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Superwicking Black Metal Surface for Solar-Thermal Water Sanitation

RESEARCHERS

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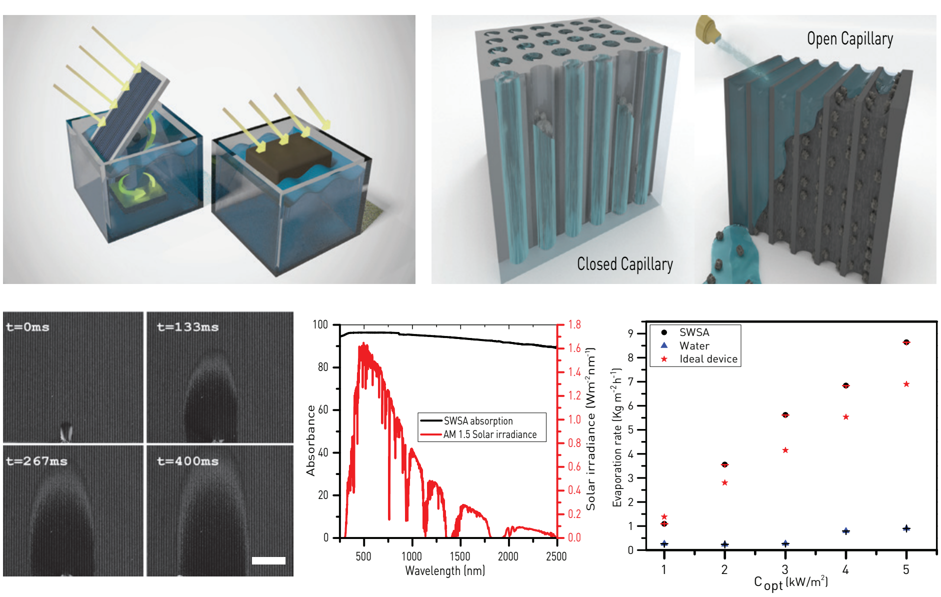
The combined effects of climate change, population increase and inadequate wastewater management have fueled a global water crisis. Wastewater recycling could be part of an environmentally feasible solution. In a recent work, we made a push toward that end, introducing a super-wicking, super-light-absorbing (SWSA) solar trackable panel for water sanitation.[1]

As it does with natural rain, solar energy can make wastewater drinkable. Traditional solar water-evaporation systems, however, suffer from severe thermal losses. Recently, an interfacial evaporation approach was developed, whereby solar-thermal heat generation and water evaporation occur at the same surface.[2] However, such evaporators require a solar absorber with a wicking surface. Most previously developed solar absorber surfaces, however, are geometrically constrained by their out-of-plane and closed microcapillary architectures.[2,3] That means that, to wick water, these evaporators must float on the water surface horizontally, and are thus unable to track the sun to optimize available solar irradiance.[3] As a result, the efficiency of these evaporators significantly decreases when the sun is at larger zenith angles.

In the system we developed,[1] a shiny piece of aluminum is turned pitch black and made superwicking through femtosecond laser processing.[4] The resulting SWSA surface has, on average, around 97% absorption, and water runs uphill on the vertically mounted surface with high speed. Moreover, the interaction of water molecules with the surface changes its intermolecular bonding, resulting in a significant reduction in the enthalpy of vaporization.

Combining all of these features, we demonstrated high-efficiency solar-thermal generation of water vapor, with an evaporation rate exceeding that of an ideal device operating at 100% efficiency. In contrast to most previous, closed-microcapillary-based absorbers, our SWSA surface has an array of open microcapillaries parallel to the surface that supports a high rate of water transport on the panel mounted at any angle. The SWSA surface can thus be integrated with commercial trackable solar-thermal technologies to increase the total available solar flux for efficient vapor generation. We also demonstrated a bifacial SWSA panel that had an efficiency 150% greater than a single-sided SWSA.

Because of its open-capillary architecture, the SWSA surface can be easily cleaned and reused, requiring low maintenance. Our experiments showed that the SWSA-based device can be used to purify water from a range of contaminants, with contaminant levels in the purified water well below WHO and EPA standards for safe, drinkable water. OPN



Top: Comparison of solar-tracked and flat evaporators (left) and of closed- versus open-microcapillary architectures. Bottom: Water-wicking dynamics at vertically mounted SWSA surface (left); SWSA absorbance and AM1.5 solar irradiance (center); and evaporation rates from the SWSA surface, an ideal device, and bulk water at different optical concentrations (right).