVB film

★ 1952/53

Launch of TROSIFOL® PVB film

★ 1940s

Growing use of laminated glass in the automotive, aviation and construction industries

★ 1930s

Invention of today's laminated safety glass with PVB film



TRAIN STATION TURIN, ITALY
MODULE PRODUCED BY ENERGY GLASS

LAMINATION PROCESSES

Depending on the type of PV module, TROSIFOL® can be processed in one-stage vacuum laminators or in the two-stage process, i.e. with either the vacuum process or the nip-roll/calender deairing process with subsequent autoclaving.

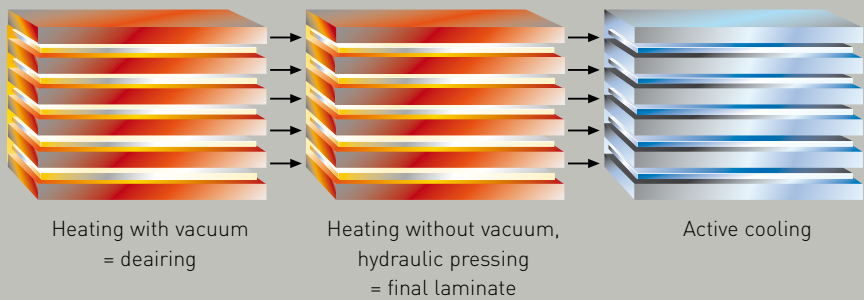
CHARACTERISTICS

- Very little edge flow during the laminating process (high edge stability)
- No contamination of the glass surface, e.g. by contaminated membranes
- Adjustable sandwich deairing rate by using films with different surface roughnesses
- Longer service life of laminator membranes and other components/longer oil change intervals
- Excellent long-term protection of thin-film modules (Study of an independant PV research institute on CIS modules)

VACUUM LAMINATOR

TROSIFOL® SOLAR – a non-crosslinking thermoplastic – is readily processed in vacuum laminators. Cycle time is 8 - 20 minutes for glass/back sheet and 8 - 25 minutes for glass/glass modules, depending on glass thickness, laminator type and features (standard or multi-stage laminator).

MULTI-STAGE LAMINATOR



LAMINATION. IN PERFECTION.



Vacuum laminator,
Source: 3S Swiss Solar Systems AG, Lyss; 3S Modultec – Laminating Line

RUBBER BAG PROCESS

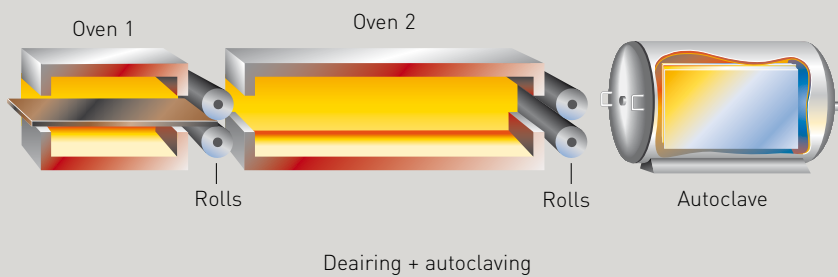
On the same principle as laminated safety glass, glass/glass modules are preferably deaired in bags made of plastic or rubber and in a vacuum of < 100 mbar in a hot-air oven. The maximum temperature is about 135°C . The modules are then laminated in an autoclave at elevated temperature and pressure.

ROLL LAMINATOR PROCESS

The deairing and subsequent encapsulation of TROSIFOL® SOLAR in the roll laminator process is geared to glass/glass PV modules. This is a highly efficient process with decades of successful use on the industrial scale and is also suitable for coated glass.

It permits high machining speeds, even for large-format modules, and hence high area throughput (cycle time approx. 60 s/module). Depending on the process and the nip roll deairing equipment.

ROLL LAMINATOR + AUTOCLAVE



CHARACTERISTICS

- No edge flow during the lamination process (high edge stability), possibly no need for subsequent trimming
- Effective process control
- High area output, larger formats and non-standard module geometries possible
- High production efficiency and flexibility for glass/glass PV modules

PROCESSING. FUTURE IS NOW.

Source: Inventux Technologies AG/Germany

AUTOCLAVE PROCESS

In the two-stage process with glass/glass modules, autoclaving is carried out as the second process step.

