Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Asymmetric micro-ratchets regulated drop dispensing on bamboo mimetic surface

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Supporting Information Includes:

One PDF file with Experimental Section, 12 Supporting Figures, and Video file with three Supporting Movies.

Figure S1 – S12

Movie S1

Ejection of drops on *Phyllostachys Pubescens* leaf and *Nelumbo sp.* leaf.

Movie S2

Asymmetric Ratchet Regulated Micro-Drop Dispensing.

Movie S3

Applications of asymmetric ratchet regulated micro-drop dispensing to microfluidic for drops chemical reactions.

Experimental Section

Plant Samples. *Phyllostachys pubescens* and *Nelumbo sp.* plants were purchased from Beijing Tongxia flower wholesale market (Beijing, China). Optical images of the plants were captured by a digital camera with 105 mm macro lens (D5300, Nikon, Japan). SEM specimens of the plants were prepared by freeze-drying. The micro-scaled morphology of the *Phyllostachys pubescens* and *Nelumbo sp.* plants surfaces were captured by SEM (JEOL 7500, Japan) operating at 5 kV.

Observation of Drops Dispensing. High speed camera (FASTCAM Mini UX 100, Photron, Japan) were used to record the drop dispensing dynamics from side view. Analysis software PFA was used to analyze the motion curve of the drops.

Materials. The photopolymerized resin, VeroClear-RGD 810, used for 3D printing was purchased from Stratasys Ltd., United States. Water was acquired from Milli-Q with a resistance of 18.2 MΩ. $CuSO_4$ and NaOH, were purchased from Beijing Chemical Works. Erioglaucine disodium salt and fast green FCF were purchased from Acros. Sunset Yellow FCF was purchased from TCI. 2.0 g PS (Polystyrene, Aldrich) and 1 g of hydrophobic fumed silica nanoparticles (Evonik Degussa Co.) were added into 30 ml of trichloromethane. The solution was stirred for 40 min in a sealed bottle to form the superhydrophobic coating solution.

Fabrication. Bamboo-mimetic surfaces were achieved by Stereolithography 3D printer (Form 2, Unite Staters). 3Ds Max 2016 Software (Autodesk) was used to draw the surface morphology of the models, and Preform software 2.12.2 (Formlabs) prepares 3D models without using supports. Stereolithography 3D printer (Form 2, Unite Staters) was used to print the mimetic mold. The printing process was performed at a resolution of 25 μm with a 405 nm irritation at 120 mW. Obtained printed samples are immersed in ethanol for 2 minutes and, then, washed in a 1:1 vol/vol solution of methanol and water. Post curing process is performed in a tank with 20 w muti-directional LEDs emitting 405 nm light for 2 minutes at room temperature to enhance mechanical properties. The experimental setup and the tilted plate were printed by a Fused Deposition Modeling (FDM) printer (RAISE 3D N2, United States). Wettability patterned superhydrophobic ratchet surfaces are prepared by masking the plate and then spraying a layer of superhydrophobic nanospheres composited coating onto the surface.

Characterization. Surface morphology characterization of the bamboo mimetic surface was achieved by Zeiss stereo discovery microscope (Zeiss Discovery V8). Contact angles were examined using a contact angle meter (OCA 20, Data Physics) at ambient temperature with droplets of 3.0 μL. At least five different positions were measured for the same sample. High speed cameras (Fastcam Mini UX 100, Photron, Japan) were used to record the drop movement dynamics on the mimetic surface from top and side views. Analysis of the water spreading behavior on the peristome mimetic surface were recorded by FASTCAM Mini UX 100, Photron, from top and side views. PFA Software was used to analysis the water drops' motion behaviors.

