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# Supporting Information

## Microdroplet self-driven transport on the surface with bionic coupled cone-gradient groove

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Table 1: Calculation results under different cone angles

| cone angles (°) | $F_L$(mN) | $F_c$(mN) | resultant force F(mN) | Transport speed(mm/s) |
|---|---|---|---|---|
| 7 | 6.8 | -0.2 | 6.6 | 4.8 |
| 9 | 8.7 | -0.2 | 8.5 | 9.8 |
| 11 | 10.6 | -0.2 | 10.4 | 21.4 |
| 13 | 12.5 | -0.2 | 12.3 | 8.5 |
| 15 | 14.5 | -0.2 | 14.3 | 5.8 |

According to the calculation results and experimental data in Table 1, when the cone angle is small ($\alpha < 11°$) the Laplace force ($F_l$) and the capillary force ($F_c$) increase as $\alpha$ increases. When $\alpha$ is small, the resultant force of $F_l$ and $F_c$ is relatively small and cannot effectively overcome the gravitational force ($F_G$) and the resistive forces ($F_H$ and $F_D$), resulting in a low transportation speed (4.8 mm/s). When the cone angle is large ($\alpha > 11°$), although the resultant force continues to increase, an excessively large cone angle leads to a significant reduction in the effective length ($L_0$) covered by the oil droplet. The oil droplet only makes partial contact with the surface of the structure, and thus the Laplace force and the capillary force cannot be fully activated (mechanism shown in Figure 2e).

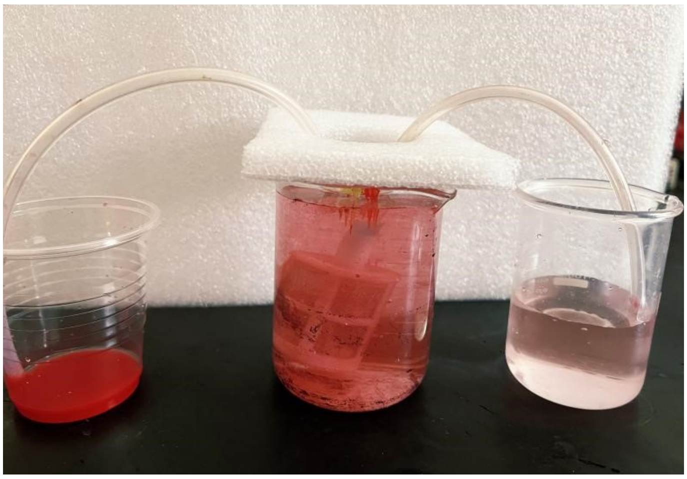

Figure S1 Schematic diagram of the experimental setup for the oil-water separation experiment in which the BCGG array collects micro oil droplets.

Annotation:(Figure S1. Schematic illustration of the experimental setup. During the schematic design, certain details of the sealing connection between the suction pump and the 2-BCGG array were omitted to emphasize the core components of the experimental process. This simplification may result in temporary ingress of dyed oil into the water phase, leading to a faint red appearance in the separated water phase. It is explicitly noted that in actual experiments, the water phase remains clear due to the integration of a microporous filter membrane (pore size: 0.22 μm) and optimized sealing protocols.)

The schematic diagram of the experimental setup for the underwater self-driven oil collection device is shown in Figure S1. The 2-BCGG array unit is integrally formed using a 3D printing device. This geometric configuration can effectively guide the oil droplets to converge towards the top of the device, reducing fluid resistance and enhancing the transportation efficiency simultaneously. The 2-BCGG material, after special surface treatment, possesses the characteristics of superoleophilicity and underwater superhydrophobicity. Once the oil-water mixture enters the device, the oil droplets can penetrate the water film and adhere to the surface of the micro-nano array structure of the 2-BCGG. Then, under the combined action of gravity and capillary force, the oil droplets spontaneously migrate upwards. A miniature oil suction pump is equipped in the device to extract the collected oil droplets through negative pressure and transport the oil to an external oil storage tank via an oil delivery pipe. Additionally, a miniature water suction pump is installed in the device to pump out the water after the separation of oil droplets to an external water storage tank.