Electronic Supplementary Information (SI) for Lab on a Chip.

Supplementary Materials

Dual-mode droplet rolling strategy: Mimicking Earth's rotation and revolution for dual-cycle synergy in the efficient capture and controlled release of trace targets

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Supplementary Figures:

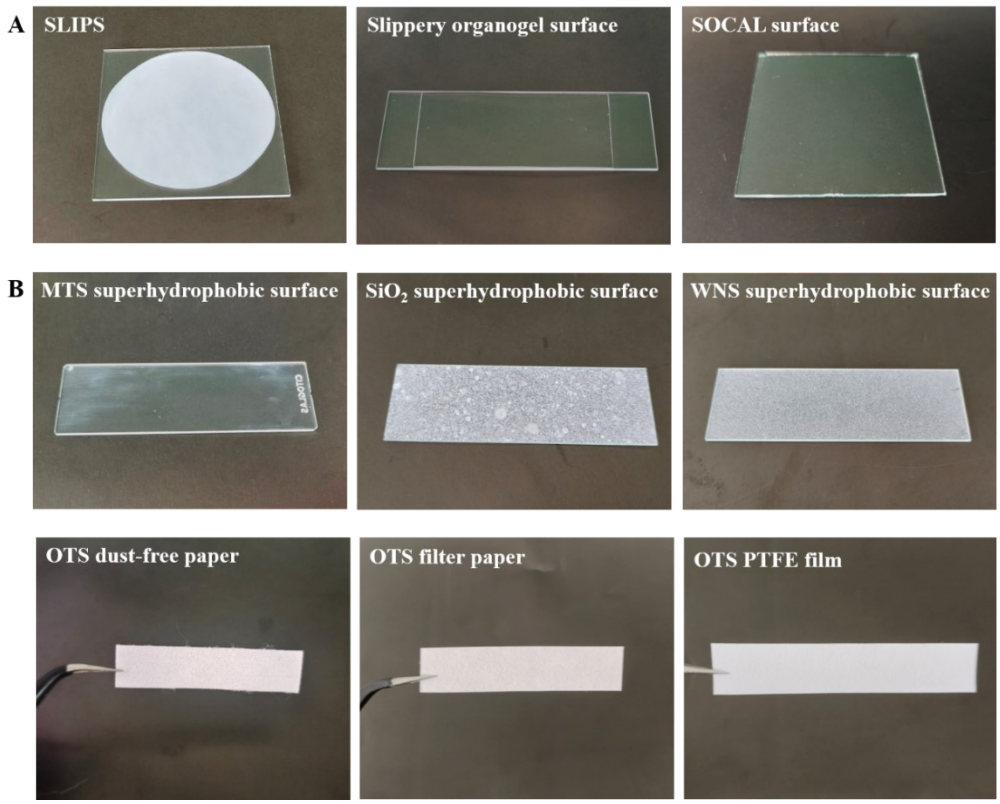

Figure S1. Exploration of different superslippery and superhydrophobic surfaces. (A) Visual representations of slippery liquid-infused porous surface (SLIPS), slippery organogel surface, and slippery omniphobic covalently attached liquids (SOCAL) surface. Among these, the SOCAL surface has been chosen as the target superslippery region, since it can be directly fabricated on a glass substrate, which ensures superior compatibility with superhydrophobic surfaces. (B) Photographs of superhydrophobic surfaces fabricated with methyltrichlorosilane (MTS), SiO_2, WNS, and octadecyltrichlorosilane (OTS). After a comprehensive evaluation considering factors such as compatibility with superslippery surfaces and no debris shedding, the OTS superhydrophobic coating has been identified as the optimal superhydrophobic region. The polytetrafluoroethylene (PTFE) membrane has been selected as the base material for OTS preparation, attributable to its large pore size (0.1 μm) and ultra-thin thickness of 150 μm.

