Graphene oxide film for efficient solar desalination under one sun with a confined 2D water path

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With the support by the National Natural Science Foundation of China and the State Key Program for Basic Research of China, the research team led by Prof. Zhu Jia (朱嘉) at the National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Nanjing University, improved the efficiency of solar desalination using graphene oxide film through suppressing the conduction loss, which was published in *PNAS* (2016, 113(49): 13953—13958).

As water scarcity becomes one of most pressing global challenges of our time, efficient solar desalination could provide a promising solution to produce clean water directly out of solar energy without extra energy input, particularly urgent for developing countries and remote areas without basic infrastructures. However, the efficiency of traditional solar still is about 40% mainly due to large heat loss.

In most if not all of previous designs, the absorbers are always in direct contact with bulk water (as shown in Fig. A) that the absorbed solar energy can be efficiently transferred to bulk water to generate vapors. However, even with advanced heat localization designs with all of the other parasitic heat loss minimized, bulk water itself (with thermal conductivity around 0.5 W/mK) becomes an intrinsic and dominant thermal conduction path. For all of these direct water contact designs, high efficiency can only be achieved with the assistance of optical concentrators and/or thermal insulation, as the heat loss through bulk water can only be minimized under these rather strict conditions. Efficient solar steam generation under normal one-sun illumination without extra thermal or optical supporting systems will fundamentally improve the scalability and feasibility of this technology.

Here, enabled by a confined two-dimensional (2D) water path, the absorber (graphene oxide film) is not in direct contact with bulk water. Instead, they are physically separated by a thermal insulator (a polystyrene foam, thermal conductivity of ~0.04 W/mK) to ensure much suppressed parasitic heat loss (Fig. B, zoom-in). A 2D water path is enabled by a thin layer of cellulose wrapped over the surface of the thermal insulator. Because the entire structure can float naturally on the surface of water, with only the bottom side of cellulose in direct contact with bulk water, an efficient water supply to the absorber on the top surface can be enabled by a 2D surface water path within the cellulose pumped by capillary force. Different from "bulk water supply," because of reduced dimensionality of the water path, the heat dissipation through water will be minimized (Fig. B).

Therefore, through this elegant design of a 2D water path, efficient water supply and minimized heat loss are achieved simultaneously. An efficient (80% under one-sun illumination) and effective (four orders salinity decrement) solar desalination device is demonstrated. More strikingly, because of minimized heat loss from the absorber to bulk water, high efficiency of solar desalination is independent of the water quantity and can be maintained without thermal insulation of the container. A foldable graphene oxide film, fabricated by a scalable process, serves as efficient solar absorbers (>94%), vapor channels, and thermal insulators. With unique structure designs fabricated by scalable processes and high and stable efficiency achieved under normal solar illumination independent of water quantity without any external supporting systems, our device represents a concrete step for solar desalination to emerge as a complementary portable and personalized clean water solution.

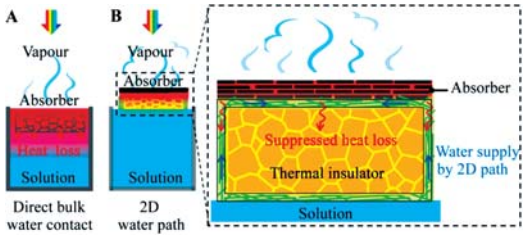

Figure (a) Schematics of conventional solar steam generation with direct water contact; (b) schematics of solar desalination devices with suppressed heat loss and 2D water supply.