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EDITORIAL

EcoMat FUNCTIONAL MATERIALS FOR GREEN ENERGY AND ENVIRONMENT WILEY

Solar thermal energy conversion and utilization—New research horizon

Solar energy is abundantly present in most parts of the world where there are human activities. The vast abundance and inexhaustibility of solar energy, when coupled with low carbon footprint of its utilization in comparison to fossil fuels, makes solar energy a very compelling energy source in solving our grand challenges especially in the contemporary context of global warming. Studies have projected life-cycle emissions from solar power to be 4–12 gCO_2eq/kWh, which is in a sharp contrast to 400–1000 gCO_2eq/kWh of fossil fuels.

Recent rise of solar thermal energy conversion and utilization is fueled by the re-emergency and also by our recognition of the importance of many low-grade heat driven processes and is exemplified by an almost exponential growth of research efforts on the photothermal material-assisted solar thermal based water evaporation and distillation in the past 8 years. Satisfactory photothermal materials, when combined with proper structural design, are able to effectively capture light and efficiently convert light energy to heat. Various photothermal materials with strong absorbance in the entire solar spectrum (250–2500 nm) have been intensively investigated in the past, including carbon-based materials, metals, metal oxides, and polymers. The absorbed light induces an electric field inside the crystals of the photothermal materials, which in turn drives mobile carries to generate heat. In comparison to light absorption, the light-to-heat conversion performance of most photothermal materials receives much less attention, not due to the lack of efforts but to the fact that most photothermal materials possess very high light-to-heat efficiency. As a matter of fact, the past research efforts have pushed the solar photothermal conversion efficiency close to the theoretical limit in many reported works.

The generated solar heat has been utilized to many kinds of exciting applications, such as clean water production by advanced solar distillation, solar electricity generation, atmospheric water harvesting (AWH), and so forth. For instance, for both solar distillation and solar powered AWH processes, they need not any moving parts, electronic devices, and high-pressure operations, which make them low-cost and attractive especially for decentralized freshwater production from unconventional water sources for point-of-consumption (POC). Thanks to the development in photothermal materials/structures and advanced heat loss management strategies, the energy efficiency of solar evaporation and distillation has been drastically improved, leading to some unprecedented clean water production rates being reported in small-scale solar distillation devices.

However, like all other renewable energy (e.g., hydropower, wind, geothermal energy, bioenergy), solar energy has its own inherent shortcoming: limited and fluctuated power. It is therefore understandable that the complaint against solar energy is often for its low areal energy intensity in addition to its intermittency, which necessitates the use of large land areas in any form of its utilization. While solar irradiance of 1000 W/m^2 is used as a typical standard the real solar irradiance is typically below this value, varying significantly within daily cycle and affected considerably by local weather conditions.

Therefore, there are always well-justified reasons to further improve the energy efficiency of any solar energy utilization process. From solar thermal energy conversion and utilization perspective, heat management and waste energy recycling are currently among the most pursued strategies. On the other hand, the applications of many solar thermal conversion processes are still at an infant stage and there are significant barriers standing between the *status quo* and large scale and practical applications, which call for efforts to investigate the practical issues, such as material cost and stability and longevity of the operation. Last but not the least, identifying new and niche applications for the painstakingly generated solar heat that maximizes its value and that outperforms its conventional counterparts is a new research horizon.

With this general background, we are pleased to present to you this special issue on Solar Thermal Energy Conversion and Utilization, which assembles 8 research articles and 4 reviews. These papers cover topics from the effective and/or low-cost photothermal functional materials/structures (Alketbi, S. et al.; Wang, Y. et al.; Guo, S. et al.; Hu, Y. et al.; Singh and Guo) to advanced and forward looking applications: autonomous solar ocean farm (Guo, S. et al.), freshwater production from soil moisture (Zhang, M. et al.), volatile organic compound (VOC) removal during solar distillation (M, J. et al.), photothermal hydrogen production (Zhang, T. et al.), solar-driven soil decontamination (Wu, P. et al.), stable solar evaporation of brine (Kunjaram, U. et al.), brine treatment with controlled salt excretion (Xia, Y. et al.), and solar receivers for concentrated solar power generation (Nie, F. et al.). It is our sincere hope that this special issue can be of help to our readers for them to gasp the latest developments in the field and it would inspire more passions in them to devote themselves to this important endeavor.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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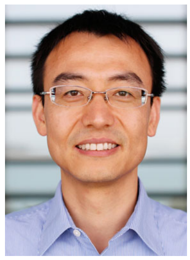

Peng Wang is a faculty member at The Hong Kong Polytechnic University and King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. His research interest is in advanced technologies for sustainable water-energy-food nexus. He has published three academic books and more than 110 peer-reviewed papers in prestigious journals, including *Nature Sustainability, Nature Communications, Joule, Energy and Environmental Science, ES&T, JACS, Angew Chemie*, and so forth. Dr. Wang obtained his bachelor in Environmental Science at Nanjing University, received his MS from Sun-Yat Sen University, and PhD from University of California, Santa Barbara (UCSB). He joined KAUST in 2009 as a founding faculty member and was the program chair of Environmental Science and Engineering at KAUST from 2013 to 2017. He currently serves as a member of Advisory Committee to Water Supply of Hong Kong. Dr. Wang is the Fellow of Royal Society of Chemistry (FRSC). He received "Distinguished Alumni Award" from Zijin Quanxing Environmental Foundation of Nanjing University in 2021. He was the recipient of the 9th Prince Sultan bin Abdulaziz International Prize for Water (PSIPW) in the category of alternative water resources (2020). He received the Nanova Frontier Research Award from the Chinese-American Professors in Environmental Engineering and Science (CAPEES) in 2020. He serves as an Executive Editor and Associate Editor of *Environmental Science & Technology* (ES&T).

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