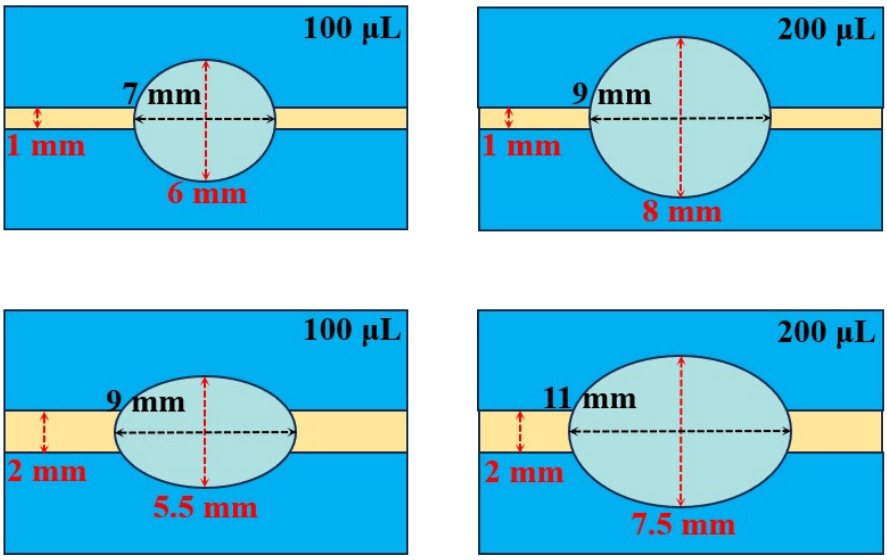

Figure S2. Contact area of droplets with different volumes on composite orbits under varying parameter combinations. To ensure that droplets retain rolling rather than sliding along the tracks and to prevent the droplets from derailing under slight impacts, a relationship is established between the track width and droplet volume. Specifically, for a track width of 1 mm, the droplet volume is set to 100 µL, while for a track width of 2 mm, the droplet volume is set to 200 µL. In this study, we primarily selected a track width of 2 mm with a droplet volume of 200 µL for the experiments.

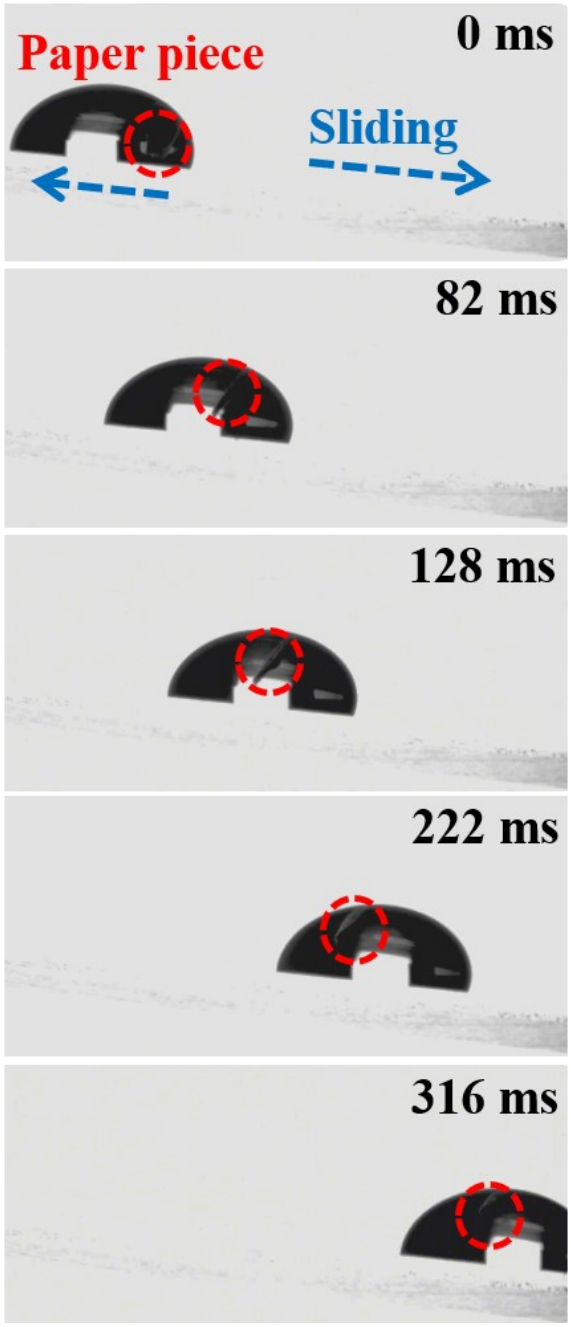

Figure S3. Images of a paper piece suspended in a droplet marking the sliding behavior of the droplet on superslippery surfaces as a control. The blue straight arrow indicates the sliding direction of the droplet, and the blue curved arrow suggests the movement direction of the paper piece within the droplet.

