Protection of Organic Solar Cells for Long Lifetime

Plessing A. K., Depiné N., Erler B., Feichtner M., Gradwohl J., Krumlacher W., Muckenhuber, H., Reininger A., Reisinger F., Ruplitsch A., Seitler E., Skringer A., Spanring J.

International Symposium towards Organic Photovoltaics

Linz, Johannes Kepler Universität

2008, February, 6-8

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Photovoltaics

Outline

1. Overview

- Historical background
- Standard Isovolta products for the PV industry

2. Encapsulation Material for Flexible Solar Cells

- Requirements
- State of the art
- Concepts
- Today`s results

3. Automated encapsulation

4. Summary

Isovolta AG

A Constantia INDUSTRIES COMPANY

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Werndorf Plant
2005

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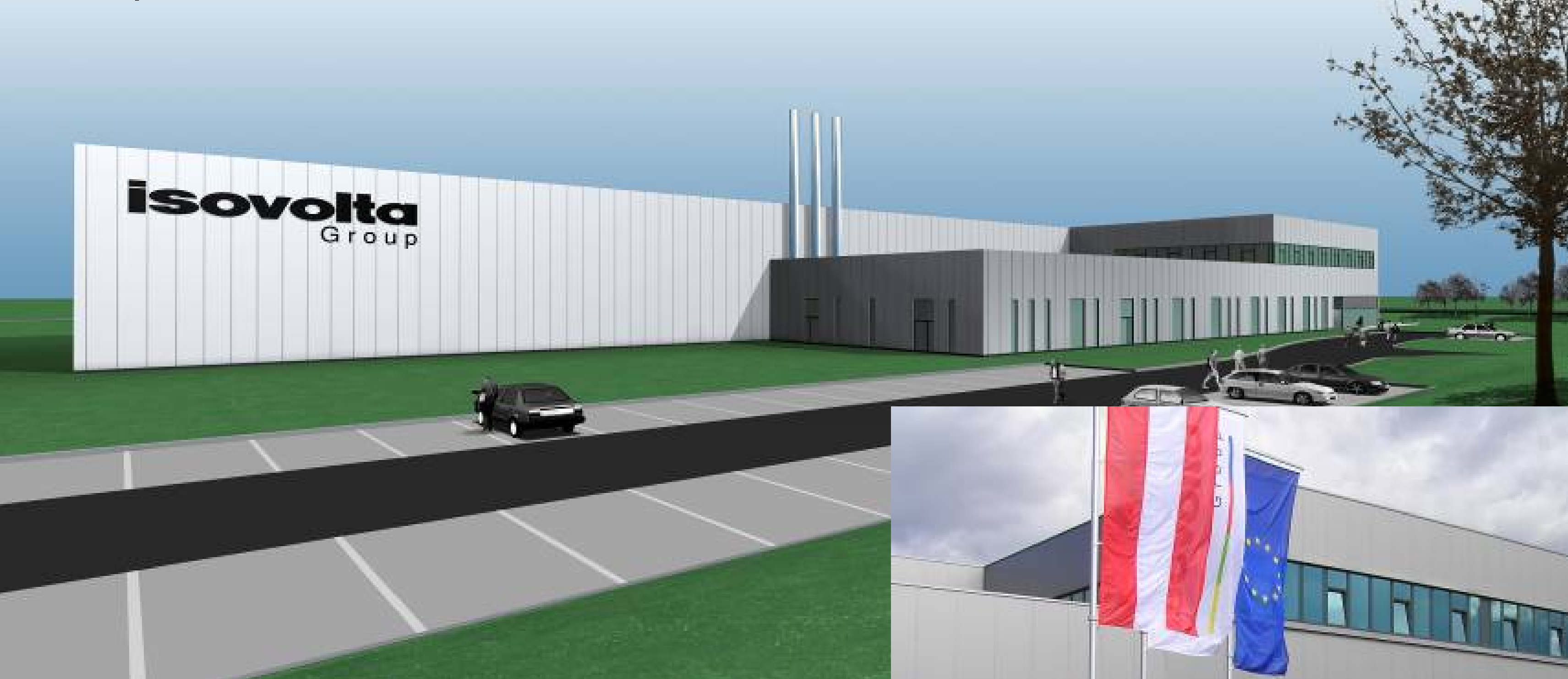
Lebring Plant

- opened 2005
- expanded 2008



Wr. Neudorf Plant & Headquarters

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Locations

•Isovolta Werndorf, AT		1949
•Isovolta Wr.Neudorf, AT		1962
•Isovolta India, IND	(40%)	1984
•Skyline, USA	(100%)	1989
•Isovolta Hong Kong, CN	(76%)	1990
•Teinser, E	(60%)	1992
•Changzhou Isovolta, CN	(70%)	1995
•Nippon Rika Isovolta, JP	(34%)	1996
•Isovolta S.A., RO	(99%)	1998
•Micafil Glimmer-Aktivitäten, CH	(100%)	1999
•Isovolta di Mexico, MX	(60%)	2000
•Gatex, DE	(100%)	2001
•Isoma, BG	(100%)	2002
•Skylife spol. s.r.o., SK	(100%)	2003
•Isovolta Inc./US Samica, USA	(100%)	2003
•Changzhou Olong, CN	(40%)	2004
•Changzhou T C , CN	(70%)	2005
•Lebring, AT	(100%)	2005
•Deglarges, F	(60%)	2006

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ISOVOLTA GROUP

Division

High Voltage

Low Voltage & Transformers

Rigid Laminates

Market

Photovoltaics

Composite Materials

Aircraft

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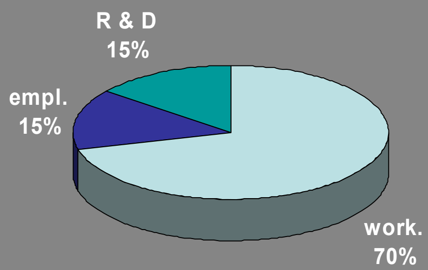
Competence Center Werndorf