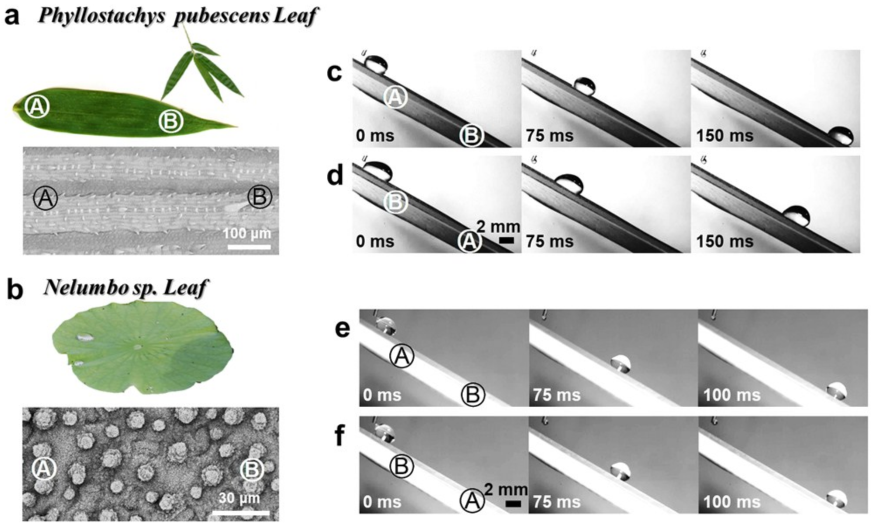

Fig. S1 Dripping and motion sequences of drops on the *Phyllostachys Pubescens leaf* and *Nelumbo sp. leaf*. (a) and (b), Optical and scanning electron microscope image of *Phyllostachys pubescens* leaf and *Nelumbo sp.* leaf, respectively. Ⓐ denotes the rim and Ⓑ denotes the tip of *Phyllostachys pubescens* leaf. (c) and (e), Image sequences of drops dripping and scrolling towards the direction of the tip on *Phyllostachys pubescens* leaf and *Nelumbo sp.* leaf, respectively. (d) and (f), Image sequences of drops dripping and scrolling back towards the direction of the tip on *Phyllostachys pubescens leaf* and *Nelumbo sp. leaf*, respectively. The inclination angle α of the substrate is 30°.

