Tech Science Press

ICCES, 2024, vol.29, no.2
DOI: 10.32604/icces.2024.011736

PROCEEDINGS

Ultrafast Self-Transport of Multi-Scale Droplets Driven by Laplace Pressure Difference and Capillary Suction

Fujian Zhang[1], Ziyang Wang[1], Xiang Gao[1] and Zhongqiang Zhang[1,*]

[1]School of Mechanical Engineering, Jiangsu University, Zhenjiang, 212013, China

[*]Corresponding Author: Zhongqiang Zhang. Email: zhangzq@ujs.edu.cn

ABSTRACT

Spontaneous droplet transport has broad application prospects in fields such as water collection and microfluidic chips. Despite extensive research in this area, droplet self-transport is still limited by issues such as slow transport velocity, short distance, and poor integrity. Here, a novel cross-hatch textured cone (CHTC) with multistage microchannels and circular grooves is proposed to realize ultrafast directional long-distance self-transport of multi-scale droplets. The CHTC triggers two modes of fluid transport: Droplet transport by Laplace pressure difference and capillary suction pressure-induced fluid transfer in microchannels on cone surfaces. By leveraging the coupling effect of the cone curvature gradient and microchannel gradient, the maximum transport velocity of the droplet can reach 208.6 mm/s driven by Laplace pressure difference, which is four to tens of thousands of times that of natural or biomimetic structures with single curvature gradient. Intriguingly, the microchannel ensures that the residual water layer and the water droplet detained on the CHTC due to the surface adhesion effect, pinning effect, or gravity can still be spontaneously transported to the base of the CHTC, thereby realizing the transport integrity of droplet. The residual water layer in different microchannels is connected through circular grooves, enabling its transport across the ridges into the adjacent microchannels and improving transport efficiency. Through the calculation of the internal pressure difference between the droplets on the base and detained on the middle of CHTC, the driving force responsible for the self-transport of both detained water droplet and residual water layer is elucidated, and a theoretical formula among suction pressure, CHTC parameters, droplet parameters, and the tilt angle is established. Importantly, the fog collection efficiency of the CHTC is about twice as high as the cone without microchannels due to the dual-mode water transport. These findings will open the door to achieving long-distance directional ultrafast self-transport of droplets and will provide tremendous inspiration for the design of water harvesting apparatus.

KEYWORDS

Cross-hatch textured cone; gradient microchannel; droplet self-transport; capillary suction; water collection

Funding Statement: This work was supported by the National Natural Science Foundation of China (NSFC) with Grants (Nos. 12272151, 52005222), and the Major Program of NSFC for Basic Theory and Key Technology of Tri-Co Robots (No. 92248301).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.