> 340 employes



Production

Process Technology

R & D International

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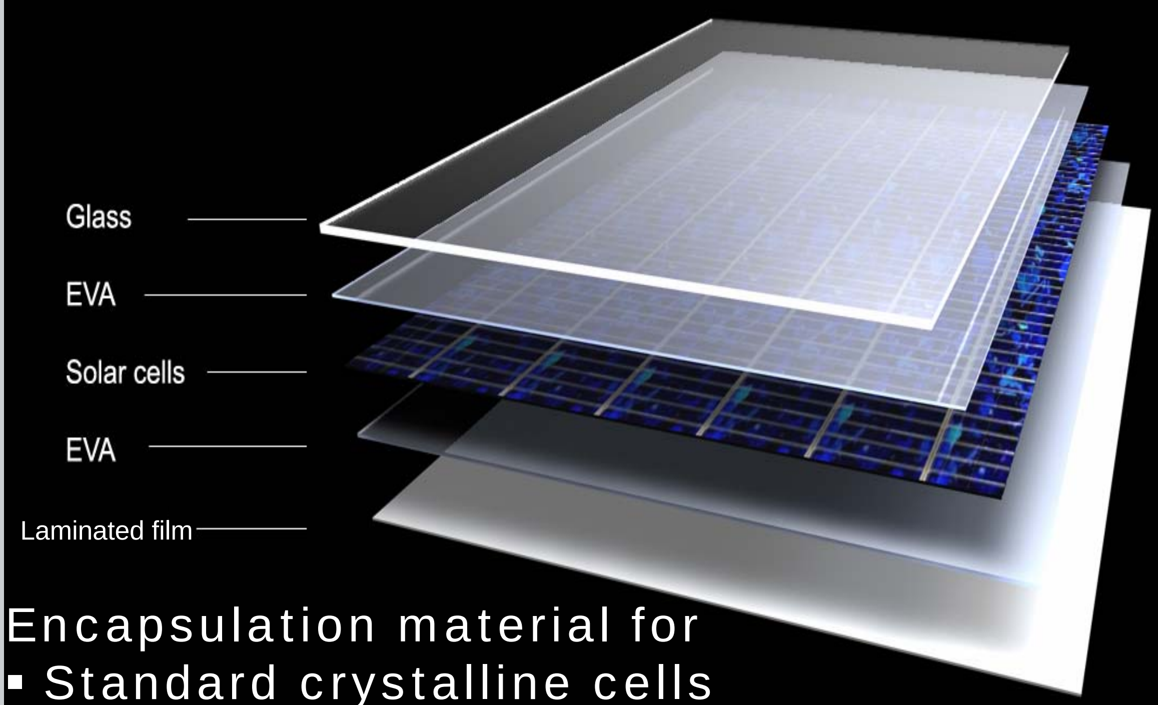
PV Module

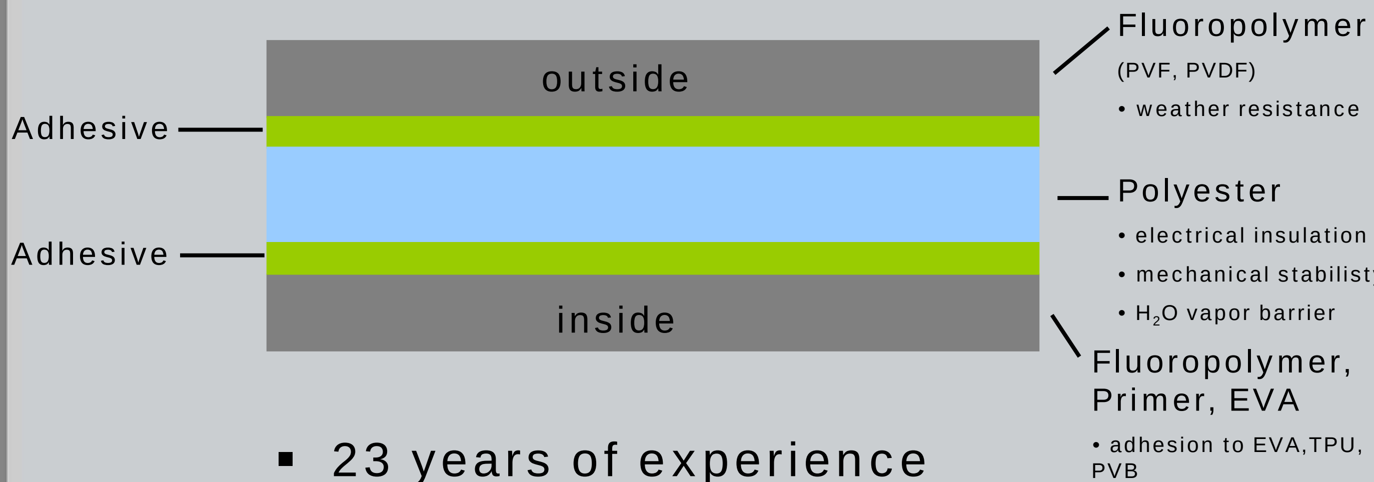


Encapsulation material for

- Standard crystalline cells
- Thin film cells
- Special encapsulation application solutions

Laminated Film

Laminated Film



- 23 years of experience
- 25 years guaranteed lifetime
- +30 years lifetime

Long Term Stability of Encapsulating Materials

Crystalline solar cells

Weatherability

- Damp-Heat Test @ 85 °C/ 85% r.h.: 2000 h – 3500 h
- UV-Stability: IEC 61730

Evaluation

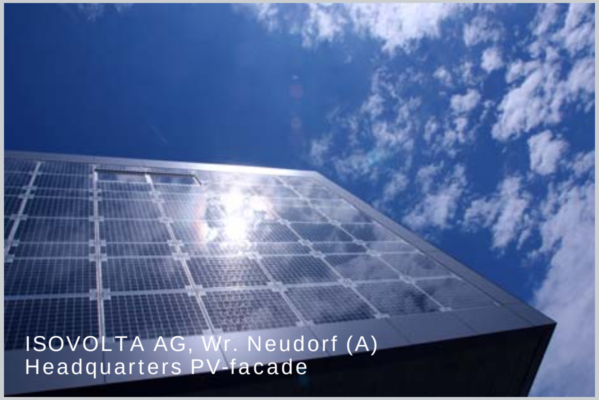
- Adhesion between layers
- Discolouration

Application of Laminated Films

stand-alone

PV-facility, New Mexicco (USA)
(Shell Solar Industries LP)

integrated

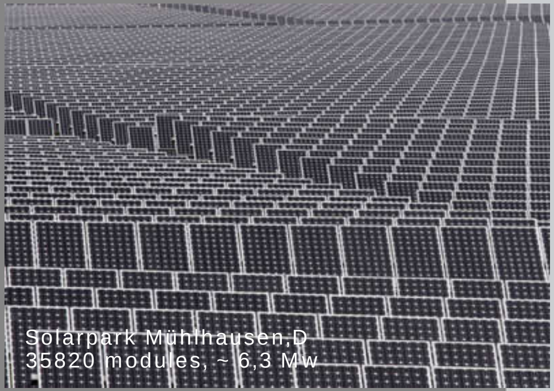


ISOVOLTA AG, Wr. Neudorf (A)
Headquarters PV-facade

transparent

Floriade
(Siemens Nederland N.V.)