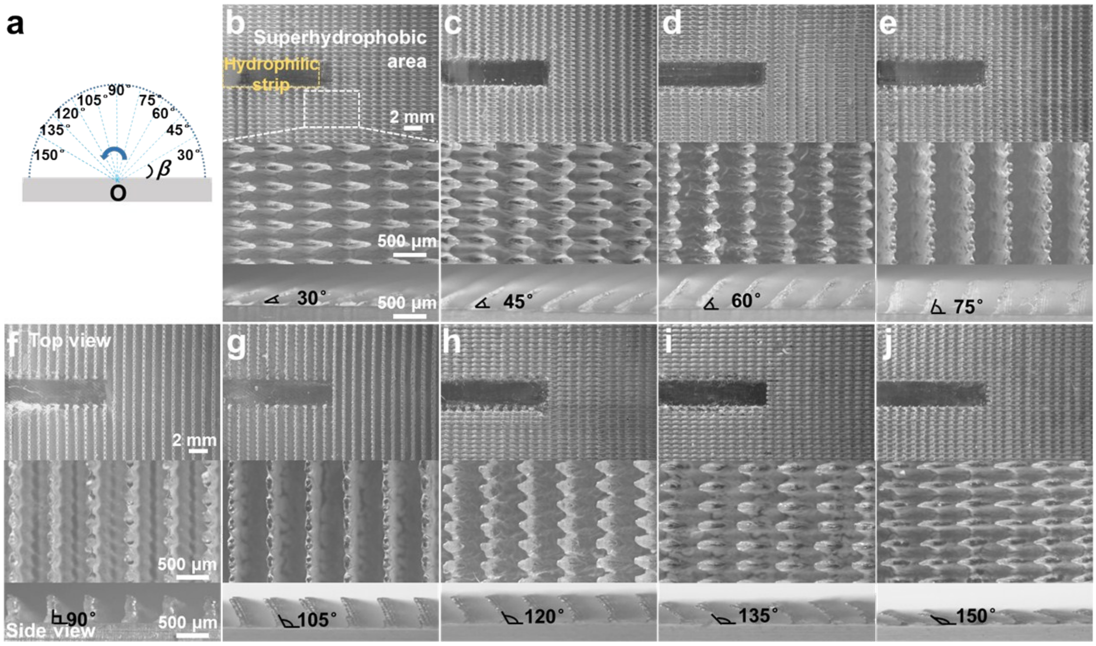

Fig. S2 Surface morphologies of the fabricated substrates. (a) Schematic image of the definition for micro-scaled ratchets' inclined angles, β. **(b) - (j),** Substrate is composed of hydrophilic strip and superhydrophobic ratchets. Drop is produced through the process that water flow moving along the strip to the superhydrophobic surface. The upper rows of images are captured from top-view, the middle rows of images are high magnification of the tilted ratchets, and the bottom rows of images are captured from side-view. Ratchet inclined angles are varied in between 30° and 150°.

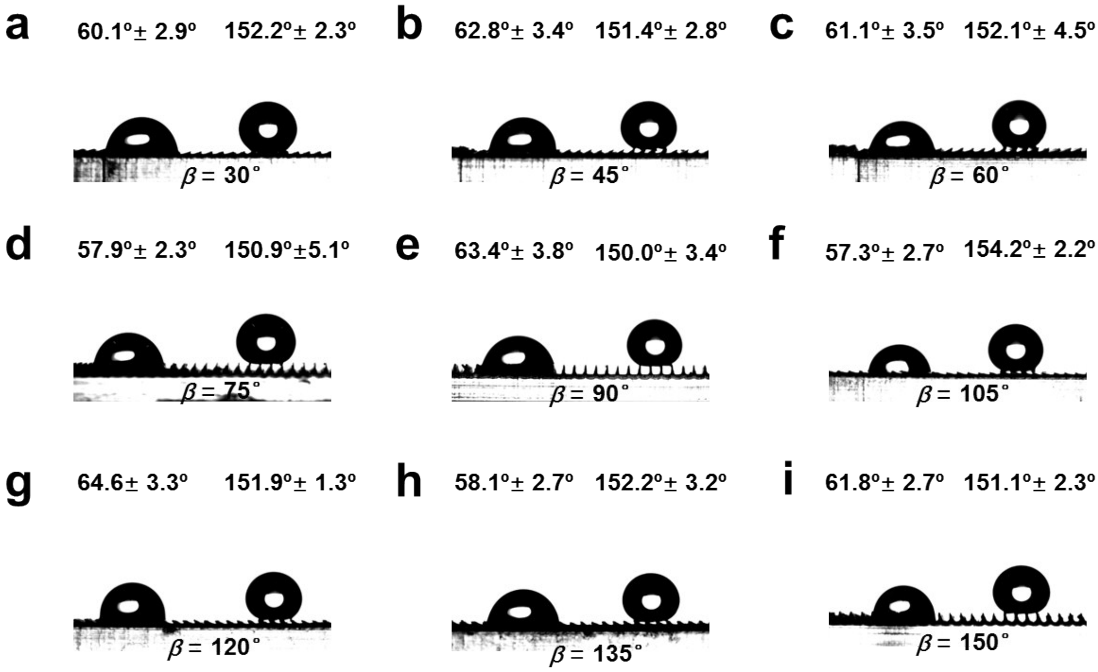

Fig. S3 Surface wettability quantified on hydrophilic strip and superhydrophobic ratchets. (a) - (i), Ratchet inclined angles are varied from 30° to 150°, respectively. The long striped areas all state hydrophilic with contact angles of around 60°, and the border regions present superhydrophobicity with all contact angles above 150°.

