Tech Science Press

ICCES, 2024, vol.32, no.2
DOI: 10.32604/icces.2024.013398

PROCEEDINGS

3D Printing of Bioinspired Capillary Transistors

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ABSTRACT

Inspired by the unidirectional liquid spreading on *Nepenthes* peristome, *Araucaria* leaf, butterfly wings, *etc.*, various microfluidic devices have been developed for water collection, irrigation, physical/chemical reaction, and oil–water separation [1-3]. Despite extensive progress, most natural and artificial structures fail to enhance the Laplace pressure difference or capillary force, thus suffering from a low unidirectional capillary height (< 30 mm). In this work, asymmetric re-entrant structures with long overhangs and connected forward/lateral microchannels are fabricated by three-dimensional (3D) printing, resulting in a significantly increased unidirectional capillary height of 102.3 mm for water, which approximately corresponds to the theoretical limit [4]. The overhangs can partially overlap the forward microchannels of the front structures without direct contact, thus enhancing the Laplace pressure difference and capillary force simultaneously. Based on the asymmetric and symmetric re-entrant structures, capillary transistors are proposed and designed to function as switches/valves and amplifiers/attenuators for microfluidic chips, enabling programmable adjustment of the capillary direction, height, and width in 3D space. As unprecedented open microfluidic devices, the capillary transistors provide a novel strategy for complex flow patterns and wetting, high-efficiency transpiration cooling, and advanced biochemical microreaction.

KEYWORDS

Re-entrant structure; unidirectional liquid spreading; microfluidics; 3D printing; capillary transistor

Funding Statement: K.Z. and M.G. acknowledge the financial support from the Singapore Centre for 3D Printing (SC3DP) and the National Research Foundation, Prime Minister's Office, Singapore under its Medium-Sized Centre funding scheme.

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

References

1. Li, C., Dai, H., Gao, C., Wang, T., Dong, Z., Jiang, L. (2019). Bioinspired inner microstructured tube controlled capillary rise. *Proceedings of the National Academy of Sciences, 116(26),* 12704-12709.
2. Feng, S., Zhu, P., Zheng, H., Zhan, H., Chen, C., Li, J., Wang, L., Yao, X., Liu, Y., Wang, Z. (2021). Three-dimensional capillary ratchet-induced liquid directional steering. *Science, 373(6561),* 1344-1348.
3. Liu, X., Li, B., Gu, Z., Zhou, K. (2023). 4D Printing of Butterfly Scale–Inspired Structures for Wide-Angle Directional Liquid Transport. *Small, 19(34),* 2207640.
4. Liu, X., Gao, M., Li, B., Liu, R., Chong, Z., Gu, Z., Zhou, K. (2024). Bioinspired capillary transistors. *Advanced Materials, 36(41),* 2310797.