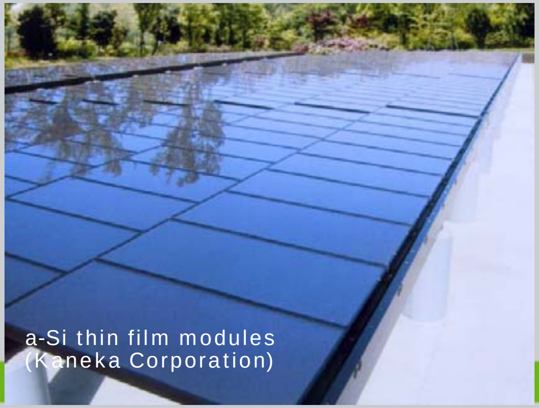
solar park



Solarpark Mühlhausen,D
35820 modules, ~ 6,3 Mw

Mercedes solar roof, D
(Webasto Systemkomponenten
GmbH & Co. KG)

thin film



a-Si thin film modules
(Kaneka Corporation)

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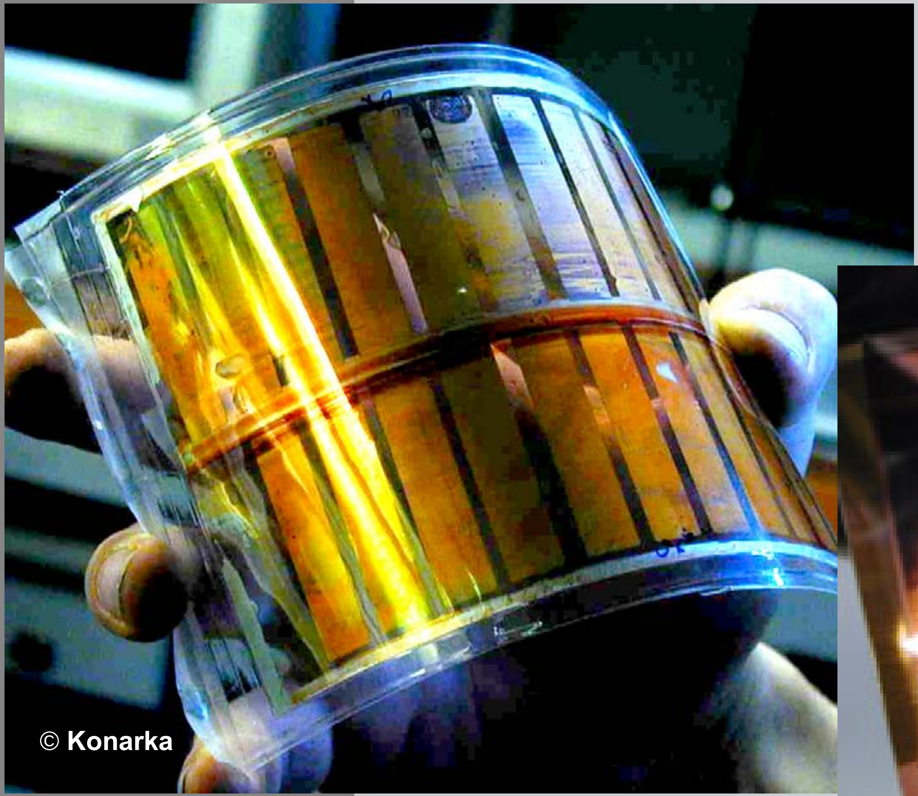
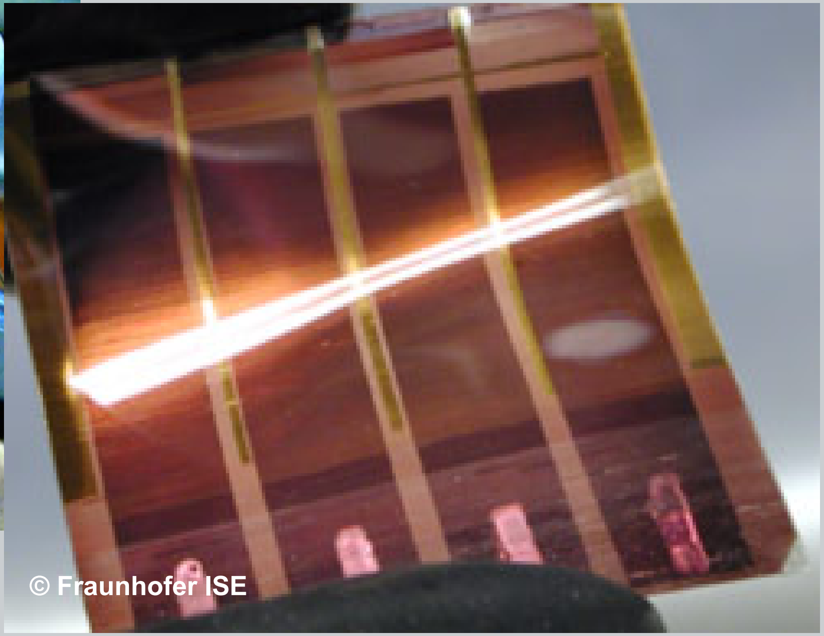
Encapsulation Material for Flexible Solar Cells





Requirements on Encapsulation Materials for Flexible Solar Cells

- weatherability
- high transparency
- flexibility
- UV-stability - low yellowing
- no brittleness
- adhesion
- cost efficiency
- availability
- barrier properties (water vapour, oxygen)

Barrier Requirements for Different Product Sectors

	WVTR $[g.m^{-2}.d^{-1}]$	OTR $[cm^3.m^{-2}.d^{-1}.atm^{-1}]$	Lifetime [a]
amorphous Si	$< 10^0$	$< 10^0$	> 20
CIS	$< 10^{-3}$	$< 10^{-3}$	> 10
Organic Solar Cells	$< 10^{-3}$	$< 10^{-3}$	> 5
OLEDs	$< 10^{-6}$	$< 10^{-5}$	> 2

<u>Water Vapour Transmission (WVTR):</u>

Standard material today: 2 $g.m^{-2}.d^{-1}$

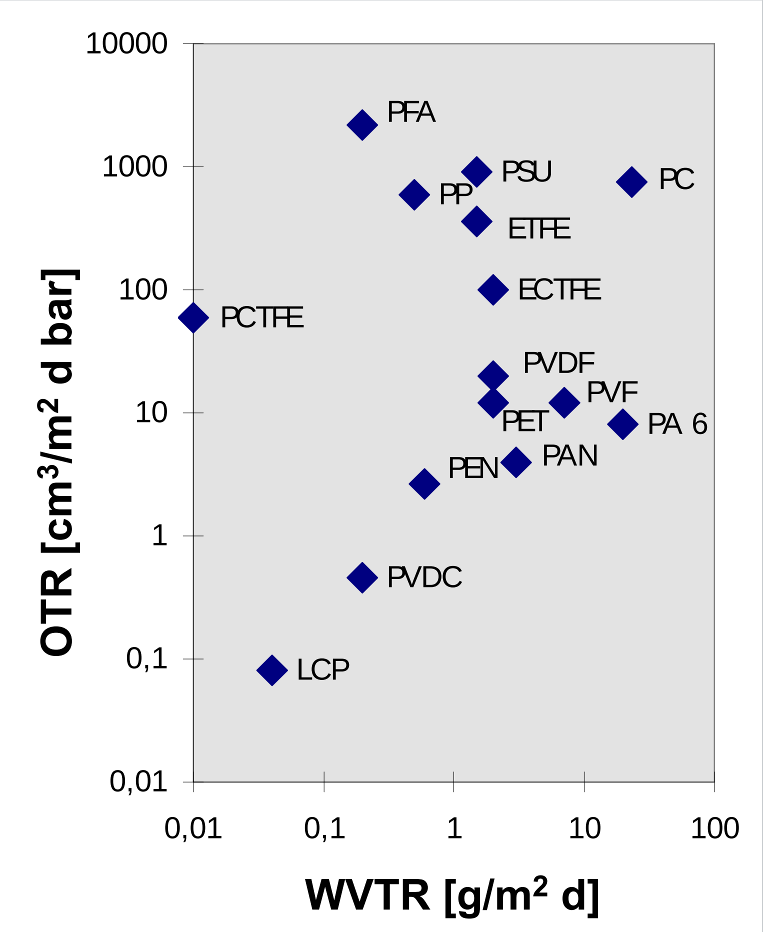
Goal: High Barrier Laminates → 10^{-5} $g.m^{-2}.d^{-1}$ and lower