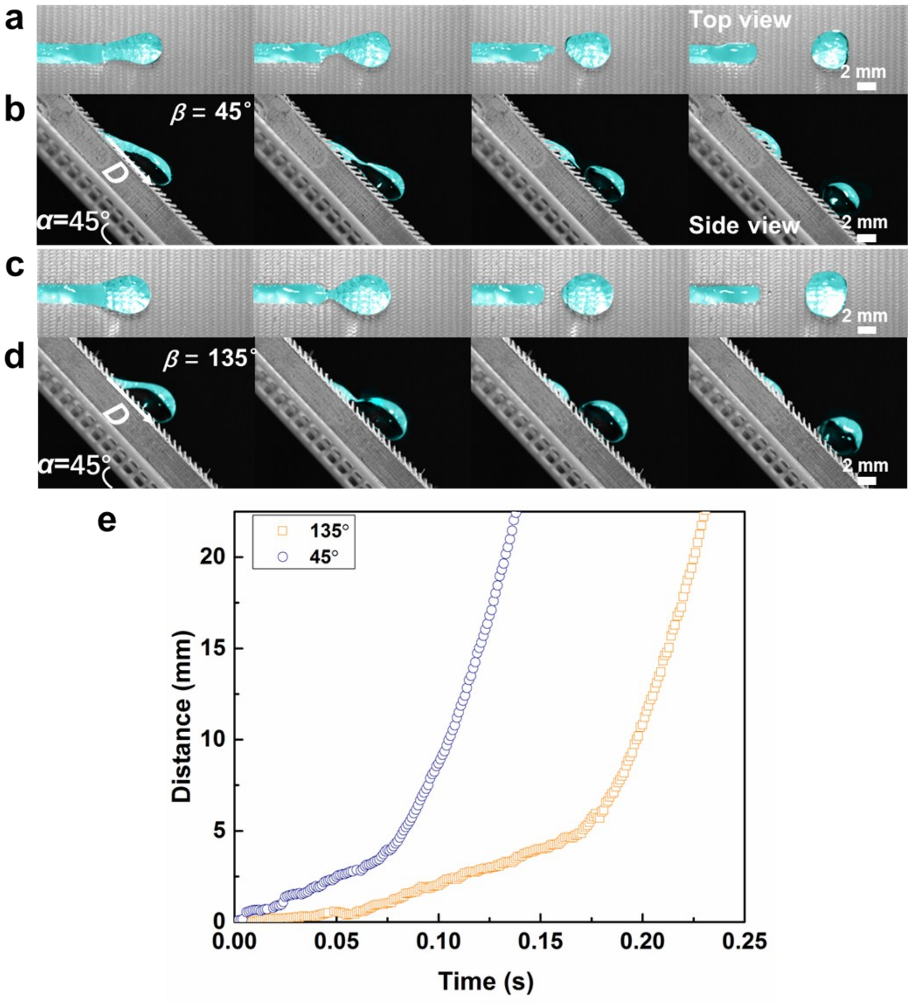

Fig. S4 Drops ejection on anisotropic wettability boundary. (a) and **(b)** Drops emission on forward tilted ratchets (β = 45°). **(c)** and **(d)** Drops emission on backward tilted ratchets (β = 135°). **(e)** Drop motion distance along the surface as a function of time for the image sequence in a-d. The inclination angle α of the substrate is 45°. The hydrophilic-superhydrophobic boundary width is 2 mm with injection speed of 0.08 ml/s. Animated video is shown in Movie S2.

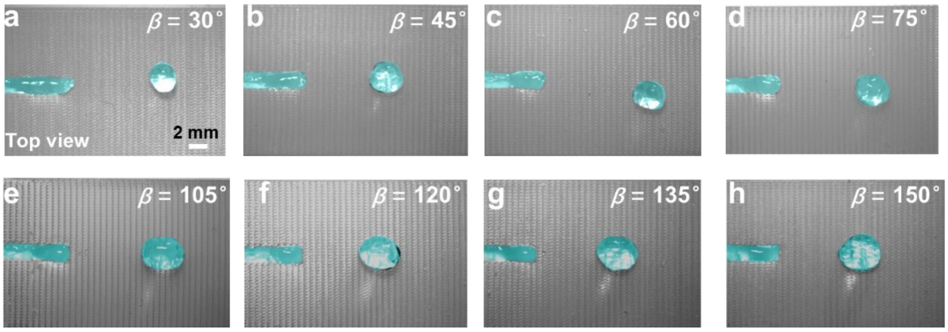

Fig. S5 The top view images of produced drop in different tilted ratchet substrates. (a) - (h) Varying the ratchets' tilted angle from 30° to 150°, the size of launched drop increases. The inclination angle α of the substrate is 45°. The hydrophilic-superhydrophobic boundary width is 2 mm with water injection speed of 0.08 ml/s. Animated video is shown in Movie S2.

