TOWARDS FLEXIBLE ENCAPSULATED PLASTIC ELECTRONICS

Christina Schinagl
Dresden, 9th October 2012
OVERVIEW

- Company Introduction
- Backsheets and Encapsulants for PV
- Flexible Electronics
- Fronsheet - Barrier Material
- Organic Radical Batteries
- Conclusion
COMPANY INTRODUCTION

ISOVOLTAIC

INNOVATIVE BACKSHEETS. PROVEN EXPERIENCE.
ISOVOLTAIC - FIRST IN BACKSHEETS

Global market and technology leader in the development and production of backsheets for photovoltaic modules

Turnover 2011: approx. 190 Mio. EURO

Employees: approx. 250 at 3 sites

Management: Thomas Rossegger / CEO
Manfred Schlögl / CTO
25 YEARS OF EXPERIENCE IN THE SOLAR MARKET

Founding of ISOVOLTA in Werndorf (AT):
Leading manufacturer of electrical insulation materials and technical composites

1949

Development of high-quality backsheet films for solar cells

1985

ICOSOLAR® 0711 is the first ICOSOLAR® product to be officially launched in the market

1988

Construction of a photovoltaic specialized plant in Lebring (AT)

2005

Expansion of production facilities in Lebring (AT)

2008

Spin-off of ISOVOLTA photovoltaics division and incorporation as stand alone company

2009

New ICOSOLAR® products on the basis of modified polyamide are introduced to the market

2010
CORPORATE LOCATIONS

Lebring / AT
- Headquarters & Management
- Marketing & Sales
- Production
- R&D

Eisenstadt / AT
- Production
- R&D

Changzhou / CN
- Sales
- Finishing
COMPONENTS OF A CRYSTALLINE SOLAR MODULE

ICOSOLAR® Backsheets and Encapsulants
Key components of a solar module

ISOVOLTAIC develops, produces and sells flexible composite films for protecting and embedding crystalline and thin film solar cells
WAY OUT OF SCARCITY OF RESOURCES

Improved raw material supply and increased entry barriers due to vertical integration

- TPT backsheets, historically ISOVOLTAIC’s key product, dependent on supply of PVF
- Strong demand growth in 2010 could not be met with PVF supply; substantial excess demand
ICOSOLAR® FOR CRYSTALLINE SI-MODULES

ICOSOLAR® Properties:

• Excellent resistance to atmospheric conditions
• Outstanding electric insulation
• Very good mechanical stability
• Standard colors: white and black, transparent, special colors available

inside: PA, PVF or Primer  
core: PA or PET  
outside: PA, PVF or F

Source: Solarworld
ICOSOLAR® FOR BACK CONTACT SOLAR CELLS

ICOSOLAR® Properties:

- Direct contact to solar cell

inside: Copper
core: PET
outside: PVF

Source: Solland Solar
10% higher power/m²
ICOSOLAR® FOR THIN FILM MODULES

ICOSOLAR® Properties:

- Absolut barrier against water vapour with aluminium
- WVTR (23°C/85%) between 0.2 and 1.6 for transparent ICOSOLAR®
ICOSOLAR® ENCAPSULANT

ICOSOLAR® Encapsulant: One Product - many possibilities

- Backsheet or Frontsheet combined with a layer of thermoplastic encapsulation material
- Improved damp heat and UV stability and less water absorption compared to EVA
- Optimization of production process due to shorter lamination time
- No EVA necessary (no formation of acetic acid that might cause damage to the module)
- High Transparency and increased UV-stability
- Helps to reduce the effects of potential induced degradation (PID)
FLEXIBLE ELECTRONICS

ISOVOLTAIC

INNOVATIVE BACKSHEETS. PROVEN EXPERIENCE.
Flexible OLEDs for Displays and Lightning

Flexible Solar Cells
- CI(G)S, CdTe
- DSSC, OPV

Vacuum Isolation Panels

Printed electronics

RFID

Capacitor, Batteries

OLED Displays
- Source: OLED Displays

OLED Lightning
- Source: globalmarket.com

Smart Labels or ID Tags
- Source: Shanghai Zangtian Electronic Co.

Photovoltaics
- Source: Konarka

Flexible Battery
- Source: Stanford University

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FLEXIBLE ELECTRONICS - FUTURE ASPECTS

- Renewable energy
  - Low cost and light weight solar cell
- Low CO₂ Emission
  - Low BOS costs
  - 1kWh solar power avoids 679g CO₂
- Global
  - ~1.4 billion people are without energy
MARKET WATCH

By 2022...

- $380 million market for barriers for inorganic PV
- Corresponds to 12 million m²
- 32% of total electronic market will be flexible

Source: IDTechEx Barrier Films for flexible Electronics 2012-2022

By 2020...

- Global market forecast for organic devices
  - OPV, OLED, e-paper
- 48% of total organic electronic market will be flexible

NEEDS OF FLEXIBLE ELECTRONICS

Why do we have to protect flexible electronics?

- Electrode materials undergo oxidation very easily
- Active organic layers are sensitive to moisture (water vapour) and oxygen
- Scratch resistance
- UV Stability
- Electrical insulation

Source: Maurer/Unisolar
FRONTSHEET - BARRIER MATERIAL
WHY NOT GLASS?