Barrier properties of technical polymers

Permeability, normalized to 100 µm thickness

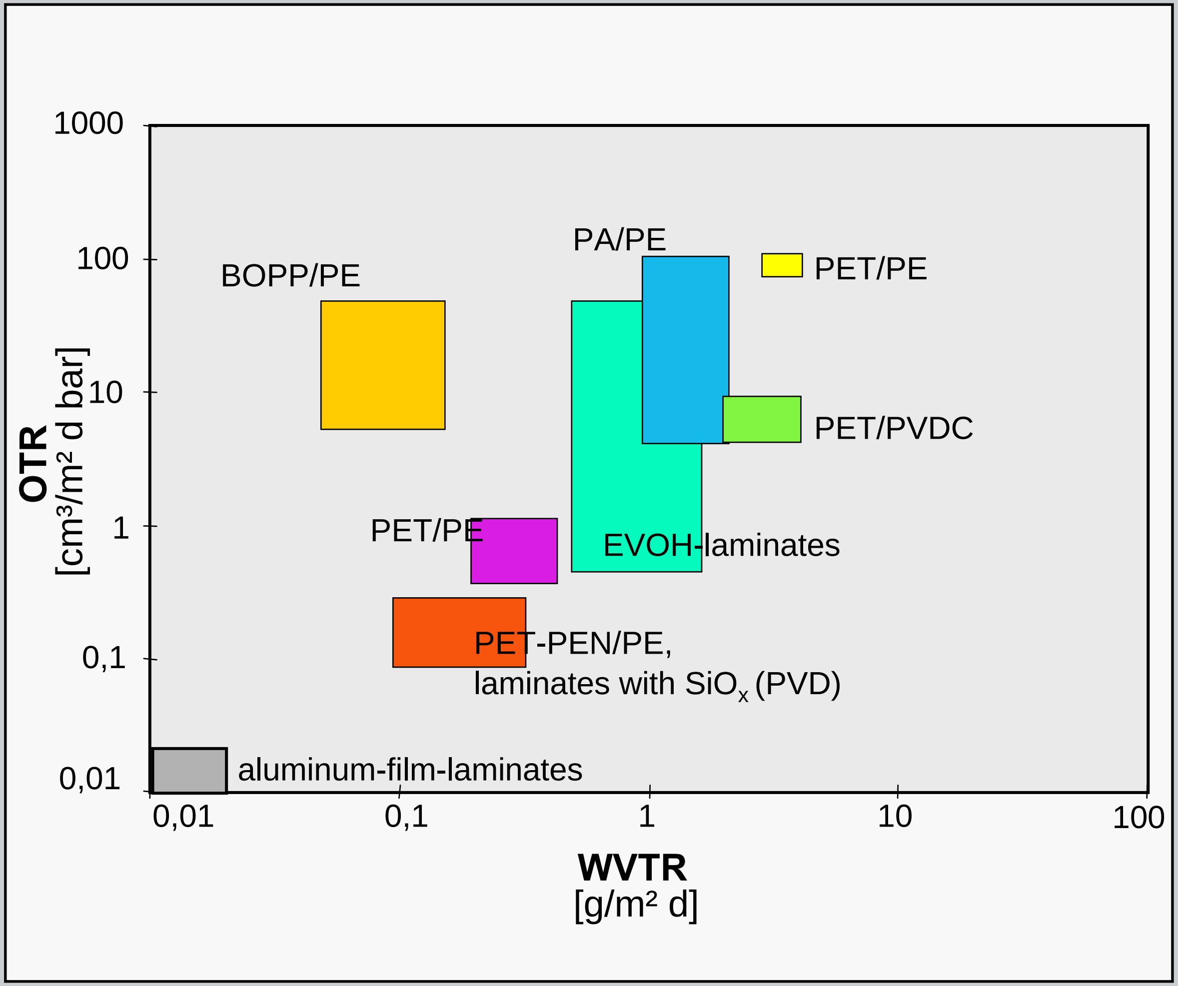
Oxygen transmission (DIN 53 380): 23°C, 50% r.h.

Water vapor transmission (DIN 53 122): 23°C, 85% r.h. to 0% r.h.



Barrier properties of laminates and composite materials

(PVD: physical vapor deposition)



OTR: (DIN 53 380: 23°C, 50% r.h.)

WVTR: (DIN 53 122: 23°C, 85% r.h.)

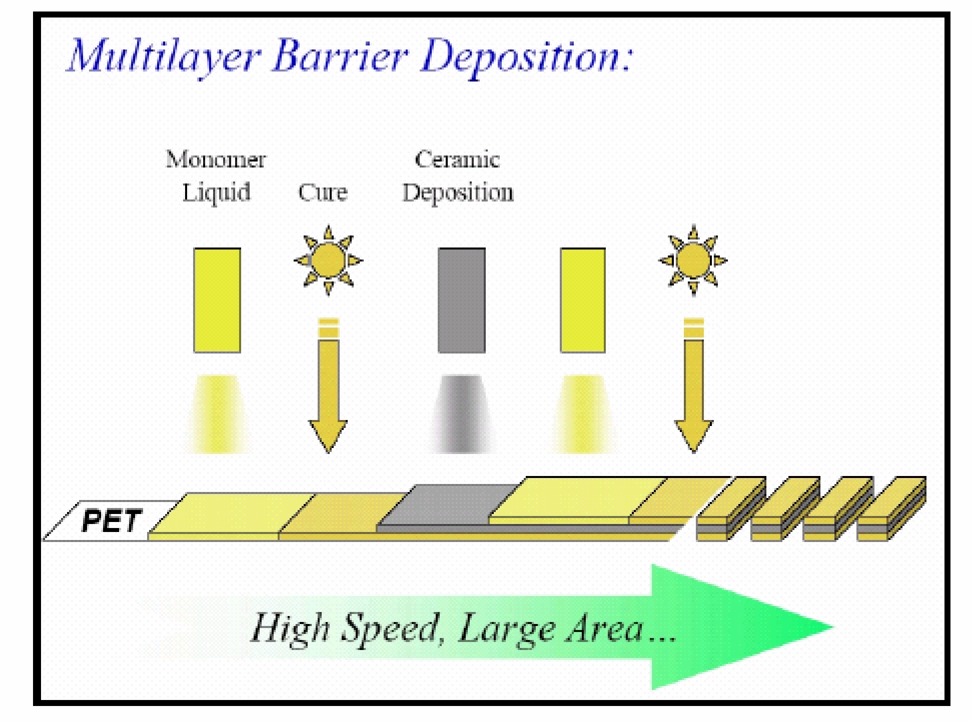
Flexible Encapsulation Materials: State of the Art (1)

PML®-Process

Polymer **M**ulti **L**ayer **P**rocess (by Vitex Systems, Inc.)

