Characterization of Ground Albedo Materials for Bifacial Solar Farms

[1]Fernanda Garcia, [1]Benny Tam, [1]Dr. Jean Lee, [2]James Vance
[1]Materials Engineering Department, California Polytechnic State University, San Luis Obispo, CA
[2]Clearway Energy Group, San Francisco, CA

Introduction

- Bifacial solar cells are of significant importance in the solar energy industry due to their ability to harvest energy from both direct and reflected sunlight, leading to greater electricity production. However, the amount of energy produced from reflected sunlight is highly dependent on the material used on the ground to reflect light since different materials have different albedos.
- Albedo refers to the ratio between the reflected solar radiation and the incident solar radiation, and ranges between 0 and 1. One represents a surface that fully reflects the solar radiation while zero represents a surface that fully absorbs solar radiation.
- Although white surface materials are known to exhibit high albedo, it is hypothesized that silver, mirror-like materials may also be capable of achieving high albedo.

Objective

Determine which of six candidate materials is the best for placing on the ground for use with bifacial solar panels through albedo measurements, accelerated weathering testing (AWT), and tensile testing.

Methods and Materials

Materials

Six candidate materials were investigated:

- White non-reinforced polyethylene with black backing, 6 mil thick (PE)
- White scrim-reinforced polyethylene, 6 mil thick (SR-PE)
- White woven polyethylene 12 mil thick (W-PE)
- White woven polypropylene, ~26 mil thick (PP)
- White road paint with reflective glass beads (RPB). One side of a 10 mil thick gray polyethylene tarp was painted with 1-gallon white road paint, with reflective glass beads sprinkled on while the paint was wet.
- Highly reflective silver Mylar, 2 mil thick (M)

Samples of each of the six candidate materials were prepared for albedo measurements, AWT (i.e., UV exposure), and tensile testing as shown in Figure 1.

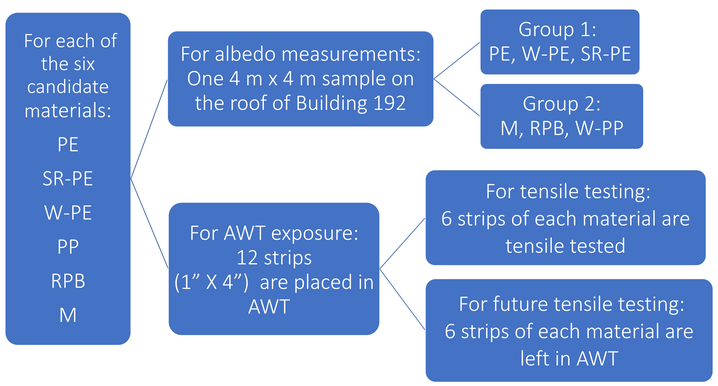

Figure 1. Description of samples made from each of the six candidate materials for albedo measurements, AWT, and tensile testing.

Methods

Albedo Measurements 	Albedo was measured using a Huskeflux SRA01 albedometer following ASTM E1918-21 at solar altitude angles of 20°, 25°, 30°, 35°, and 40°. These solar altitude angles occur twice each day; therefore, one group of three candidate materials (see Figure 1) is measured in the morning and the other group of three candidate materials is measured in the afternoon each day from Tuesday – Thursday over an 8-week period, with Group 1 and Group 2 materials measured in the morning on alternate days. The order in which materials in each group were measured was randomized each week over the 8-week period.
Accelerated Weathering Testing (UV exposure) 	The AWT exposed the samples to UV light for 20 hours a day at 50°C with a 4-hour resting period each day with no UV exposure at 30°C. The samples were checked bi-weekly to identify any damaged or fallen samples. One month in the AWT translates to about 1-4 months of real-time UV exposure. Samples were placed in the AWT for varying amounts of time.
Tensile Testing 	An Instron Micro Series 55MT2 operating at an extension rate of 10 mm/min until sample failure or for 10 minutes was used to assess the samples' physical degradation from UV exposure. Young's modulus (E), yield strength (σ_Y), and maximum tensile strength (σ_{MAX}) data from tensile testing were used to compare the mechanical integrity of the six candidate materials after UV exposure.

Results and Discussion

Albedo values depend on the sample material but are also affected by multiple environmental factors like shade, wind, dew, and dust that lead to albedo variation.

