High-Performance Solar Thermal Energy Conversion with Dry Cooling

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Solar Power Generation: Optical Concentration

Large-Scale CSP

Light Absorption
Vapor Generation
Condensation &
Dry Air Cooling

100-MW Shams-1 Concentrated Solar Power Plant in Abu Dhabi


Saving ~200 million gallons water/year
Solar Steam Generation: Thermal Concentration

Floating solar receiver for steam generation @ 1 Sun

G. Chen (MIT) & T.J. Zhang (Masdar Inst.)

Light Absorption → Vapor Generation → Condensation → “Water” Cooling

Enhanced light absorption
(1) Gap plasmon; (2) Destructive interference

**Light Absorption: Nanocomposite Absorbers**

- Additional Ag deposition on cermet absorption
- Ag deposition on SiO$_2$-coated Ag layer

![Diagram of nanocomposite layer](image)

- Ag-SiO$_2$ (37 nm) on Ag (43 nm)
- SiO$_2$ (100 nm)
- Ag (100 nm)

**Absorption Analysis**

- (a) Absorptance (%)
- (b) Absorptance (%)
- (c) SEM image of 100 nm Ag layer
- (d) SEM image of 100 nm Ag layer
- (e) Absorptance (%)

**Additional Notes**

- High FF ~ 60%; Low FF ~ 30%
- 10nm Silver Nanoparticles

**References**

To combine the strong interference in ultrathin Ge film absorber with localized surface plasmons around Au nanopores

Bilayer ultrathin film system (Ge 20nm onto Au 150nm)

- FDTD simulation results
- Visible absorption enhancement
- Radius of holes $\leq$ 100nm
- Good option for solar evaporation

T.J. Zhang (Masdar Inst.) & N. X. Fang (MIT)
Light Absorption: Nanoporous Absorber Fab.

[ Laser interference with Lloyd mirror ]

(Laser interference lithography + E-beam evaporation)

Averaged solar absorptance over 89.3%

UV-Vis-NIR Spectrophotometer

Vapor Generation: Microstructured Surfaces


E.N. Wang (MIT) & T.J. Zhang (Masdar Inst.)
Development of a dry-out heat flux model for vapor generation

- Capture the meniscus along the wicking distance
- Capture the coupled fluid flow, pressure and interface

T.J. Zhang (Masdar Inst.) & E.N. Wang (MIT)

Vapor Generation: Thin Liquid Film Evaporation

- W.L. Yang, H.X. Li, ..., T.J. Zhang, “Prediction of Thin Liquid Film Evaporation Characteristics with a Thermal Lattice Boltzmann Method”, ITherm2016, Las Vegas.

E.N. Wang (MIT) & T.J. Zhang (Masdar Institute)
Superhydrophobic microporous surfaces for Jumping Droplet-enhanced Condensation

Nanostructured micro-mesh surface morphologies

Condensation on porous (left) & flat surfaces (right)

Faster growth of droplets on microporous surfaces:
1) Only in upward direction; 2) Larger solid contact area;
3) Lower temperature on base than on wire

Quantum Simulation of Surface Wettability

First-Principles Prediction of Contact Angle

\[
\cos(\theta) = \frac{U_{SL} - U_{LV}/2}{U_{LV}/2}
\]

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**Earth’s Energy Budget**

iac.ethz.ch

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**High-Performance Compact Solar Thermal Power and Cooling Systems**

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Profs. Evelyn Wang, Gang Chen, Nicholas X. Fang (Massachusetts Institute of Technology, MIT)  
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**Transient Characterization and Energy Harvesting of Shams-1 Concentrating Solar Power Plant**  
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