Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary Information

Anisotropic Sliding on Dual-Rail Hydrophilic Tracks

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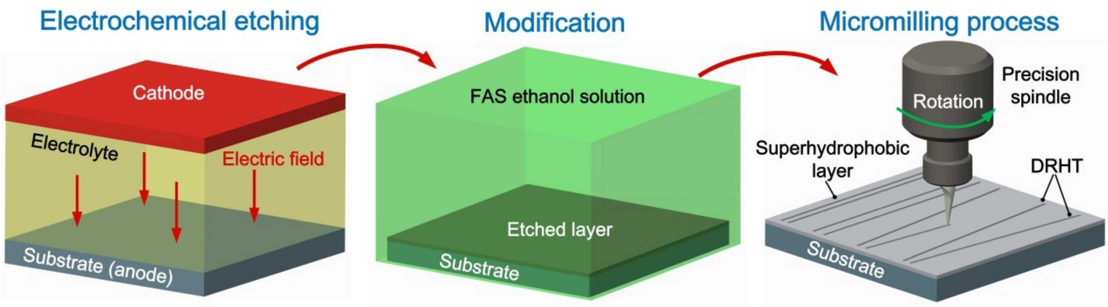

Fig. S1.
Schematic illustration of fabrication of dual-rail hydrophilic tracks (DRHTs) on superhydrophobic substrates. The polished Al was firstly electrochemical-etched in NaCl solution and then modified in FAS ethanol solution to obtain superhydrophobicity. Micromilling process was finally applied to directly mill smooth gooves on the superhydrophobic surfaces. The milled smooth tracks show hydrophilicity due to lack of micro structures.

