MATERIALS SCIENCE

Artificial transpiration: an efficient means of waste-water treatment

Ming Zhou and Zongfu Yu*

Efficient solar vapor generation has been attracting a lot of attention for its potential in various applications, such as desalination, sterilization and chemical purification with a minimal carbon footprint. Tremendous progress has been achieved with materials designs for photon [1–3] and thermal management [4–6]. However, with those improvements, losses related to convection and conduction start to dominate. For this reason, it becomes essential to minimize losses related to radiation, convection and conduction simultaneously for optimal solar steam performance and widespread application. So far, high solar-to-heat conversion efficiency (~80%) can only be achieved by using complicated structures [1].

In an article published in the *National Science Review*, the Zhu group from Nanjing University demonstrated a new concept: 'artificial transpiration.' The method, inspired by the transpiration processes of trees, uses a 3D hollow-cone structure based on graphene oxide film (black hollow cone in Fig. 1) [7]. In this unique 3D artificial

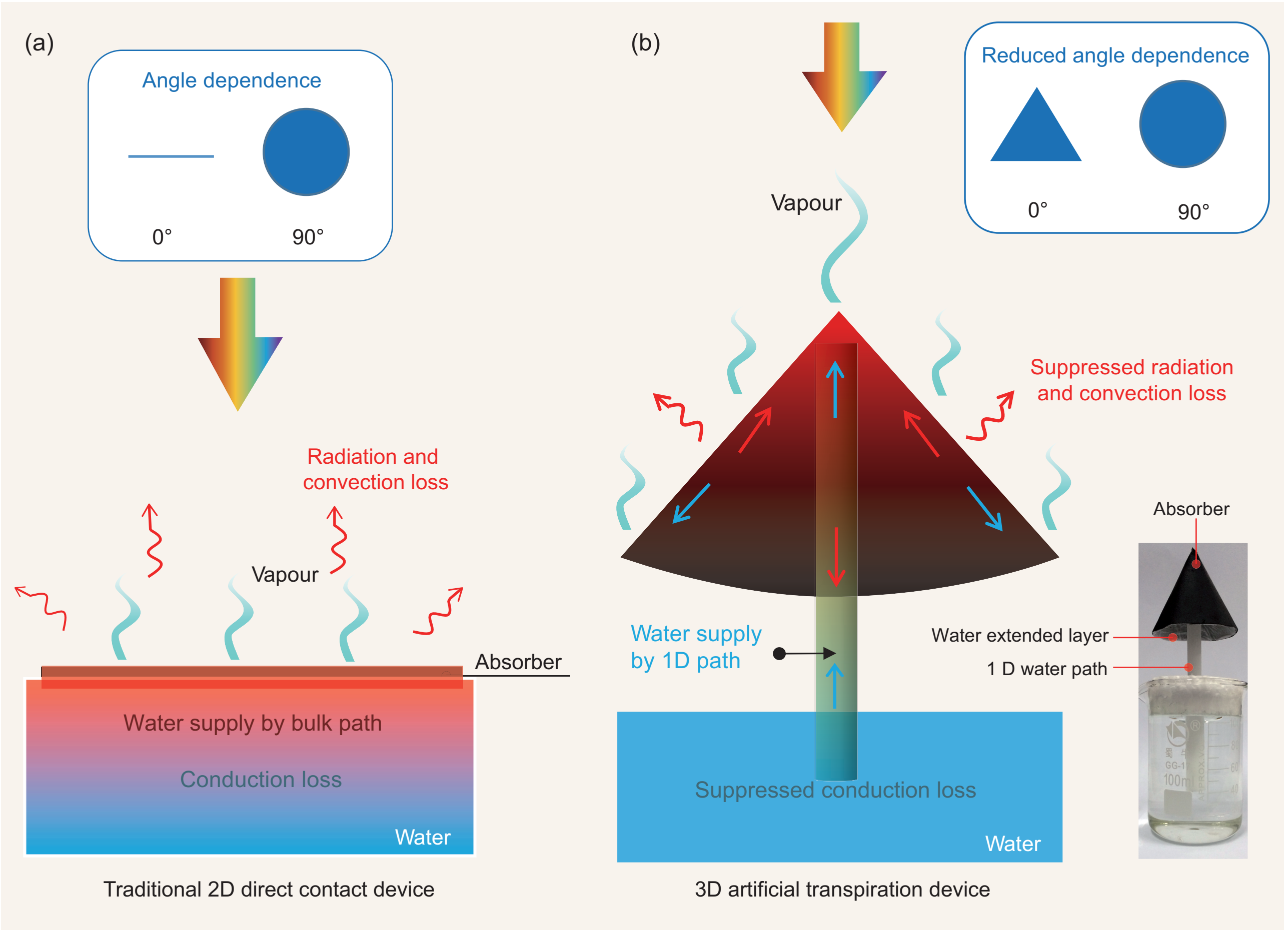

Figure 1. Schematics of different solar steam generators reported by Zhu *et al.* (a) Traditional 2D direct contact. (b) 3D artificial transpiration device; the red straight and blue arrows represent the direction of heat conduction and water supply, respectively, while the red wavy arrows represent the direction of heat convection and radiation. Adapted from [7].

