Comparison of TPT and Thermally Conductive Backsheets in PV Modules

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Introduction
- Module temperature plays the second largest role, next to irradiance, in dictating the performance of photovoltaic (PV) modules
- The thermal conducting property of PV module backsheet can have a large impact on the module operating temperatures
- The focus is to compare cell and backsheet temperatures of modules with Tedlar-Polyester-Tedlar (TPT) and four thermally conductive backsheets (TCB) installed at different sites having varied climatic conditions
- In this study, thermal conductivity of backsheets and NOCT of modules with these backsheets ($T_{BS}$) were also measured to compare TCBs and TPT.

Experimental Setup

<table>
<thead>
<tr>
<th>Site</th>
<th>AZ-1 site</th>
<th>AZ-2 site</th>
<th>NC site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather condition</td>
<td>Hot and dry (low wind speed)</td>
<td>Hot and dry (high wind speed)</td>
<td>Temperate</td>
</tr>
</tbody>
</table>

- Glass/EVA/Cell/EVA/Backsheet Modules (20.5" x 22" nine-cell modules)
  - TPT: Tedlar-PET-Tedlar
  - TCB_A: PVDF-PET-EVA
  - TCB_B: PA-Aluminum-PET-PA (polyamide)
  - TCB_C: encapsulant -PET-ECTFE (fluoropolymer)
  - TCB_D: PA- Core layer- E layer (modified polyolefin)
- Identical module installation
- Data analysis (seasonal trends)
  - Fall 2018: September 21st- December 20th
  - Winter 2019: December 21st- March 20th

Results and Discussion

1. Thermal conductivity of backsheets
- All TCBs clearly have higher axial thermal conductivity values as compared to TPT as measured by a thermal-conductivity meter

<table>
<thead>
<tr>
<th>Back sheet manufacturer</th>
<th>Axial Thermal Conductivity (W/m·K)</th>
<th>Radial Thermal Conductivity (W/m·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPT</td>
<td>0.153</td>
<td>0.486</td>
</tr>
<tr>
<td>TCB_A</td>
<td>0.259</td>
<td>0.571</td>
</tr>
<tr>
<td>TCB_B</td>
<td>0.352</td>
<td>13.53</td>
</tr>
<tr>
<td>TCB_C</td>
<td>0.256</td>
<td>0.387</td>
</tr>
<tr>
<td>TCB_D</td>
<td>0.238</td>
<td>0.343</td>
</tr>
</tbody>
</table>

2. Nominal Operating Cell Temperatures (NOCT)
- NOCT represents cell temperature under 800 W/m² irradiance, 20 °C ambient temperature, and 1 m/s wind speed.
- Individual NOCT determined by taking average of NOCT measured on three clear sunny days
- The NOCT of TCB_A is about 2 °C lower than TPT

Fig. 2 NOCT of nine-cell modules with 5 different backsheets (1 TPT and 4 TCBs)

Table 1: Thermal conductivity values measured at 24 °C


3.1 Comparison between 2 TCBs and TPT at different sites

- Fig. 3(a) $\Delta T_{BS}$ (TPT–TCB_C/TCB_D) seasonal trend at 3 sites
- Fig. 3(b) $\Delta T_{cell}$ (TPT–TCB_C/TCB_D) seasonal trend at 3 sites
- Fall and Winter seasons have same $\Delta T_{cell}$ trends with median values about 0.2 °C - 0.5 °C
- $\Delta T_{BS}$ values in Fall > $\Delta T_{BS}$ values in Winter. But Fall and Winter seasons have same $\Delta T_{cell}$ trends.
- $\Delta T_{cell}$ of the actual cell temperature differences between TPT and all TCBs, is higher than $\Delta T_{BS}$ values
- Median $\Delta T_{cell}$ values between TPT and TCB_A is about 2 °C and higher than with any other TCBs

3.2 Comparison between 4 TCBs and TPT at AZ-1 site

- Fig. 4(a) $\Delta T_{BS}$ trends between TPT and 4 TCBs at AZ-1 site
- Fig. 4(b) $\Delta T_{cell}$ trends between TPT and 4 TCBs at AZ-1 site
- $\Delta T_{BS}$ values (Fig. 4) in Fall > $\Delta T_{BS}$ values (Fig. 4) in Winter. But Fall and Winter seasons have same $\Delta T_{cell}$ trends.
- $\Delta T_{cell}$, the actual cell temperature differences between TPT and all TCBs, is higher than $\Delta T_{BS}$ values
- Median $\Delta T_{cell}$ values between TPT and TCB_A are about 2 °C and higher than with any other TCBs

4. Cell-to-cell differences between TPT and TCBs

- (a) TPT
- (b) TCB_C
- (c) TCB_D

- Center cell operates at about 2 °C higher than edge/corner, temperature differences highest in TPT
- TCB-based module maintain more uniform temperature throughout the module compared to TPT

Fig. 5 Histogram of temperatures between center, corner, and edge at AZ-1 site for Fall 2018 (a) TPT (b) TCB_C (c) TCB_D

Conclusions

- The thermal conductivity measurements clearly showed that TCBs have higher axial TC than TPT
- NOCT values of nine-cell modules are lower for TCB than TPT with difference as high as 2 °C in TCB_A
- All TCBs (TCB_A, TCB_B, TCB_C and TCB_D) operate at lower cell temperatures than TPT under hot climatic conditions. Since backsheet temperatures are largely and dynamically affected by wind speed, only TCB_A operates at lower temperature as compared to TPT
- TCB_C and TCB_D nine-cell modules operate at lower cell temperatures than TPT in temperate climates

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