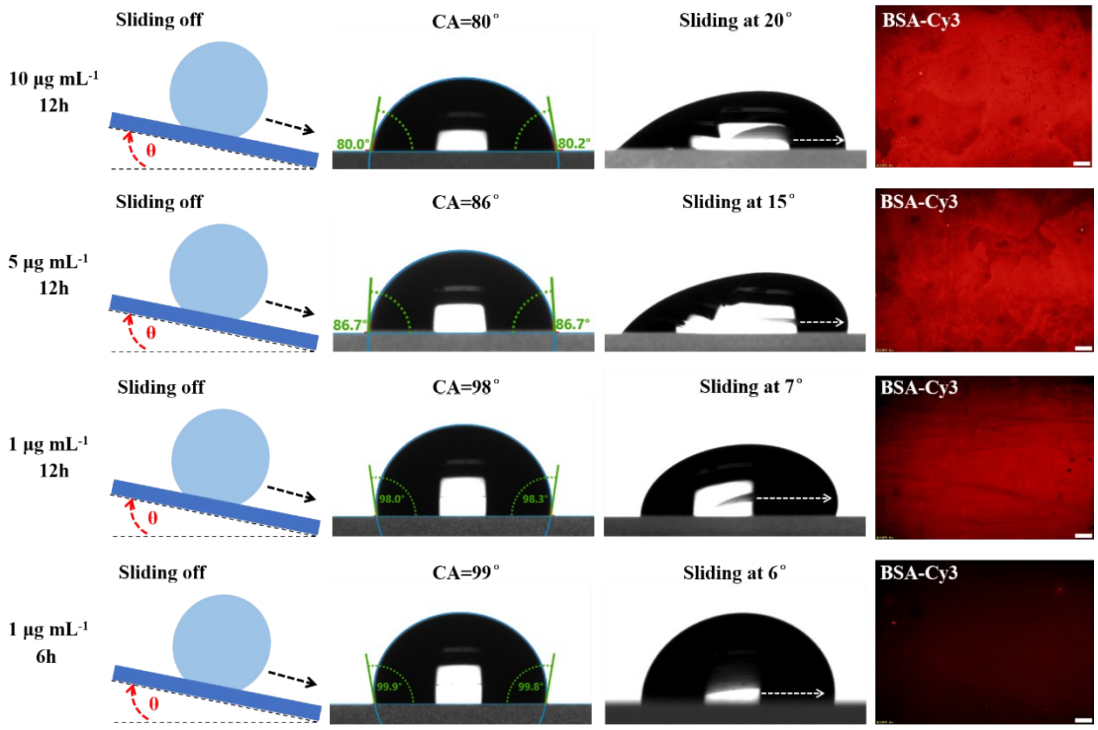

Figure S4. Static contact angles, sliding angles, and fluorescence images of surfaces modified with Cy3 labeled BSA (BSA-Cy3) are presented. In the process of surface modification, to conjugate BSA-biotin efficiently on the superslippery surfaces while maintaining their original slipperiness to the greatest extent, an optimal concentration of 1 μg mL^{-1} was selected for BSA-biotin, with an incubation time of 12 h. All scale bars represent 100 μm.