A pressure of 10-13 bar is set at a holding temperature of 135-145°C, and the process can take between one and two hours, depending on the total glass thickness and cell type even longer. If the autoclave has adapters permitting the generation of the vacuum in the pressure vessel, the initial step can take place here.

SUMMARY

Laminator process

Standard laminator

Process time*
17 min

6 modules
per cycle

Multi-stage laminator

Process time*
8 min

10 modules
per cycle

Autoclave process

Pre-nip process

Cycle time = 60 s/module**

Rubber bag

Pre-lamination:
Deairing and
sealing
the edges

Autoclave

12 bar, 140°C, process time 90 min,
> 120 modules per cycle

Lamination:
Production of a
durable laminate

* depending on module size/structure, Process time reduction possible

** Indicated cycle times are examples of laminator equipment used in PV industry for solar module production.

CERTIFICATION OF SOLAR MODULES

Glass/glass modules with TROSIFOL® SOLAR encapsulation film satisfy all the key system requirements for series modules, depending on cell type. In the case of crystalline cells, they conform to IEC 61215:05 (2005).

Solar modules produced with TROSIFOL® SOLAR by various thin-film module manufacturers are certified by TÜV Rheinland to IEC 61646:2008 and IEC 61730, among others. For solar modules from turnkey system suppliers with standardized compositions, a master certificate is usually issued, which is then transferable to the individual module manufacturers.



Certified in the module to IEC 61646 and IEC 61730



TROSIFOL® SOLAR is also UL-listed. This facilitates the certification of solar modules to US standards (Underwriters Laboratories, UL 1703).

SELECTION OF TESTING BODIES FOR PV MODULE CERTIFICATION

Fraunhofer ISE, Freiburg/Germany

TÜV Rheinland Group, Cologne/Germany

Arsenal Research, Vienna/Austria

JRC ISPRA, Italy

TÜV InterCert, Padua/Italy

AT4 wireless, Málaga/Spain

CENER, Sarriguren, Navarra/Spain

Arizona Photovoltaic Testing LAB (ASU-PTL), USA

Japan Electrical Safety & Environmental Technologies Laboratories (JET), Tokio/Japan & other places



With courtesy of: Fraunhofer ISE, Freiburg/Germany

PRODUCTS AND LOGISTICS

TROSIFOL® SOLAR

Product	Colour	Thickness [mm]	Roughness R _z * [µm]	Roll length [m]
SOLAR R40	Clear	0.50	40	370
SOLAR R40	Clear	0.76	40	250/450
SOLAR R40	ULTRA WHITE	0.50	25	370
SOLAR R40	ULTRA WHITE	0.76	35	250
SOLAR R100	Clear	0.76	100	200
SOLAR UV+	Clear	0.50	40	370
SOLAR UV+	Clear	0.76	40	250

* SOLAR R40 is available on request in other film thicknesses (0.38 mm/1.14 mm); max. width 3210 mm

In Kuraray's corporate philosophy, long-term, future-oriented growth is closely tied to sustainable business processes and the sparing use of limited resources. The goal of this forward-looking approach is to reduce the impact of emissions on the environment, develop environment-friendly products and select suitable raw materials on the principle of "green procurement".

TROSIFOL® SOLAR products are supplied as standard with a polyethylene interleaf in order to prevent the consumption of additional energy during storage and shipment.*

Processing is recommended in a moisture-controlled lay-up room with a relative humidity of 25-30% (roll laminator) / 50% (vacuum laminator) and at a temperature of 15-20°C.

* Refrigerated films are available on demand.

ADVANTAGES OF SAFETY GLAZING WITH TROSIFOL® SOLAR

Glass/glass PV modules for building integration, e.g. for façades, overhead glazing and parapets, have to satisfy specific safety requirements and legal provisions.

The film properties therefore have to meet the needs of conventional safety glazing, which also applies when the PV module is integrated in an insulation glazing element.

Glass/glass PV modules manufactured with TROSIFOL® SOLAR PVB film satisfy the highest safety requirements governing glazing in the building envelope.