- alternating coating systems → acrylates & inorganic barrier layers

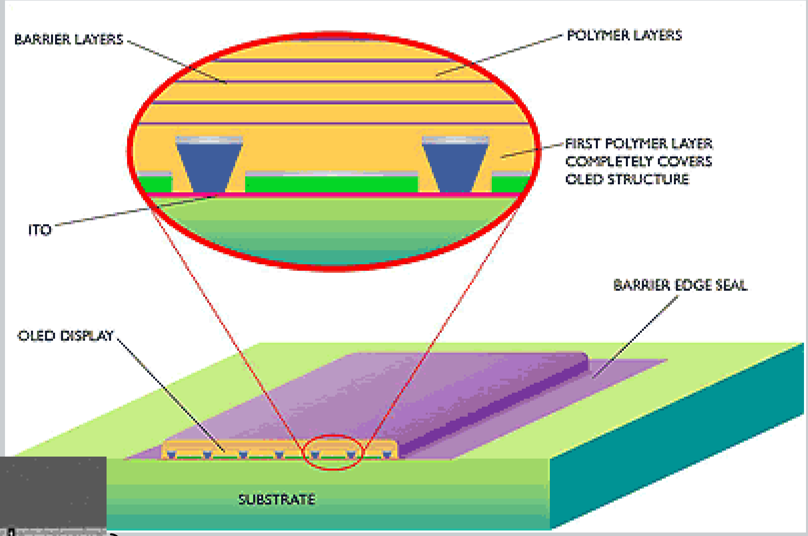
BARIX™ encapsulation



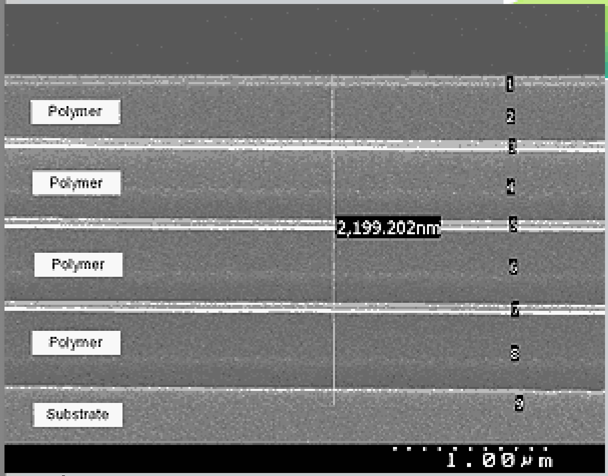
Burrows, P.E. et al.; MRS spring Meeting 2002, Boston, USA

Flexible Encapsulation Materials: State of the Art (2)

Vitex, Inc.



PML® process



©Vitex Systems

Barrier stack (alternating coating of acrylates and inorganic barrier layers)

Teonex® PEN substrate

Barrier properties

WVTR: 10-5 g/m^2*d

OTR: 10-5 cm^3/m^2*d

(Ca test)

- *direct deposition on OLED, OSC substrate*
- *flexible*
- *formats: 7-9 in wide, up to 100 ft long*

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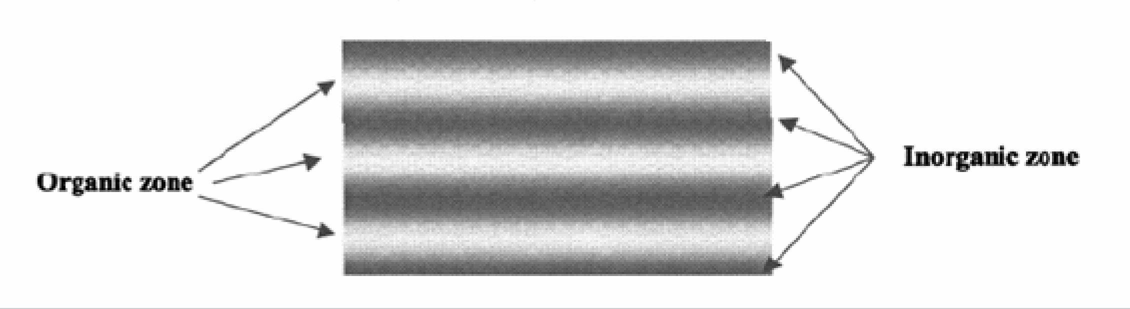
Flexible Encapsulation Materials: State of the Art (3)

SABIC (former GE Plastics)

Scheme of the graded inorganic / organic barrier layers:



The moisture rate of a PC substrate with the ultra high barrier (UHB) coating measured by the Ca corrosion test is less than **1×10^{-5} g/m$^{2}\cdot$d**.

Application: 24 x 24 in OLED display (cooperation with Konika Minolta)

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J. Vac. Sci. Technol. A, Vol. 23, No. 4, Jul/Aug 2005

Flexible Encapsulation Materials: State of the Art (4)

Nova Plasma, Canada

- developement of new encapsulation technology for OLEDs
- inorganic / organic PEVCD coating deposition on polymer substrates
- one-step multilayer
- flexible, transparent
- excellent T resistance
- OTR & WVTR rates: below the sensitivity limit of standard Mocon instrument (< 0.005 g/cm^2 *day)

United Solar Ovonic, USA

- world leader in thin-film amorphous PV technology & applications
- manufacture of a-Si cells & R2R vacuum deposition on substrate (substrate: rollable stainless steel)
- flexible Building-Integrated photovoltaic solar energy systems dimensions: 1.5 miles long, 14 in wide

Flexible Encapsulation Materials: State of the Art (5)

University and Related Institutes

- IMRE, Singapore (Institute of Materials Research and Engineering):
  - flexible barrier development
  - develpment of measurement system (> 10^{-6} g/ m2*d)
- Fraunhofer Gesellschaft, D (FhG): development of flexible tailor made barrier layers (organic / inorganic hybrid materials)

Film Manufacturers – Barrier Films

- DuPont Teijin, worldwide
  - Teonex® Q65FA
  - Melinex® ST 506/504

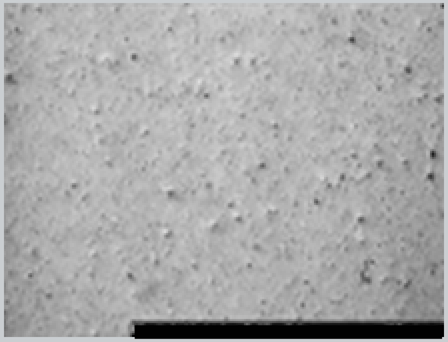
  } heat stabilized, optical clear, planarized
- Honeywell, USA
  - Aclar ® (PCTFE)
  - OxyShield® (PVdC coex. Nylon: moisture & O_2 barrier)
- Vacumet, USA (metallized polymer films, e.g. BARRIER-MET®)
- Pliant Engineered Films, USA (Synergy™: hybrid moisture barrier)

