Durability and efficiency of anti-soiling coatings for primary mirrors

Raiselife Workshop
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Motivation: Soiling

- Traditional CSP sites (e.g. USA & Spain) have good conditions concerning soiling
- Soiling very site dependent
- Potentially more severe at new/future sites (Sahara, Middle East, China)

- Direct influence on optical efficiency of solar field, and thus output, strategies, etc.
- One approach for soiling mitigation: anti-soiling coatings (apart from site selection, cleaning strategies, protection (e.g. fences))
Anti-soiling coatings

- Application of thin transparent layers on front surface of commercial silvered-glass mirrors
  - Reduce soiling adhering to surface
  - “Easy-to-clean” properties
  - Not affecting the optical properties of the base reflector (no absorption or scattering)
  - Maintain properties over lifetime

- Different effects used to realize anti-soiling properties:
  - Hydrophobic (“Lotus” effect)
  - Hydrophilic
  - Photocatalytic
  - Anti-static
Evaluation Techniques

- **Outdoor campaign**, regular *measurements*, cleaning
  - Man power needed,
  - Fixed or adaptable cleaning/measurement frequency
  - Test different cleaning techniques
- **Continuous** outdoor measurements (**TraCS**)
  - Automated system for soiling measurements
- **Outdoor exposure** without regular cleaning/measurements
  - Mainly durability evaluation to outdoor conditions
- **Accelerated aging**, laboratory tests
  - Quick
  - Controlled conditions
  - Be sure to select adequate tests/parameters
Measurement Parameters

- Specular reflectance $\rho_{s,\varphi}$
- Cleanliness $\xi = \frac{\rho_{s,\varphi}}{\rho_{s,\varphi,\text{clean}}}$
- Cleanliness difference/gain
  \[ \Delta\xi = \xi_{AS} - \xi_{\text{uncoated}} \]
- Accumulated cleanliness gain
  \[ \overline{\Delta\xi}(t) = \frac{\int_{t=0}^{t} \Delta\xi \, dt}{\Delta t} \]
Outdoor Campaigns

- 1 for Fla (start 2011, 6 years duration)
- 1<sup>st</sup> Raiselife for Fla
- Wascop
- 2<sup>nd</sup> Raiselife for Fla
First campaign commercial AS coatings

- Start 2011, duration nearly **6 years**
- Different coatings tested, **two coatings** chosen to measure until end
- 2 cleaning frequencies (2&4 weeks)
- Excellent AS behavior in the beginning
- Both coatings **degrade**
- Around **3% reflectance loss** over the exposure period
- **Disadvantage** compared to uncoated after **2-4 years**.


![Graph showing reflectance difference before and after cleaning with Advantage AS1 and AS2 coatings.](image-url)
First Raiselife campaign

- 2 anti-soiling coatings
- 2 cleaning techniques
- 2 years outdoor exposure

First Raiselife campaign

- 2 anti-soiling coatings
- 2 cleaning techniques
- 2 years outdoor exposure
- Different results for different cleaning techniques
- 1 material shows **better AS behavior BUT degrades** (ca. 5% reflectance drop with brush cleaning)

Accumulated cleanliness gain

<table>
<thead>
<tr>
<th>( \Delta \xi ) (2 years)</th>
<th>AS1</th>
<th>AS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 (pressure)</td>
<td>0.008</td>
<td>-0.005</td>
</tr>
<tr>
<td>S2 (brush)</td>
<td>-0.009</td>
<td>0.005</td>
</tr>
</tbody>
</table>

TraCS soiling rate measurements

- Continuous measurements: cleanliness and soiling rate at 2 sites (PSA & Missour)
- 10 months exposure
- AS2 lower, AS1 higher soiling rate than reference (possibly due to degradation)

<table>
<thead>
<tr>
<th>Mirror sample</th>
<th>Average soiling rate [%/day]</th>
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<tbody>
<tr>
<td></td>
<td>PSA</td>
</tr>
<tr>
<td>AS1</td>
<td>-0.424</td>
</tr>
<tr>
<td>AS2</td>
<td>-0.235</td>
</tr>
<tr>
<td>Ref1</td>
<td>-0.362</td>
</tr>
<tr>
<td>Ref2</td>
<td>-0.318</td>
</tr>
</tbody>
</table>

[Wolfertstetter et al, 2019. Parallel soiling measurements for 4 mirror samples during outdoor exposure with TraCS, SolarPACES, Daegu]
**Wascop campaign**

- 1 coating analyzed
- 2 cleaning techniques
- Nearly 2 years of exposure

- No degradation detected
- Around 1% cleanliness gain
- Higher cleanliness gain for pressure water

2nd Raiselife campaign

- 3 coatings
- Campaign running, 10+ months of measurements available
- 1 liquid coating showed very low mechanical stability and was discarded after only few weeks of measurement
- **Cleanliness gain of 1-1.7% with no degradation**
Accelerated aging

- Standard weathering tests recommended:
  - Mainly UV/humidity/temperature
- Special focus on **mechanical tests**
  - Taber abrasion [UNE206016]
  - Washability [ISO11998], brush cleaning
  - Erosion, Sandstorm simulation
Conclusions

• Anti-soiling coatings pose an interesting option for soiling mitigation
  • Overall **cleanliness gain** of 1-3% detected
  • Potentially higher at sites with stronger soiling

• **Durability** is an important issue
  • Mechanical stability?

• Evaluation/ **testing** of coatings prior to application
  • Selection of **testing parameters** based on knowledge of planned installation site and implementation
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Thank you for your attention!