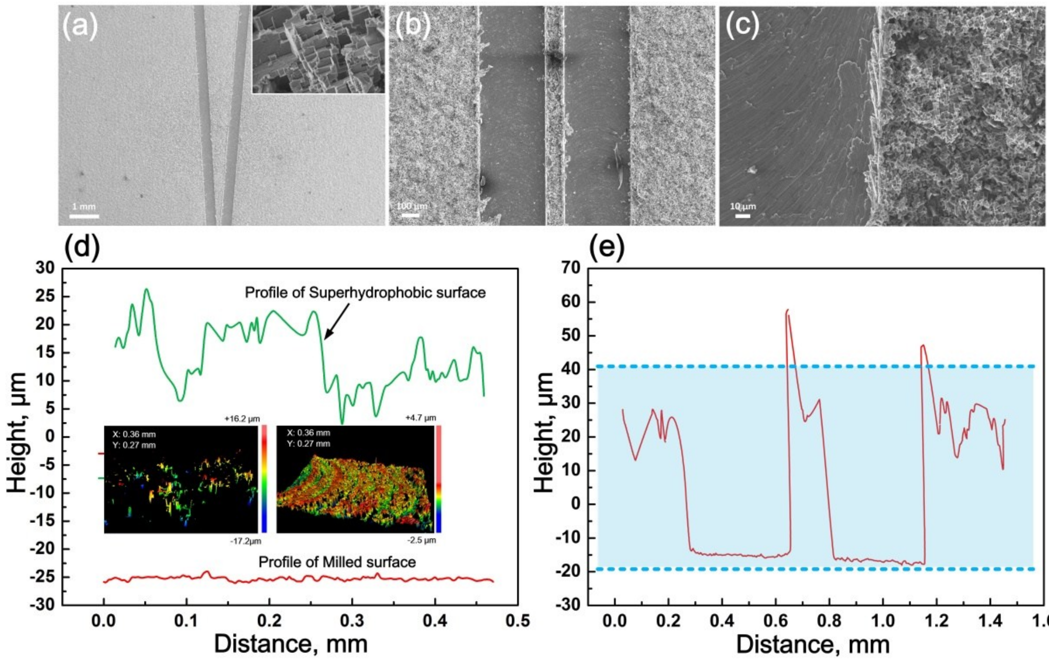

Fig. S2.
Morphology characterization of the fabricated DRHTs. SEM images of (a) narrowing DRHTs with a branch angle of 6°, (b) parallel DRHTs with spacing of 0.5 mm and (c) boundary between the milled and superhydrophobic areas; Inset in (a) is magnified SEM image of the superhydrophobic area; Those images display that the essential superhydrophobic microstructures were completely removed by the rotary milling cutters, leaving a very smooth groove track behind. The tracks have a width of ~400 μm, and boundaries between the milled track and the etched areas are clear and distinct. (d) Surface profiles of the superhydrophobic surface and the milled surface. Insets in Fig. S2d are 3D models of the superhydrophobic area (the left) and the milled area (the right); surface profile data shows that roughness of the milled surface is ~Ra 0.29 μm, which is much lower than that ~Ra 3.88 μm of the superhydrophobic area. (e) Cross-sectional profile of the parallel DRHTs with spacing of 0.5 mm. The cross-sectional profile demonstrates that the height of the milled tracks is ~60 μm, which is consistent with the cutting depth.

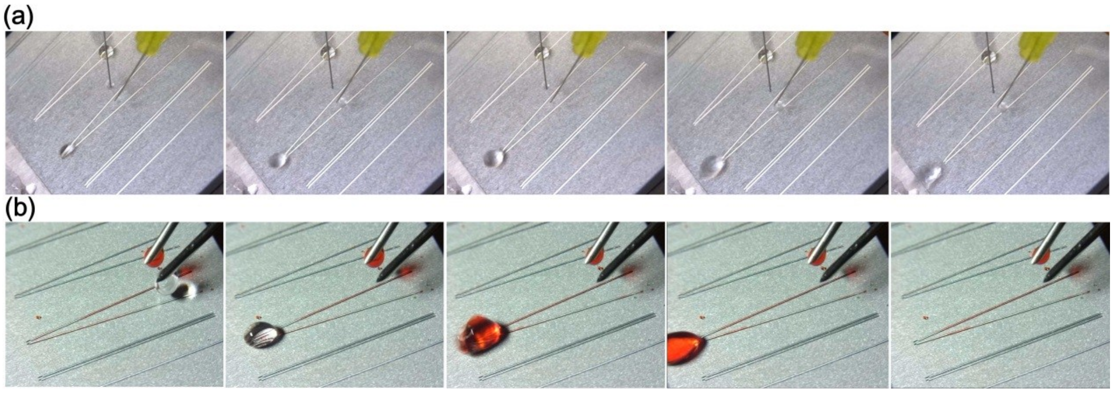

Fig. S3.

Droplet volume range that spontaneously mixing & detaching process works for. By inclining the substrate at specific angles, this function can work for droplets with different volumes. (a) When the substrate was inclined at 32°, minimum 4 μL droplets which were alternately released from the two needles were transported and pinned at the narrowing tail end of the narrowing DRHTs system. After four droplets, the mixed droplet finally detached from the tracks. (b) When the substrate was inclined at 8°, two 40 μL droplets could also be transported and mixed on the same track system.

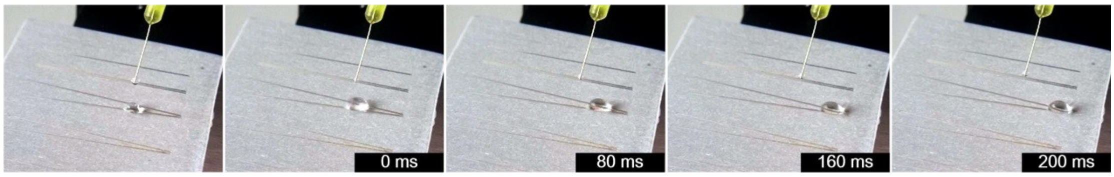

Fig. S4.