ADVANTAGES

+ cheap
+ waterproof
+ long shelf life

DISADVANTAGES

- very heavy
- rigid
- fragile
- processability

With **Back- and Frontsheet** lower BOS are possible by cheaper transport cost, less installation time and no need for metal racks.
MAIN DRIVERS FOR FLEXIBLE FRONTSHEET FOR PV

- Lifetime up to 20 years
- Thin and lightweight
- r2r processability
- Barrier against water vapour and oxygen
- Integrable into portable devices
- Special performance e.g. anti-reflection layers

Source: Konarka
Source: Global Solar
Source: Empa
Source: Wikipedia/Mion
Source: Heliatek
BARRIER PROPERTIES

Barrier properties

<table>
<thead>
<tr>
<th>OTR (cm³/m²/bar)</th>
<th>WVTR (g/m²/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10⁻⁶</td>
<td>10⁻⁶</td>
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<tr>
<td>10⁻⁵</td>
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<td>10⁻¹</td>
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<tr>
<td>10⁰</td>
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</table>

Food packaging, technical products

Source: Fraunhofer ISC
DEFINITION WVTR

Definition WVTR (water vapour transmission rate) of 100 to $10^{-6}$ g/m$^2$ d:

Amount of water vapour that permits through a polymer film in the size of a soccer field per month!
HOW TO MEASURE THE WVTR?

• Coulometric method (Keidel)
  • Mocon:  \( \text{WVTR}: 5 \times 10^{-4} \, \text{g/m}^2 \, \text{d} \)
  • \( \text{OTR}: 5 \times 10^{-3} \, \text{cc/m}^2 \, \text{d} \)
  • time: \( \sim 2 \) weeks

• Calcium test
  \[
  2\text{Ca} + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{CaO} + \text{H}_2\text{O}
  \]
  reflective
  conductive
  transparent
  insulating

• HTO test (Tritium test)
  • radioactive!
  • measuring range: \( 10^{-7} \, \text{g/m}^2 \, \text{d} \)
  • time: 30-45 Tage (22°C / 100%)

• time: dependent on barrier performance

\[ \text{two „detection-possibilities“} \]
**TRANSPARENT BARRIER FRONTSHEET - SPECIFICATION**

- WVTR <10^{-4} g/m^2 d for CIGS
- >85% Transmission in the visible range
- Good stability under accelerated test conditions
- Good UV stability
- Low thickness, good adhesion to cell material
- Width: 2100 mm
- Compatibility with various surfaces

**Components:** Polymer-MeOx, Organic Hybrid Polymers, Adhesion layers, anti-weathering layer,...
BARRIER MATERIALS - PET/MeOx SUBSTRATES

Measurements of various PET/MeOx substrates:
Substrates 1-5: PET/SiOx
Substrates 6-9: PET/AlOx

Light Transmission [%]
BARRIER MATERIALS - ELECTRON MICROSCOPY

WVTR: 0.017 g/ m² d
@ 23°C/85% r.h.

WVTR: 0.2 g/ m² d
@ 23°C/85% r.h.
BARRIER MATERIALS - MEOX LAYERS

<table>
<thead>
<tr>
<th>MeOx layers</th>
<th>WVTR [g/m² d]</th>
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<tr>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
</tr>
<tr>
<td>8</td>
<td>0.03</td>
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**BARRIER MATERIAL - ORGANIC HYBRID POLYMER**

**Tortuous Path:**

- **H₂O molecule**
- **Pinhole/defect**
- **organic barrier layer**
- **inorganic barrier oxide**
- **tortuous diffusion path**
- **polymer substrate**

BARRIER MATERIAL - MULTILAYER STACK

Below MOCON detection limit

WVTR [g/m²·d]

PET/SIOx  PET/SIOx/Hybrid

Multilayer stack measured with different methods
BARRIER MATERIAL - MULTILAYER STACK

Mocon detection limit
<5*10^-4 g/m² d

Transmission > 85%
for transparent frontsheets
in visible range

Damp Heat Test (DHT)
85°C / 85% rh
BIPV - ROOFING MEMBRANE

- Barrier material with WVTR <10^{-4} g/m^2 d
- Development of encapsulation material
- r2r production
- New monitoring concept
ORGANIC RADICAL BATTERIES
ORGANIC RADICAL BATTERIES

Ragone Plot

- Faster charge- and discharge behaviour than Li-Ion batteries
- Higher charge density than condensators

Possible use for...

- Sensors
- Packaging (RFID)
- Health Care (detection of blood sugar)
- Smart Cards
**ORGANIC RADICAL BATTERIES**

- fast charge- and discharge behaviour
- flexible devices possible
- wet coating or printing possible
- light weight
- aqueous electrolyte possible

CONCLUSION

- Non-transparent materials for crystalline and thin film applications are available in different color and thickness
- Backsheets with copper for back-contact solar cells are available
- Materials with encapsulant layer are available
- Research on Transparent Barrier Frontsheets shows good results
- Organic Radical Batteries for flexible applications, work in progress
NanoMend aims to pioneer the research & development of in-line, micro & nano-scale defect detection and correction systems on thin-films, which will transform the performance of a range of products including thin-film photovoltaics and fiber-based packaging.

- €7.25million grant funded, 4 year long FP7 project from Jan 2012
- 14 European Partners from Industry and academia
- The Project is being led by the University of Huddersfield
R2R-CIGS aims to develop cost effective processes and technologies for the roll-to-roll production of thin film **flexible** CIGS solar modules in high volumes

- European collaborative project
- Started in April 2012
- Duration 42 months
- info@r2r-cigs.com
AKNOWLEDGEMENT

- All project partners
- Klima und Energiefonds in Kooperation mit FFG (Österreichische Forschungsförderungsgesellschaft)

THANK YOU FOR YOUR ATTENTION!

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