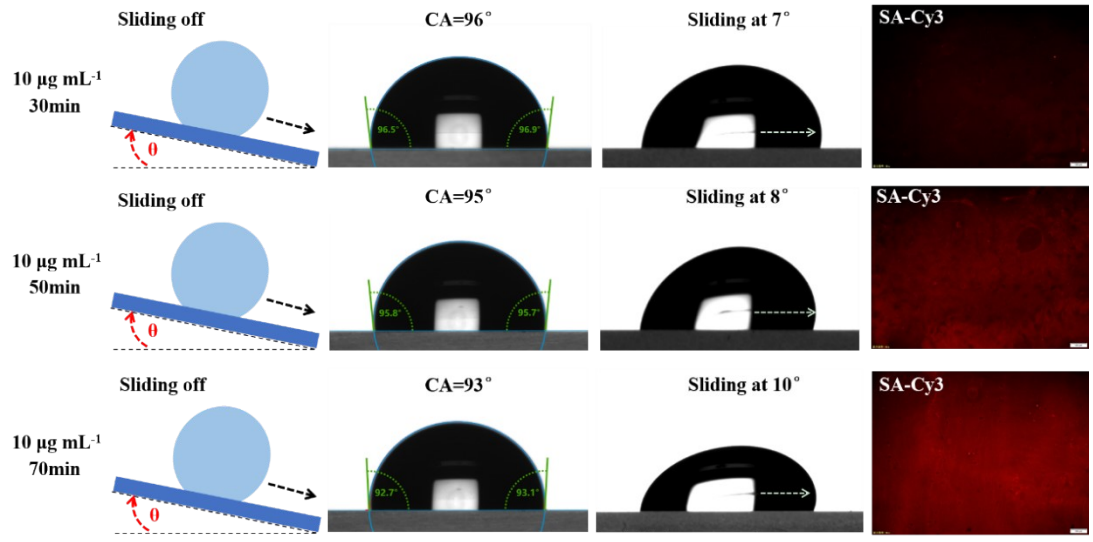

Figure S5. Static contact angles, sliding angles, and fluorescence images of surfaces modified with Cy3 labeled streptavidin (SA-Cy3) are shown. The optimal concentration of streptavidin was determined to be 10 μg mL^{-1}, and the modification time was set to 50 min to effectively connect streptavidin to the BSA-biotin-modified surfaces while minimally affecting their original slipperiness. All scale bars represent 100 μm.

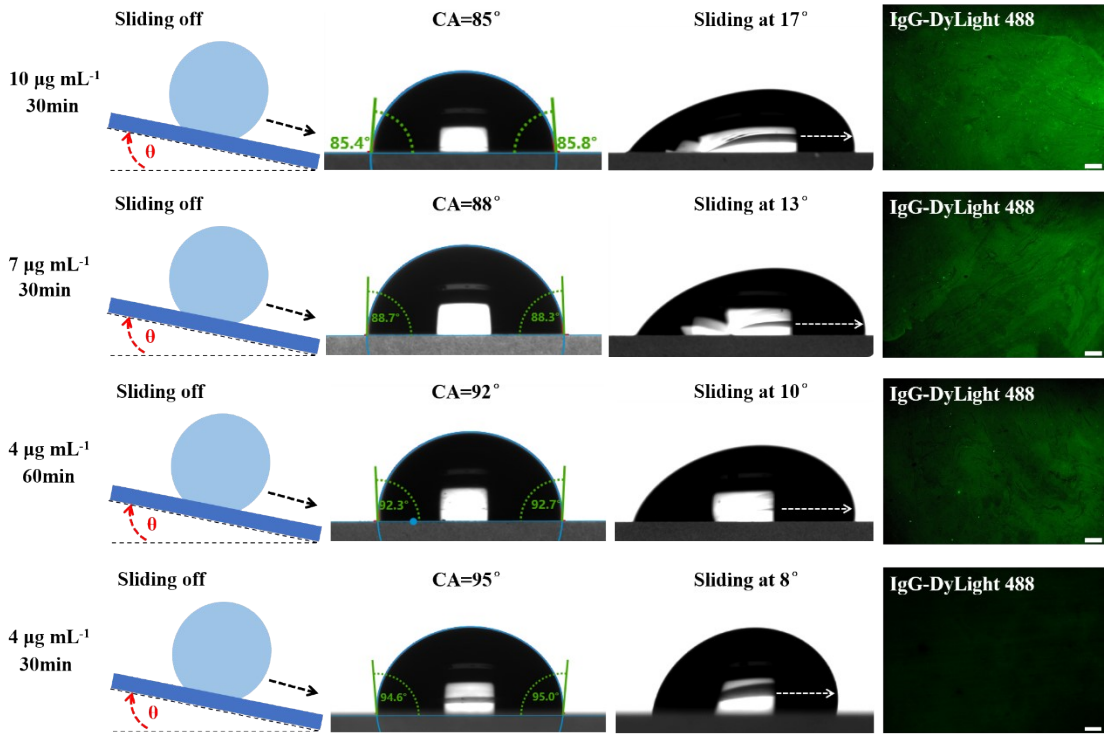

Figure S6. Static contact angles and sliding angles of biotinylated antibody-modified surfaces, and fluorescence images of surfaces modified with biotinylated antibody and DyLight 488-labeled secondary antibody (IgG-DyLight 488), are presented. When the usage concentration of biotinylated antibody was determined to be 4 μg mL^{-1}, and the time was set to 60 min, biotinylated antibody uniformly connected to the streptavidin-modified surfaces with minimal disruption to their original slipperiness. All scale bars represent 100 μm.

