Porous radiative cooling paint for building thermal management

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Porous Polymer Cooling Paint for Buildings

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11-04-2019
Thermal Management is Critical to Buildings

- Various scenarios need cooling (buildings, vehicles, shipping).
- Cooling/refrigeration counts for 20% of energy in buildings.
1-Reflectance (R) = Absorptance = Emissivity (ε)
Passive Daytime Radiative Cooling

Photonic crystal

Ceramic in polymer

\[ R_{\text{solar}} = 0.97 \]
\[ \varepsilon = 0.7 \]

\[ R_{\text{solar}} = 0.96 \]
\[ \varepsilon = 0.93 \]

Radiative Cooling Panels

SkyCool Systems

https://www.technologyreview.com/s/608840/a-material-that-trows-heat-into-space-could-soon-reinvent-air-conditioning/

- Good performance, but sophisticated.
- **Manufacture and use in advanced settings.**

Raman et. al. (Nature, 2017)
Challenges: Cost, Rough Surface

- Rough surface
- Developing countries
- Different shapes
Cooling Paints

- UV/SWIR absorptance.
- Pigment particles too small to reflect large solar wavelengths.
- $R_{\text{solar}} < 0.94$, typically 0.80-0.90
- Still heat up under sunlight.
Learn from Nature

Ice: $R \sim 0.02$
$\varepsilon \sim 0.96$

Snow: $R \sim 0.8-0.9$
$\varepsilon \sim 0.99$

Scattering due to mismatch in $n$
(1.31 vs. 1)

Solar spectrum (0.3-2.5 $\mu$m): no intrinsic absorption

Infrared thermal radiation: strong intrinsic absorption (emissivity)

Broad, random nano/microstructures: efficient scattering for amplification
Radiative Cooling in Porous Polymer

Radiative Cooling in Porous Polymer

Porous PVdF-HFP: \( R \sim 0.96-0.996, \varepsilon \sim 0.97. \)

300 um thickness: \( \sim \$0.4/ft^2 \)
Radiative Cooling in Porous Polymer
Application on Various Substrates

Applicable for most substrates with conformal coating.
# Degradation Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>$\bar{R}<em>{solar} / \bar{c}</em>{LWIR}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerated thermal and wet aging tests</td>
<td>80°C in air, for 14 days.</td>
<td>0.95/0.96</td>
</tr>
<tr>
<td></td>
<td>80°C in a chamber containing water at 100% relative humidity, for 14 days.</td>
<td>0.96/0.95</td>
</tr>
<tr>
<td>Monthlong exposure test under the sky in New York</td>
<td>Location: 40.8101° N, 73.9434° W.</td>
<td>0.94/0.93</td>
</tr>
<tr>
<td></td>
<td>Date: 19 November – 18 December, 2017. Average Temperature ~5°C, average relative humidity ~65%, occasional rain and light snow.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Location: 40.8093° N, 73.9535° W.</td>
<td>0.996/0.97</td>
</tr>
<tr>
<td></td>
<td>Date: 09 August – 17 August, 2018. Average Temperature ~25°C, average relative humidity ~75%, occasional rain.</td>
<td></td>
</tr>
</tbody>
</table>

Third party test: (1000 hrs of QUV exposure): TSR from 0.96 to 0.89.
Application and Addition of Color

52% of sunlight

50% change in NIR/SWIR corresponds to 5-10 °C cooling under wind.
Acknowledgement

Collaborator:
Long-qing Chen (PSU)
Wei Min (Columbia)
Colin Nuckolls (Columbia)
Xavier Roy (Columbia)
Xianghui Xiao (BNL)
Lu Wei (Columbia, Caltech)
Nanfang Yu (Columbia)
Cewen Nan (Tsinghua)
Hua Zhou (APS)

Master students

Questions?