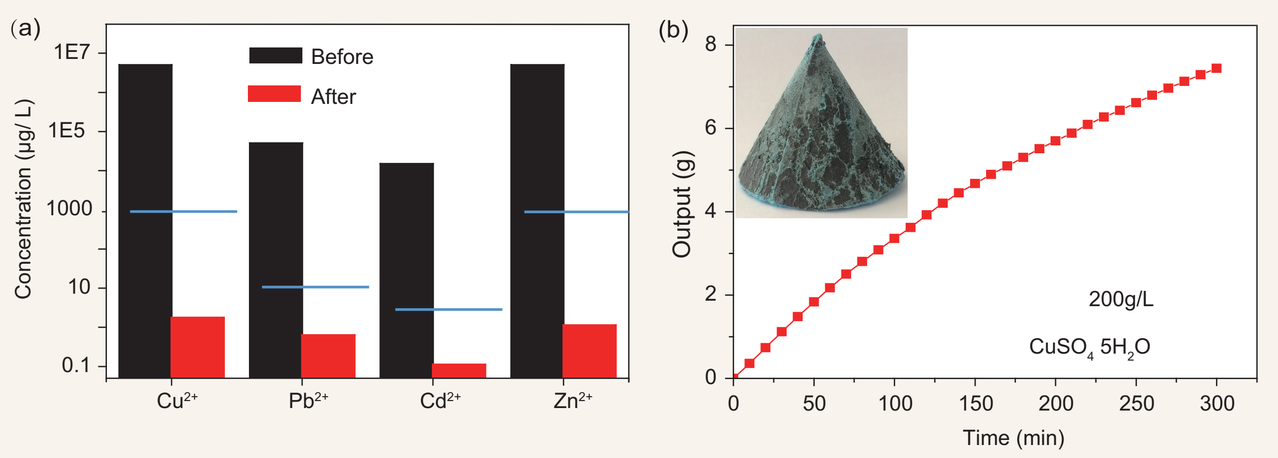

Figure 2. The performance of solar waste-water treatment reported by Zhu and colleagues. (a) Concentrations of different heavy metal ions before and after treatment. The blue colored lines represent the WHO's drinkable water standards. (b) Output of purified water over irradiation time; inset, an optical image of an absorber with recovered $CuSO_4 \cdot 5H_2O$ crystal after 5 h of irradiation. Adapted from [7].

transpiration device, conduction loss was suppressed by designing a 1D water path. The radiation and convection losses were also suppressed by increasing the surface area of evaporation. As a result, this artificial transpiration device enables over 85% solar-to-heat efficiency under one sun irradiation.

Another feature of this 3D structure is the ability to collect more sunlight throughout the day compared with a 2D flat horizontal device—about 24% more—because around 10–50% of sunlight is diffusive. Thus it performs even better in the real world than in the laboratory. The total evaporation rate of the 3D artificial transpiration device is 2.52× higher than that of the 2D direct contact device. Zhu's group first applied this structure to the solar waste-water treatment, which includes two pathways, producing clean water (as shown in Fig. 2a) and recycling heavy metals such as copper and cadmium (as shown in Fig. 2b).

Overall, this approach opens up many new possibilities to harvest and utilize solar thermal energy. In the future, the structure can be further optimized to recycle more heavy metals and increase the device life time. As new challenges arise in optimizing the device's performance, a research frontier for solar thermal energy conversion is emerging.

Ming Zhou and Zongfu Yu*
Department of Electrical and Computer Engineering, University of Wisconsin—Madison, USA
***Corresponding author.**
E-mail: zyu54@wisc.edu

REFERENCES

1. Zhou L, Tan YL and Wang JY *et al. Nat Photon* 2016; **10**: 393–8.
2. Bae K, Kang G and Cho SK *et al. Nat Commun* 2015; **6**: 10103 1–9.
3. Neuman O, Ferontic C and Neumannc AD *et al. Proc Natl Acad Sci USA* 2013; **110**: 11677–81.
4. Ghasemi H, Ni G and Marconnet AM *et al. Nat Commun* 2014; **5**: 44491–7.
5. Li XQ, Xu WC and Tang MY *et al. Proc Natl Acad Sci USA* 2016; **113**: 13953–8.
6. Ni G, Li G and Boriskina SV *et al. Nat Energy* 2016; **1**: 16126.
7. Li XQ, Lin RX and Ni G *et al. Natl Sci Rev* 2018; **1**: 70–7.

National Science Review
5: 120–121, 2018
doi: 10.1093/nsr/nwx088
Advance access publication 2 August 2017