PV Module Material

TOYOBO CO., LTD.
Industrial Films Operating Department

May. 2012
1. Overview of Toyobo
2. Toyobo’s technologies and the development for PV components
3. Proposal of Toyobo products for PV Backsheet components
4. Toyobo’s polymer 「TOYOBO GS Catalyst®」
5. Pet film for PV Backsheet 「SHINEBEAM®」
6. Enhanced EVA adhesion coated Film
7. SHINEBEAM - Milky White type -
8. SHINEBEAM - Transparent type -
9. SHINEBEAM - Cavity White type -
10. Enhanced EVA adhesion coated Film (Black type)
# 1. Toyobo Profile

**Company name:** TOYOBO Co.

**Founded:** 1882

**Employee:** 3,124 (Consolidate 11,181)

## Business

<table>
<thead>
<tr>
<th>Business</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film/Functional resin</td>
<td>Packaging, Industrial, Industrial lamination, Engineering plastics, fine chemicals</td>
</tr>
<tr>
<td>Industrial Material</td>
<td>Automobile fabric, super-fabric, functional filter etc</td>
</tr>
<tr>
<td>Life science</td>
<td>Bio, Pharmaceutical, Medical filter, Medical device, aqua-filer</td>
</tr>
<tr>
<td>Fabric</td>
<td>Functional material, fabric, textile</td>
</tr>
<tr>
<td>Others</td>
<td>Engineering etc</td>
</tr>
</tbody>
</table>
2. TOYOBO Technologies and PV material

TOYOBO Technologies

Resin Technologies
- Properties control technologies
- Catalyst technologies
- Polymerization technologies

Film Technologies
- Film-forming technologies
- Easy-adhesive Coating technologies
- Barrier Coating technologies

PV Backsheet material

Hydrolysis resistant Polyester Film

Enhanced EVA adhesion coated Film

High Barrier PET Film
3. Proposal for PV Backsheet composition

Structure of Photovoltaic Device

- Frame
- Glass
- PV cell
- Lead Frame
- EVA
- Backsheet
- Terminal Box
- Terminal Cable
- EVA Resin
- Weather Proof Film

Alternative Proposal: Backsheet structure

<table>
<thead>
<tr>
<th>Sealing Material (EVA)</th>
<th>Adhesive Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester Film</td>
<td></td>
</tr>
<tr>
<td>Moisture of Barrier (Al·PET)</td>
<td></td>
</tr>
<tr>
<td>Fluoride Film</td>
<td></td>
</tr>
</tbody>
</table>

- Fluoride Film alternation ⇒ 「SHINEBEAM」
- EVA Adhesive improvement ⇒ 「EVA Adhesive PET Film」
- Moisture of Barrier ⇒ 「Ecosyal」

Sealing Material (EVA)

- EVA Adhesive Polyester Film
- High Barrier Polyester Film
- Hydrolysis Resistant Polyester Film

[Image of diagram with labeled components]
Currently, Antimony catalysts represented by Sb2O3 are used for over 95% of polymerization of polyester in the world.

With the rising demands for environmental protection, it will become the subject of regulation.

Need the solution to dispose heavy metals

Thanks to the accumulated technologies of polyester polymerization for over 65 years, Toyobo developed the heavy metal free aluminum catalyst, which is the world’s first breakthrough technology in history.

「TOYOOBO GS Catalyst®」was developed.
## 4. Toyobo’s polymer

### ② Characteristic

<table>
<thead>
<tr>
<th>Type of Resin</th>
<th>Hydrolysis</th>
<th>Thermal oxidation degradability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin using TOYOBO GS Catalyst®</td>
<td>0.021</td>
<td>0.01</td>
</tr>
<tr>
<td>Resin using antimony Catalyst</td>
<td>0.064</td>
<td>0.18</td>
</tr>
<tr>
<td>Testing Condition</td>
<td>130°C × 6hr</td>
<td>230°C × 15 min airborne</td>
</tr>
</tbody>
</table>

GS resin has high hydrolysis resistance and low thermal oxidation degradability.

%BB : “Percent broken bonds of ester bonds” value: the lower, the better

Calculated from the equation, $\% BB (\%) = 0.245(IV_f^{1.47} - IV_{f_i}^{1.47})$

5. TOYOBO Backsheet material

①TOYOBO Hydrolysis Resistant Polyester Film (SHINEBEAM)

SHINEBEAM is PET Film developed for PV that has the following characteristics, which is recommended to be used as Protective Films for the Backsheet of PV Module.