Minimum droplet volume that mixing-triggered spontaneously droplet transport process works for. Two 4 μL droplets were released on each of the tracks at a position close to the narrowing tail end. The transport process happened immediately after the mixing process without delay. The whole process takes only ~200 ms.

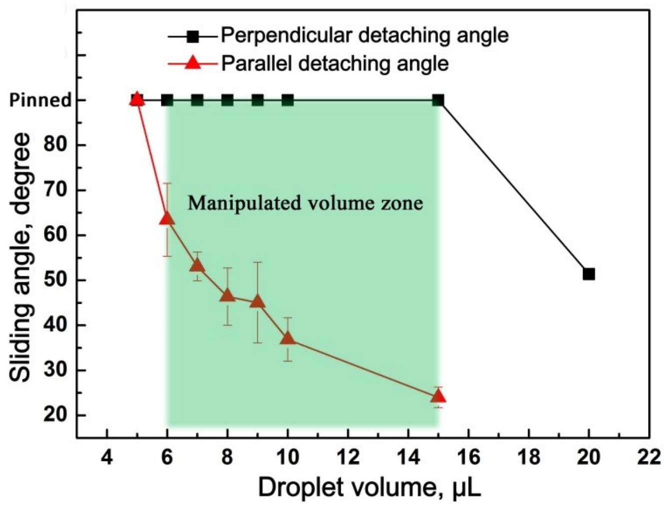

Fig. S5

Operable droplet volume range for the application of droplet mechanical hand on a single track. The width of the single track was 400 μm, which is same as that of

DRHTs system. 'Pinned' means that the droplet could not slide off. Perpendicular detaching angle of 'pinned' indicates that the droplet could be captured by the single track. Parallel detaching angle below 90° indicates that the captured droplet could be released by the track in the parallel direction. Hence operable droplet volume range for the droplet mechanical hand on a single track is between 6 and 15 μL, which is much limited compared to the value on the dual-rail track system.

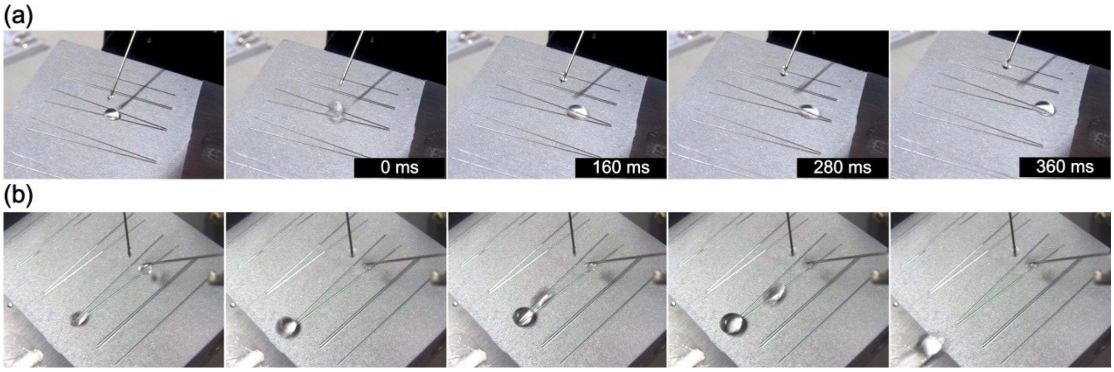

Fig. S6.
Droplet manipulation process conducted using 20wt% sucrose solution. (a) Mixing-triggered spontaneously droplet transport process; 20wt% sucrose solution has a viscosity of ~1.92 mPa s which is almost twice larger than the ~1.00 of deionized water at ambient temperature;[1] two ~10 μL sucrose solution droplets were triggered transported on the narrowing DRHTs system; the process has no obvious difference from that conducted using deionized water except that the whole time consumed in this process is slightly longer due to the high liquid viscosity. (b) Spontaneously mixing & detaching process; the substrate was tilted at ~19° and four ~10 μL sucrose solution droplets were transported, mixed and detached on the narrowing DRHTs system, which is just the same as that conducted using deionized water droplets. The branch angle of the narrowing DRHTs is 8.0°.