Isovolta Concepts for High Barrier Materials

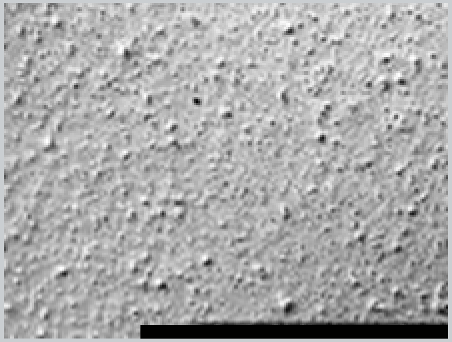
- Multilayer materials with inorganic coatings

- Multilayer structures with inorganic coatings and sealants

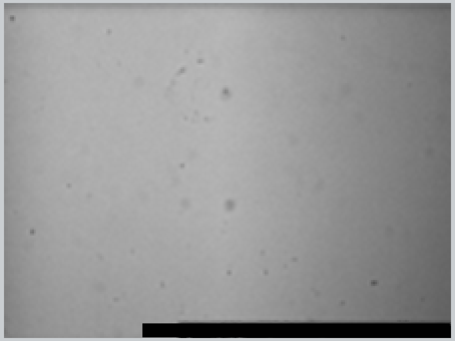
Substrates



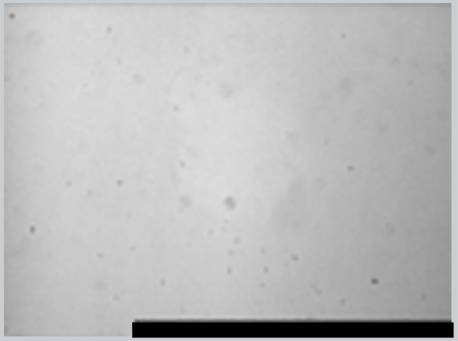
PET 1



PET 2



PET 3



PEN 1

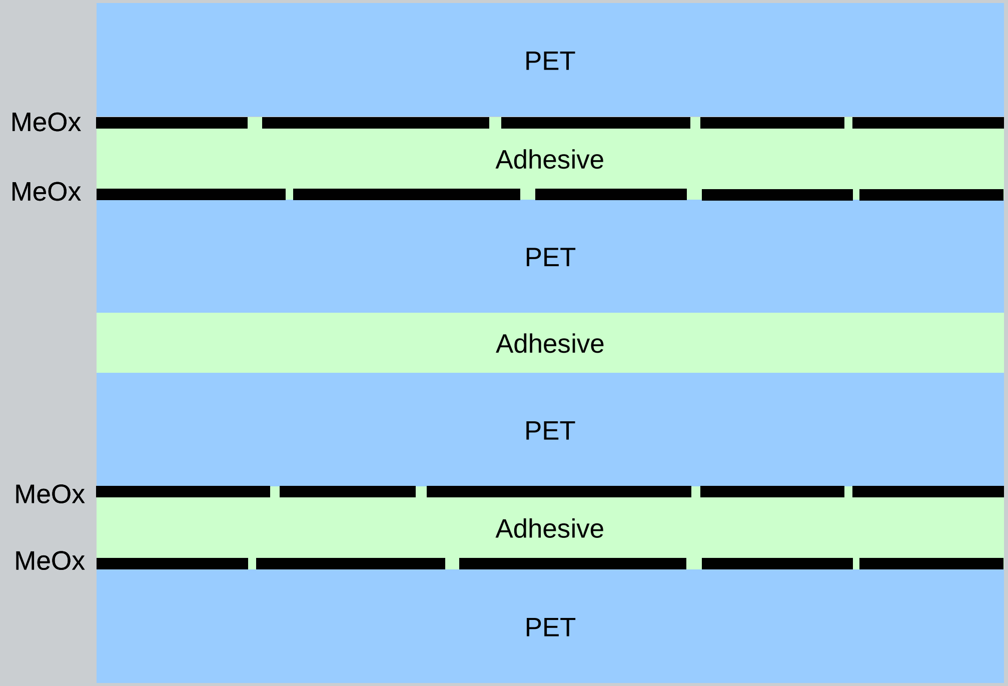
Influence of surface roughness before PEVCD !

MeO_x – vacuum deposition, PEVD

Schematic set-up

© Applied Materials

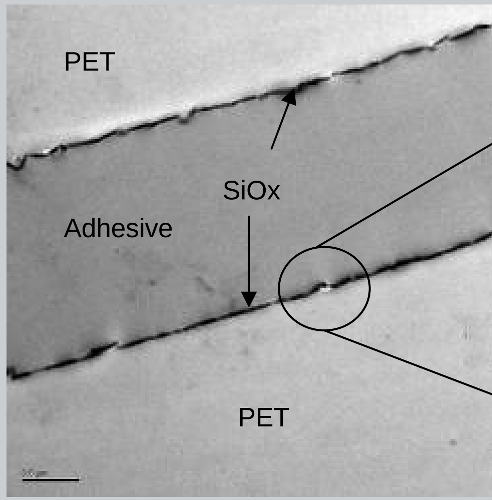
Multilayer Materials with Inorganic Coatings (1)



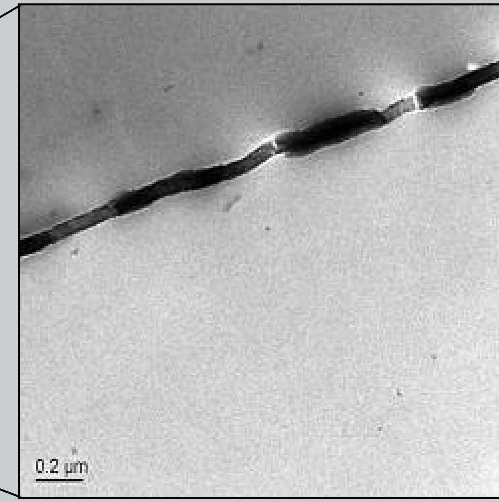
Schematic drawing of a 4 layer PET/MeO_x composite

(thickness approximately 100 µm)

Multilayer Materials with Inorganic Coatings (2)