TOYOBO SHINEBEAM
- Hydrolysis resistance is improved dramatically
- Heat life is improved
- No heavy-metal Sb (antimony) content as polymerization
- Transparent and White type
## 6. Enhanced EVA adhesion coated Film

### Conventional Structure (TPT)

- Fluoro Polymer Film (25,38 μm) PVF, PVDF, ETFE
- Normal PET Film (188,250 μm)
- Fluoro Polymer Film (25,38 μm) PVF, PVDF, ETFE

### Proposal Structure

<table>
<thead>
<tr>
<th>Proposal Structure</th>
<th>TOYOBOSHINEBEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Thickness</strong></td>
</tr>
<tr>
<td>Q1A15</td>
<td>50 μm And others</td>
</tr>
<tr>
<td>Q3215</td>
<td>50 μm And others</td>
</tr>
<tr>
<td>Q1215</td>
<td>50 μm And others</td>
</tr>
</tbody>
</table>
6. Enhanced EVA adhesion coated Film

(3) Coating Effect

Creating a sample configuration below.

Measuring the force necessary to peel the layers after endurance test.

<table>
<thead>
<tr>
<th>Surface treatment</th>
<th>Initial</th>
<th>85°C 85%RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1000hr</td>
</tr>
<tr>
<td>non-coat</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Corona treated</td>
<td>60</td>
<td>9</td>
</tr>
<tr>
<td>Adhesion coated</td>
<td>60 over</td>
<td>20 over</td>
</tr>
</tbody>
</table>

* It was impossible to measure.

The test results indicate great effective adhesion durability.
### Proposal Structure

<table>
<thead>
<tr>
<th>Proposal Structure</th>
<th>TOYOCO SHINEBEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
</tr>
<tr>
<td>EVA side</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Conventional Structure (TPT)

- Fluoro Polymer Film (25,38 μm) PVF, PVDF, ETFE
- Normal PET Film (188,250 μm)
- Fluoro Polymer Film (25,38 μm) PVF, PVDF, ETFE
**7. SHINEBEAM - Milky White -**

**TE Retention Rate after UV Test**

![Graph showing TE Retention Rate over Process time](image)

- **Process time (h)**
- **Retention Elongation at break (%)**
- **Q3215-50 μm**
- **General PET**
- **PVF**

**Test condition**
- Irradiation intensity: 1000W/㎡
- Temperature: 65℃/50%RH
- Exposed time: 100hr.
7. SHINEBEAM - Milky White -

Color Change after UV Test ($\Delta b^*$)

Test condition
Irradiation intensity: 1000W/m²
Temperature: 65°C/50%RH
Exposed time: 100hr.
8. SHINEBEAM - Transparent -

**Conventional Structure (TPT)**

- Fluoro Polymer Film (25, 38 μm)
  - PVF, PVDF, ETFE
- Normal PET Film (188, 250 μm)
- Fluoro Polymer Film (25, 38 μm)
  - PVF, PVDF, ETFE

**Proposal Structure**

<table>
<thead>
<tr>
<th>Proposal Structure</th>
<th>TOYOBO SHINEBEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
</tr>
<tr>
<td>Q1215</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2215</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
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</tbody>
</table>
8. SHINEBEAM - Transparent -

Evaluation of backsheet after 85℃ × 85%RH × 3000hr Damp Heat Test

PVF / Normal PET/ PVF

Embrittlement and yellowing

Degradation of general PET laminated with PVF

SHINE BEAM (White) / SHINE BEAM (Transparent)

Holding its structure

No peeling off recognizable

SHINEBEAM represents excellent durability

Modules are assembled and tested at AIST Highly Reliable PV Module Development and Evaluation Consortium.
SHINEBEAM is excellent compared to the fluoropolymer film.
8. Hydrolysis Resistance of SHINEBEAM

Highly Accelerated Stress Test: 121°C 100% Rh

- SHINEBEAM Q1215 (Transparent)
- SHINEBEAM Q2215 (Cavity White)
- SHINEBEAM Q3215 (Milky White)
- General PET
- PVF
- PVDF