PROCESSING ADVANTAGES

- TROSIFOL® SOLAR trimmings are collected and preferably recycled - hence environment-friendly
- PE interleaved PVB film saves energy
- All packages are taken back and disposed of (within the EU)
- Almost exclusive use of returnable packaging



Pendulum test in accordance with EN 12600

TROSIFOL® SOLAR R40 ULTRA WHITE, a registered German Utility Model (DE 212008000039 U1); Patent pending in US, EP, N, RU, JP and ZA (WO 2009071703 A2)

TECHNICAL DATA

PHYSICAL PROPERTIES OF TROSIFOL® SOLAR

Properties	Unit	Test method	SOLAR R40/R100	SOLAR R40 ULTRA WHITE	SOLAR UV+
Density	g/cm ³	DIN 53479	1.065	1.200	1.065
Refractive index	-	DIN 53491	1.482	-	1.482
Thermal conductivity	W/m	EN 12939	0.20	0.20	0.20
Resistivity*	Ω x cm	DIN IEC 60093	2.0E12	1.0E14	2.0E12
Hardness	Shore A	without dimension	65	70	65
Specific heat	J/WK	ISO 11357-4	1.85	1.85	1.85
Tensile strength	N/mm ²	ISO 527	> 23	> 23	> 23
Elongation at break	%	ISO 527	> 250	> 250	> 250
Coefficient of thermal expansion	1/K	ISO 11359-2	2.2 E-4	2.0 E-4	2.2 E-4
UV cut-off	nm	EN 410	375	-	< 280
Visible light transmittance**	%	EN 410	91	< 1	91
Glass adhesion***	N/mm ²	CSS	> 16	> 16	> 16

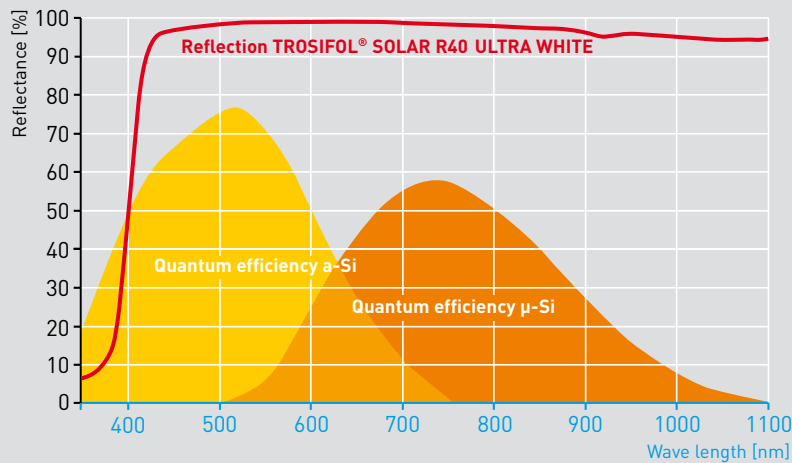
* At 0.5% H₂O content/23 °C

** LSG made of 2 x 3 mm low-iron glass

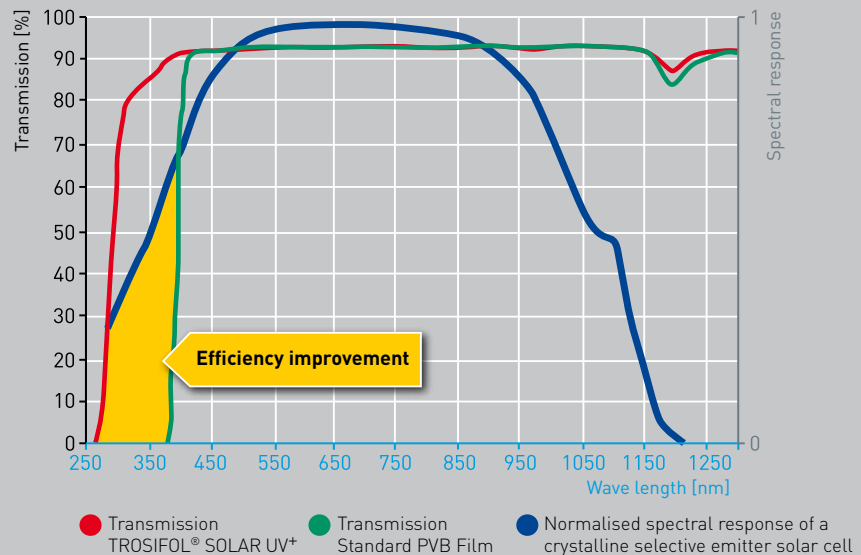
*** Compressive shear strength

Further data available on request

REFLECTANCE CURVE TROSIFOL® SOLAR R40 ULTRA WHITE



TROSIFOL® SOLAR UV+



● Transmission TROSIFOL® SOLAR UV+

● Transmission Standard PVB Film

● Normalised spectral response of a crystalline selective emitter solar cell

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