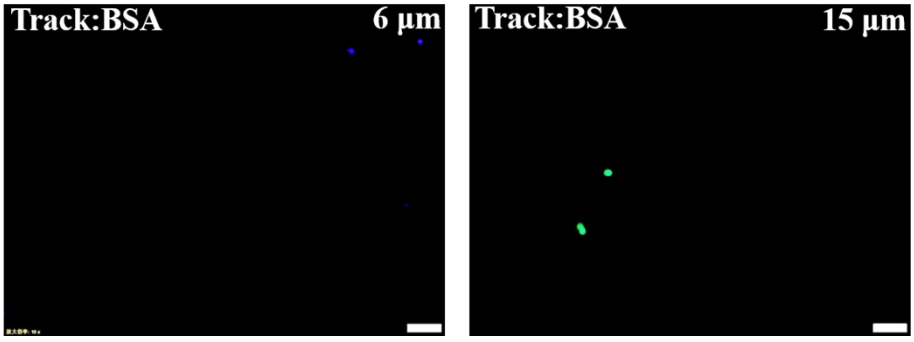

Figure S7. Fluorescence images of the captured SA-PS microspheres of 6 μm and 15 μm on the BSA-modified chips are presented, serving as a control. All scale bars represent 100 μm.

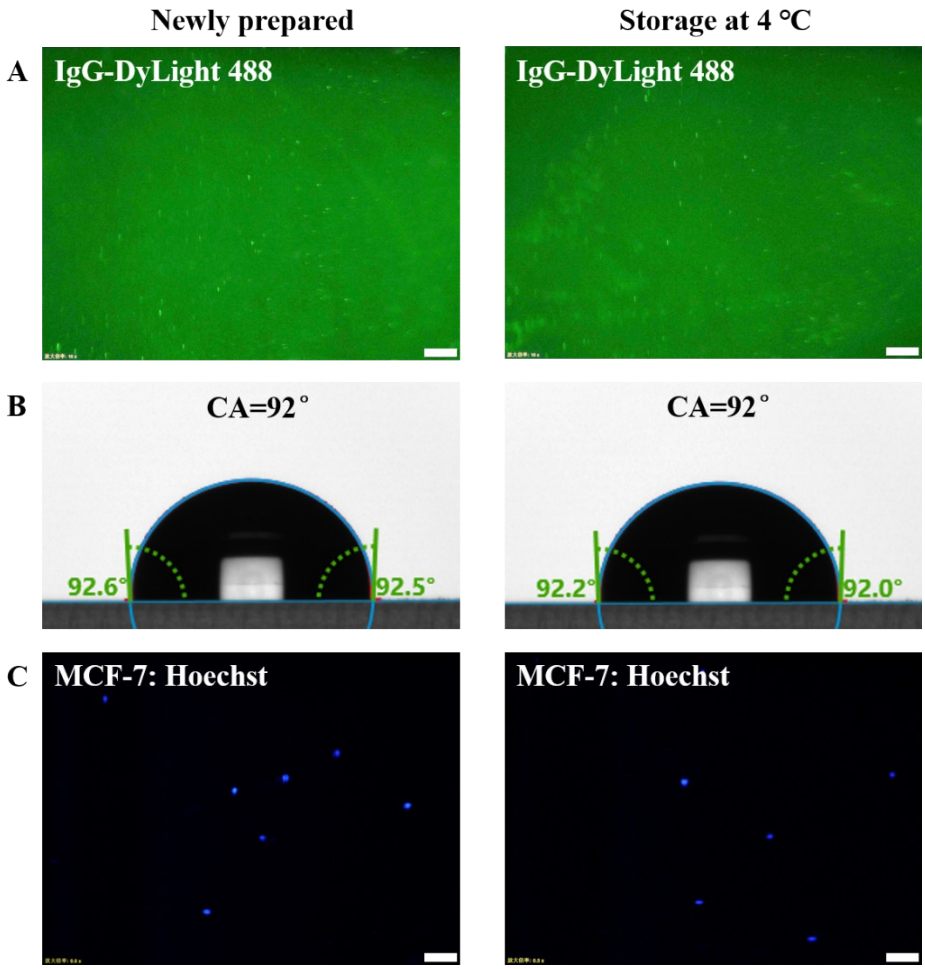

Figure S8. Long-term stability of droplet microchips. (A) Fluorescence images illustrating the surface modification with antibodies on newly fabricated functionalized droplet microchips compared to those stored at 4° C for 30 days. (B) Static contact angle measurements on the surfaces of newly fabricated functionalized droplet microchips and those stored at 4° C, indicating the hydrophobicity changes over time. (C) Fluorescence images depicting MCF-7 cells captured by newly fabricated functionalized droplet microchips and those stored at 4° C, highlighting the preservation of surface functionality and cell capture capability. All scale bars represent 100 μm.