TEM picture of a two layer composite, 26kx



TEM picture, 52kx

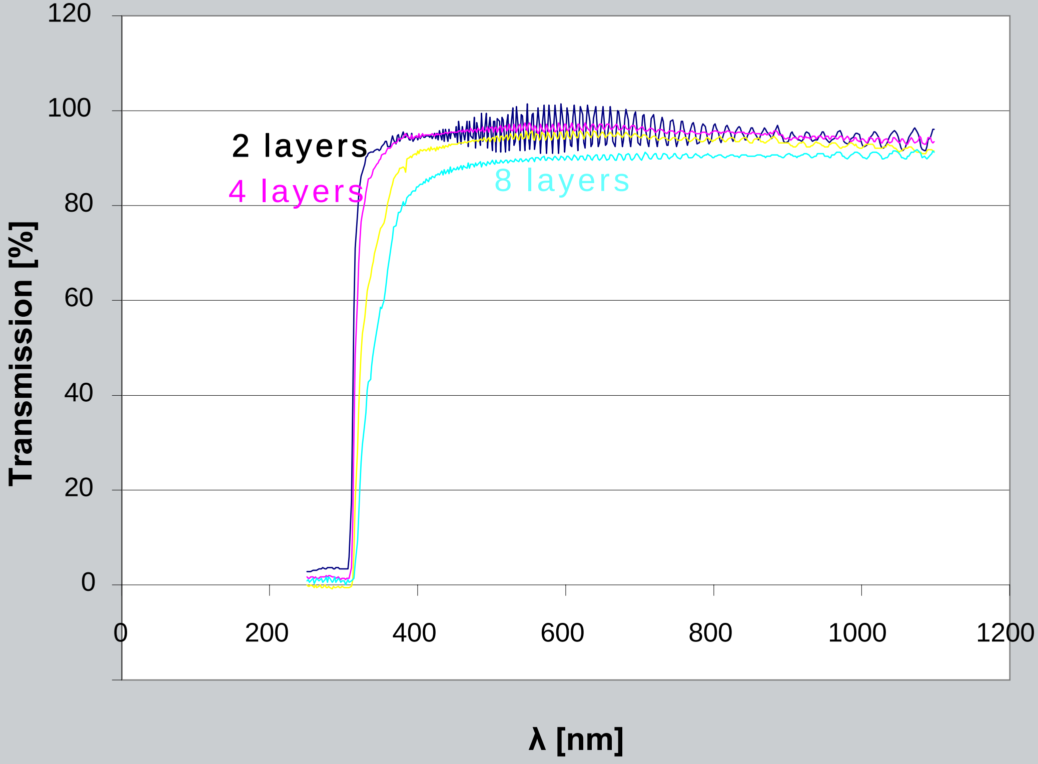
Inorganic Coating defects → decrease in barrier coating properties

Sealants → close defects

Barrier Properties of Multilayer Materials with Inorganic Coatings (3)

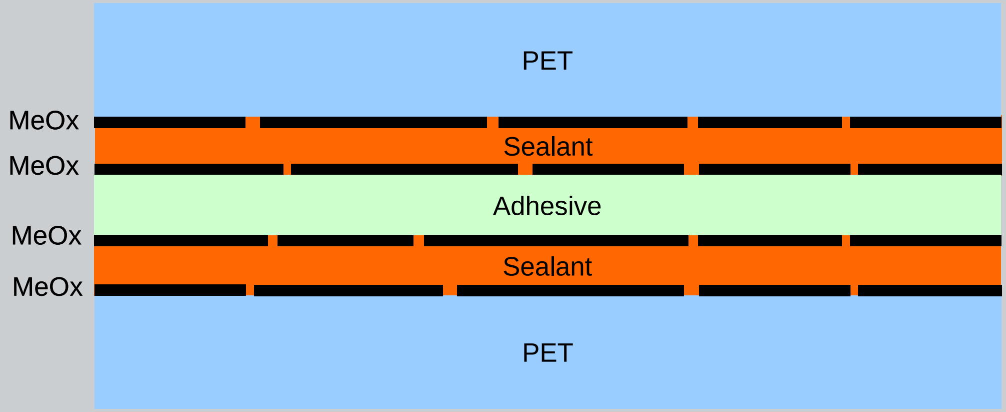
MeO_x layers	WVTR $[g.m^{-2}.d^{-1}]$
2 layers	0,40
4 layers	0,10
8 layers	0,03

Transmission of Transparent Barrier Laminates



> 85% light transmission !

Multilayer Structures with Inorganic Coatings *and Sealants*



PET/MeO_x with *sealant*, recoated with MeO_x

MeO_x layers	WVTR $[g.m^{-2}.d^{-1}]$
4 layers	0,06

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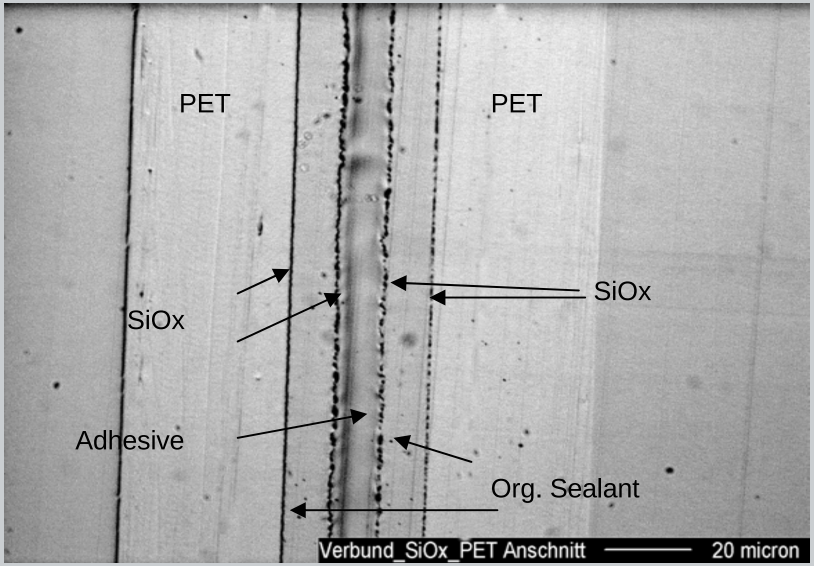
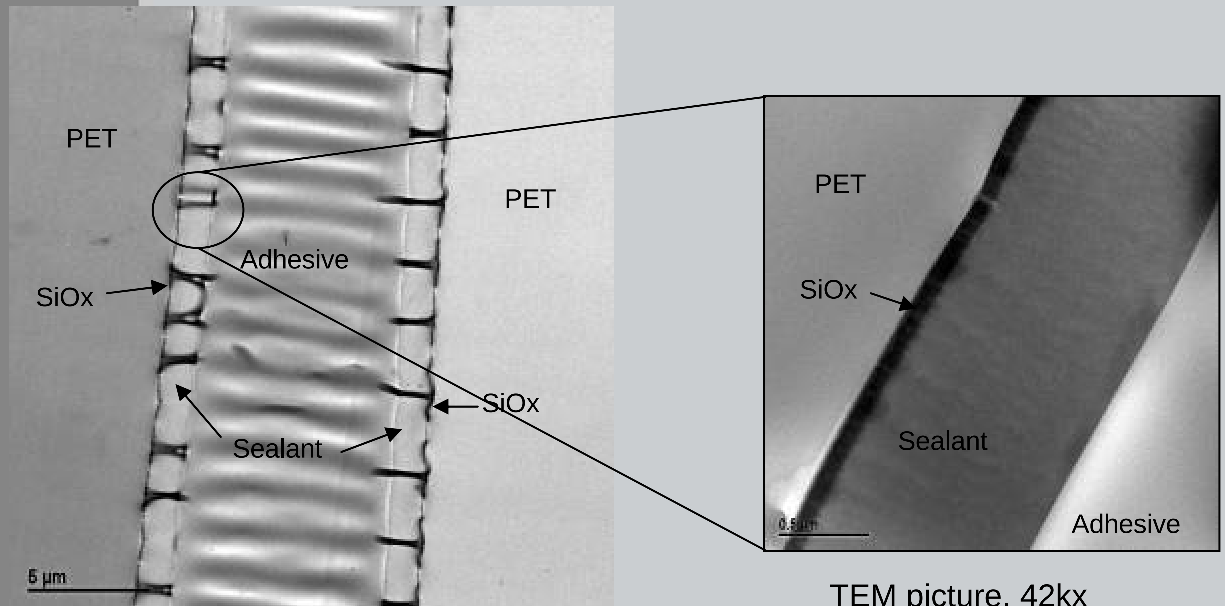
Barrier values of a 4 layer material