Retention of Elongation at break (%) vs. Process Time (hr)
8. Hydrolysis Resistance of SHINEBEAM

Damp Heat Test: 85°C 85%Rh

- SHINEBEAM Q1215 (Transparent)
- SHINEBEAM Q2215 (Cavity White)
- SHINEBEAM Q3215 (Milky White)
- General PET
- PVF
- PVDF

*Q3215 (Milky White Type) is examining.
9. SHINEBEAM - Cavity White type -

Conventional Structure (TPT)

Fluoro Polymer Film (25,38 μm)
PVF, PVDF, ETFE

Normal PET Film (188, 250 μm)

Fluoro Polymer Film (25,38 μm)
PVF, PVDF, ETFE

Proposal Structure

<table>
<thead>
<tr>
<th>Proposal Structure</th>
<th>SHINEBEAM</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Thickness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125,188, 250 μm</td>
</tr>
<tr>
<td>Q1215</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2215</td>
<td>White</td>
<td>125,188, 250 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ToyoBo
(1) Characteristic of SHINEBEAM White

< Sectional drawing >

- Superior Hydrolysis resistance
- Long Heat Life
- Heavy Metal Free (Antimony Free)
- High Reflectivity (Wavelength: 400~1200nm)
- Light Resistance
- High Insulation properties
- Better Die Cut performance

(Thanks to numerous voids contained in the film, SHINEBEAM White offers about 20% better than die cut-ability.)
The reflectance in the infrared domain of SHINEBEAM cavity white is high in a white film.
9. Power performance of SHINEBEAM cavity white type

Evaluation of power performance of polycrystalline silicone single cell module with backsheets varying in reflectance

Reflectance: Black < Semitransparent < TPT < SHINEBEAM cavity white

Output electricity is higher than module with TPT

SHINEBEAM cavity white type: Higher reflectance ⇒ Higher output electricity
Partial discharge test

Maximum permissible system voltage, $U_{sys}$

Tested: TUV Rheinland Japan Ltd. Global Technology Assessment Center
Test spec.: IEC 60664-1:2007 Clause 6.1.3.5
## Lineup and characteristic comparison

<table>
<thead>
<tr>
<th>SHINEBEAM Type</th>
<th>Color</th>
<th>Thickness (μm)</th>
<th>Hydrolysis Resistance</th>
<th>Anti UV</th>
<th>Reflectance</th>
<th>Insulation</th>
<th>Flame class UL94</th>
<th>RTI UL746B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1***</td>
<td>Transparent</td>
<td>50,125, 188,250</td>
<td>◎</td>
<td>△</td>
<td>—</td>
<td>○</td>
<td>VTM-2</td>
<td></td>
</tr>
<tr>
<td>Q2***</td>
<td>White (Cavity)</td>
<td>50,125,250</td>
<td>△</td>
<td>○</td>
<td>◎</td>
<td>◎</td>
<td>—</td>
<td>105°C</td>
</tr>
<tr>
<td>Q3***</td>
<td>Milky white (non-cavity)</td>
<td>50,75, 125,250</td>
<td>◎</td>
<td>◎</td>
<td>△</td>
<td>○</td>
<td>VTM-2</td>
<td>Same as Q1</td>
</tr>
</tbody>
</table>

◎: Excellent  ○: good  △: Standard  ×: Poor
**Characteristic**

- Adhesive property with EVA is GOOD.
- It is possible to produce backsheets with unification color design.
- It improves the generation efficiency for amorphous silicone photovoltaic by a heat storage effect.

**Application**

- TOYOBO PET Film
- EVA adhesive coated layer (black)
- PET Film
- PVF, PVDF, HR-PET etc.
### Enhanced EVA adhesion coated black film “TR809”

**【Property】**

<table>
<thead>
<tr>
<th>Item</th>
<th>TR809</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thickness</strong></td>
<td>μm</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total Light Transmittance</strong></td>
<td>%</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>MPa</td>
<td>179</td>
</tr>
<tr>
<td><strong>Heat Shrinkage</strong></td>
<td>%</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Adhesion Property</strong></td>
<td>N/cm</td>
<td>80 over</td>
</tr>
</tbody>
</table>

*Above data is typical, not guaranteed.
*Adhesion property is not guaranteed for all EVA.