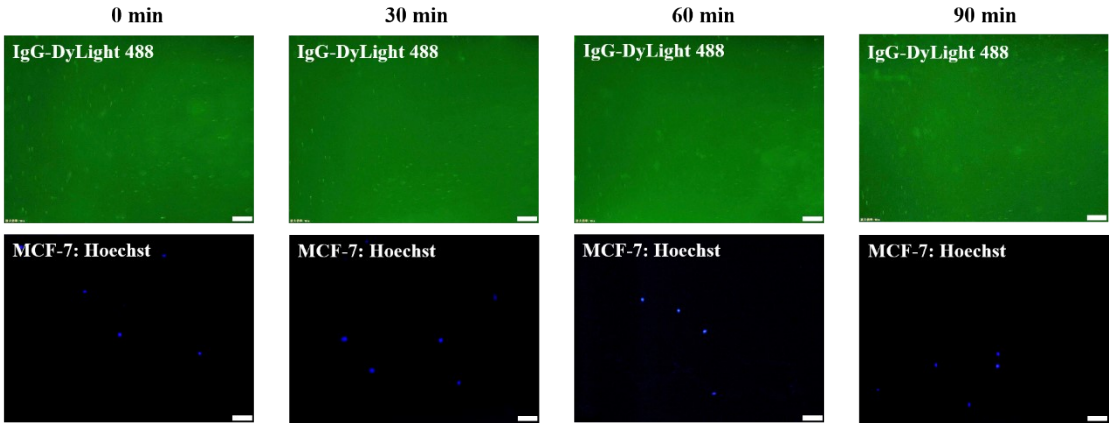

Figure S9. Repeatability of droplet microchips. Antibody modification effect and captured MCF-7 cells of functionalized surfaces treated with PBS droplets under varying rolling times. All scale bars represent 100 μm.

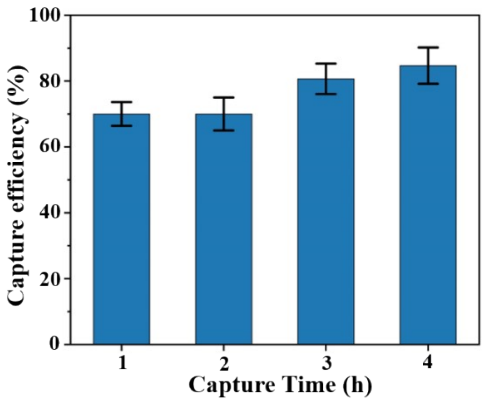

Figure S10. Optimization of *Escherichia coli* (*E. coli*) capture time using a droplet-based microchip. Considering both the capture efficiency and viability of *E. coli* comprehensively, the capture time was selected to be 3 hours.

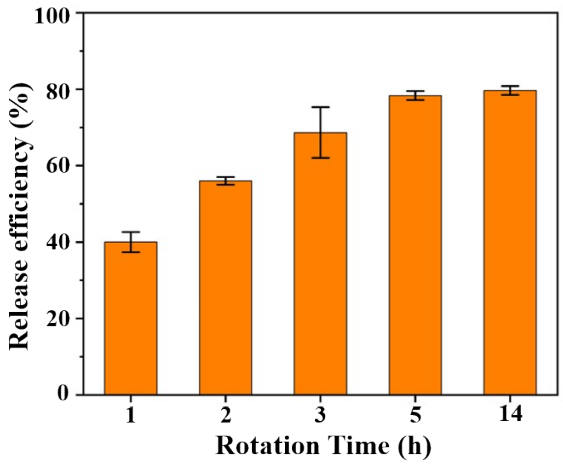

Figure S11. Release efficiencies of different rotation time of biotin droplets for *E. coli*. Taking into comprehensive consideration the release efficiency and viability of *E. coli*, a rotation time of 5 h was selected.

Supplementary Movies:

Supplementary Movie S1(.mp4). Demonstration of the infinite loop circling of the droplet on patterned superhydrophobic surfaces under the consistent mechanical drive. (1X)

Supplementary Movie S2(.mp4). Visualization of the dynamic behavior of a paper piece suspended in a droplet during its movement on inclined line-patterned superwetting surfaces. (0.02X)

Supplementary Movie S3(.mp4). Comparison of superslippery surfaces. Visualization of the dynamic behavior of a paper piece suspended in a droplet during its movement on inclined superslippery surfaces. (0.1X)