Film material	Thickness [µm]	WVTR 1 [g/m²d]	WVTR 2 [g/m²d]	WVTR 3 [g/m²d]
PET	36	5.9	6.0	-
PET-SiOx	36.08	0.4	0.6	0.6
Multilayer	102.32	0.063	0.057	-

Multilayer Structures with Inorganic Coatings and *Improved* Sealants



TEM picture, 4,4kx

TEM picture, 42kx

New sealants → further improved barrier properties

Best Barrier Properties of Multilayer Material with Inorganic Coatings and *Improved* Sealants

MeO_x layers	WVTR $[g.m^{-2}.d^{-1}]$	OTR $[cm^3.m^{-2}.d^{-1}.atm^{-1}]$
2 layers	< 0,01	< 0,05

Barriers of 10^{-4} $g.m^{-2}.d^{-1}$ could be achieved on *laboratory samples* in cooperation with Fraunhofer Gesellschaft.

Results Up to Now

	MeO_x layers	WVTR $[g.m^{-2}.d^{-1}]$
inorganic layers	2 layers	0,40
	4 layers	0,10
	8 layers	0,03
inorganic layers, improved sealants	4 layers	0,06
	2 layers	< 0,01

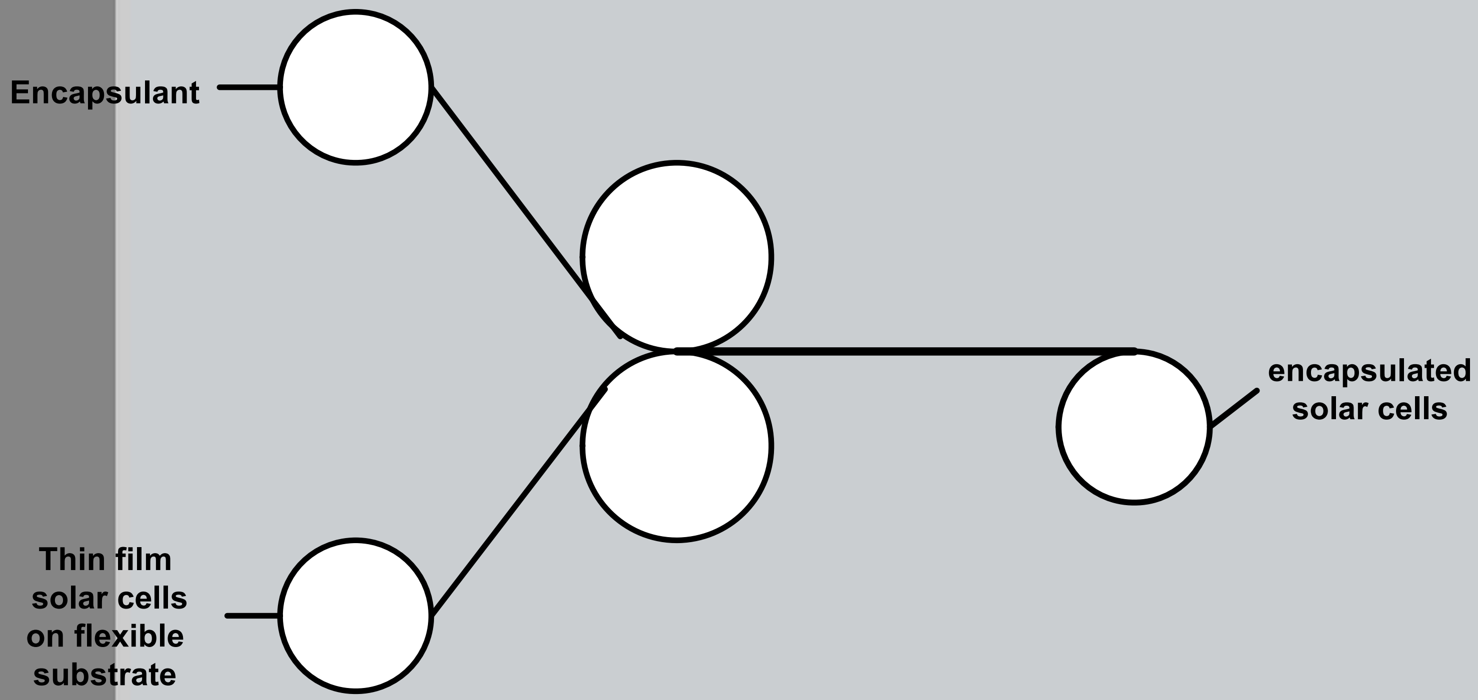
Both, hydrolysis and UV stability tests demonstrate good stability!

Further Developments in Progress

- Up-scaling of encapsulation material with 10^{-2} $g.m^{-2}.d^{-1}$ WVTR and 10^{-2} $cm^3.m^{-2}.d^{-1}.atm^{-1}$ OTR (cooperation with Fraunhofer Gesellschaft). Introduction into the market by end of 2008
- Improved sealants & MeO_x-substrates target values: < 10^{-6} for WVTR & OTR
- R2R encapsulation process

R2R Encapsulation Process (1)

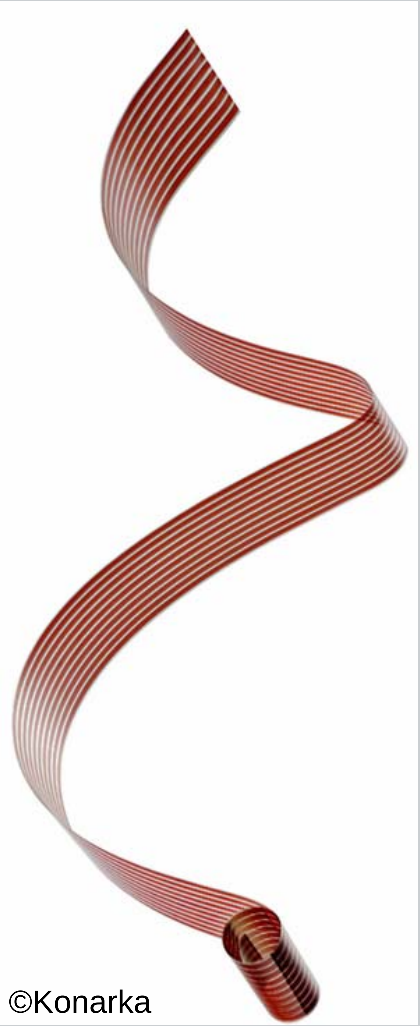
R2R encapsultion process (2)



Applications for Flexible Solar Cells


©Flexcell


©Brunton, SolarRolls™


©Konarka

Summary

- Organic solar cells require high barrier materials for encapsulation.
- Laboratory results of barriers in the range of 10^{-2} to 10^{-4} (Fraunhofer Gesellschaft) could be achieved.
- Encapsulation material, which fulfils all requirements has to be developed for industrial production processes.
- Automated encapsulation processes have to be developed.

Thank you for your attention!