Movie S1

Anisotropic sliding on the narrowing DRHTs with a branch angle of 6°. The droplet would slide at ~1.0° in narrowing A direction but would not begin to slide until ~3.2° in expanding B direction.

Movie S2

Inclination-triggered droplet mixing and detaching process. 30 μL 1 mol·L^{-1} $C_6H_8O_7$ and Na_2CO_3 droplets were laid on two tracks of the narrowing DRHTs, respectively. When the substrate was gradually inclined to 4.4°, the two droplets were transported, mixed, pinned and neutralized at the tail end on account of the large detaching resistance. When the substrate was further tilted to ~16.1° after the neutralization process, the reacted droplet finally detached from the tail end.

Movie S3

Spontaneous droplet mixing & detaching process. Four 10 μL droplets were alternately released on the two tracks of the narrowing DRHTs system. The four droplets were guided, pinned, mixed and finally detached from the tail end of tracks. This process was very stable and was repeated for 42 cycles without fault.

Movie S4

Spontaneous droplet mixing & detaching process for droplets with different volumes. When the substrate was inclined at ~32.0°, four ~4 μL droplets could be guided, pinned, mixed and detached at the tail end of the narrowing DRHTs. When the substrate was tilted at ~8°, two 40 μL droplets could also be manipulated on the same DRHTs. These two processes are stable and could be repeated for times without fault.

Movie S5

Semi-dynamic and dynamic droplet mixing-triggered transport process. Scene one shows the semi-dynamic droplet mixing-triggered transport process. A 20 μL droplet was dispensed on one track of the narrowing DRHTs, when two 10 μL droplets were released beside the previous droplet on the other track of the DRHTs, they got mixed and transported immediately after the initial mixing process. Scene two shows the dynamic droplet mixing-triggered transport process. When four 10 μL droplets were alternately dispensed on the two tracks of the DRHTs, they got mixed and transported to the tail end of the track immediately after the initial mixing process.

Movie S6

Semi-dynamic mixing-triggered transport process for two 10 μL droplets. Two ~10 μL droplets were dispensed on the waist position of the narrowing DRHTs and the dispensed two droplets were mixing-triggered transported to the tail end of the narrowing DRHTs with a very high speed.

Movie S7

Mixing-triggered transport process for two 4 μL droplets. Two ~4μL droplets were dispensed on the position close to the tail end of the DRHTs and were mixing-triggered transported to the tail end of the narrowing DRHTs.

Movie S8

Continuous mixing-triggered transport process. Two 15 μL droplets were mixed and immediately triggered transported away from the substrate along the narrowing DRHTs followed by parallel DRHTs. The mixed droplet rolled off the substrate other than was pinned at the tail end of the track hence another cycle of mixing-triggered transport process can be implemented at the same position. This process was stable and can be repeated for times without fault.

Movie S9

Mechanical hand for droplet capturing and releasing. A 10 μL droplet was captured and released on the narrowing DRHTs with a branch angle of 6°.

Movie S10

Droplet manipulation process conducted using 20wt% sucrose solution. Scene one shows the mixing-triggered spontaneous droplet transport process; the substrate was tilted at ~1.0° and two ~10 μL sucrose solution droplets were triggered transported on the narrowing DRHTs system; the process has no obvious difference from that conducted using deionized water except that the whole time consumed in this process is slightly larger due to the high liquid viscosity. Scene two shows the spontaneous mixing & detaching process; the substrate was tilted at ~19° and four ~10 μL sucrose solution droplets were transported, mixed and detached on the narrowing DRHTs system. The process is just the same as that conducted using deionized water droplets.

References and Notes

1 N. Ahmed, D. F. Nino and V. T. Moy, *Rev. Sci. Instrum.*, 2001, **72**, 2731-2734.