Table 1. Key measured characteristics of each of the six candidate materials.

	PE	SR-PE	W-PE	PP	RPB	M
Average Albedo	0.51±0.067	0.56±0.052	0.57±0.12	0.59±0.070	0.68±0.061	0.66±0.20
Cost ($/m²)	0.938	1.67	1.67	1.08	7.39	1.67
Thickness (mm)	0.14±0.010	0.25±0.010	0.28±0.010	0.28±0.020	0.49±0.39	0.050±0.00
Visible UV Yellowing?	No	No	No	No	No	No

Good Poor

- The RPB tarp has the highest average albedo, followed closely by M.
- Mylar's albedo can be greater than one, which may be due to rippling caused by wind producing a parabola-like mirror effect that can focus light. Reflection from an array of Mylar sheets may produce even higher albedo.
- Prior to moving them, Group 1 samples had higher albedo variations due to shading issues.
- Weather conditions can affect the albedo and contribute to variation. Morning measurements often had overcast skies and sometimes dew, while afternoon measurements had mainly clear skies and no dew. Water on the tarps from dew or precipitation can affect their reflectivity. As noted with Mylar, wind can also affect albedo.
- Greater thickness is desirable, making the material durable and less affected by wind.
- W-PE and M strips became brittle after AWT, with W-PE flaking significantly.
- The PP sample showed significant fraying at its edges.

Results and Discussion (cont'd.)

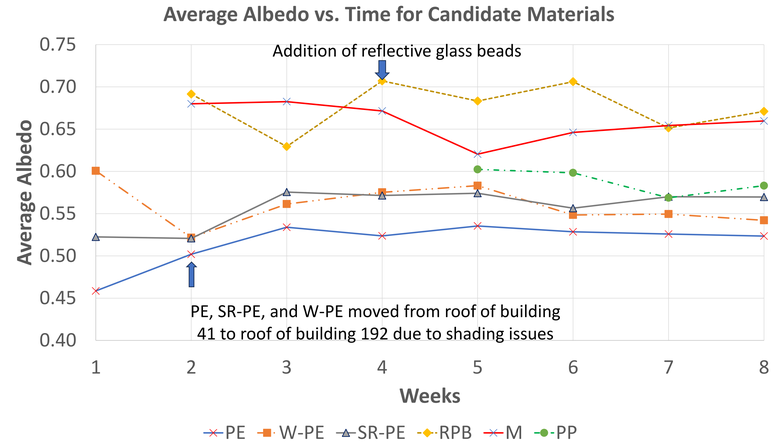

Figure 2. Weekly average albedo for each of the six candidate materials. Actions affecting albedo are indicated.

Table 2. Mechanical properties of the candidate materials.

	PE	SR-PE	W-PE	PP	RPB	M
AWT Duration	17 weeks	17 weeks	17 weeks	2 weeks	3 weeks	4 weeks
Avg. E (GPa) Unexposed	0.20±0.063	0.12±0.036	0.28±0.060	1.1±0.18	0.22±0.0010	5.1±0.11
Avg. E (GPa) UV Exposed	0.21±0.021	0.16±0.017	0.30±0.053	1.0±0.27	0.12±0.0071	4.5±0.90
Avg. σ_Y (MPa) Unexposed	5.3±0.53	3.1±0.20	37±7.7	14±3.1	36±1.2	81±2.8
Avg. σ_Y (MPa) UV Exposed	5.9±0.12	3.7±0.17	5.2±2.1	16±7.5	21±0.49	25±14
Avg. σ_{MAX} (MPa) Unexposed	11±2.6	4.1±0.50	42±9.4	45±4.3	42±1.1	110±12
Avg. σ_{MAX} (MPa) UV Exposed	15±0.97	5.6±0.35	5.5±2.1	46±5.4	25±1.1	25±14

Good Poor

- When considering the effects of UV degradation, M had the most notable decline in mechanical properties. However, M was also the thinnest material.

Conclusions

- Considering the sponsor's requirement of high albedo, we recommend RPB and M. M is the better option of these two when cost is also considered.
- When ease of installation and maintenance is added as a high priority, we also recommend SR-PE as a top choice.
- Due to unacceptable physical degradation over time, W-PE and PP are not recommended.
- Based on promising initial results from M, further testing of more silver, mirror-like materials with a greater thickness is recommended.

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