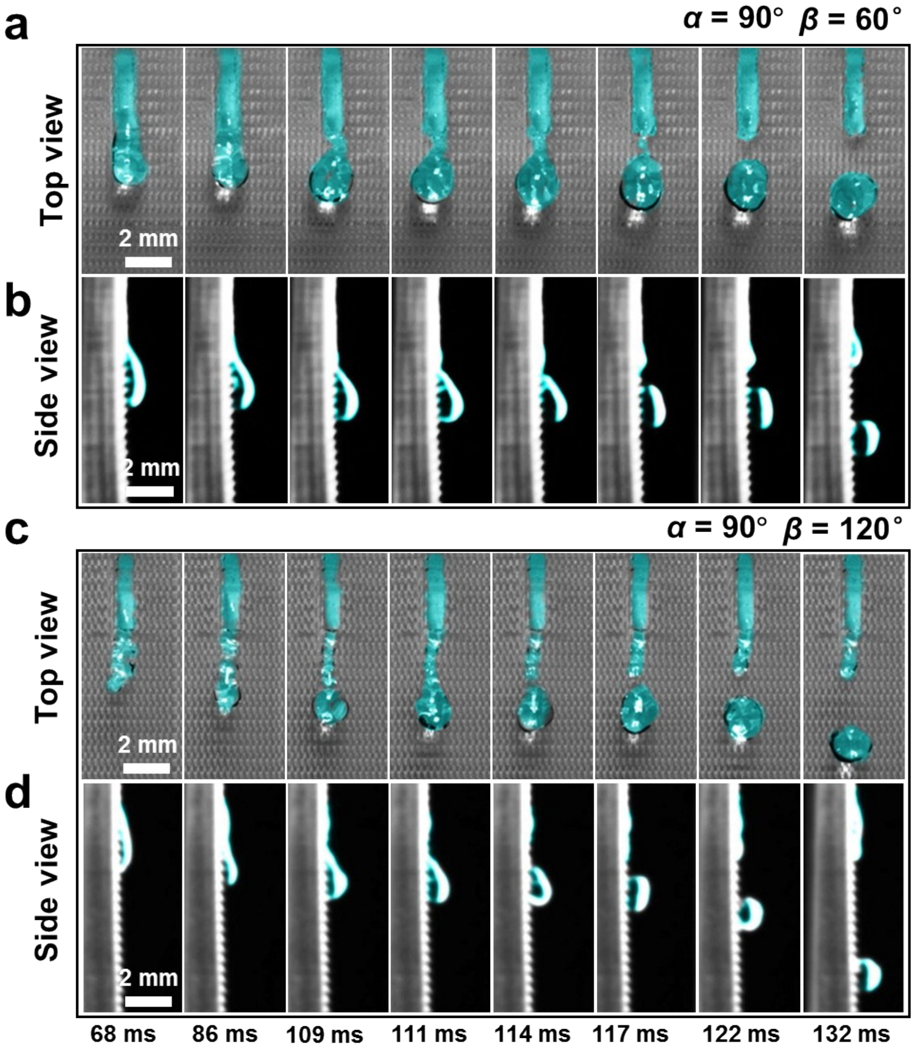

Fig. S6 Drops ejection at the anisotropic wettability boundary. (a) and **(b)** Images of drops emission on tilted micro-nano ratchets (β = 60°) structured superhydrophobic surface. **(c)** and **(d)** Images of drops emission on tilted micro-nano ratchets (β = 120°) structured superhydrophobic surface. The inclination angle α of the substrate is 90°. The hydrophilic-superhydrophobic boundary width is 1 mm with injection speed of 0.04 ml/s.

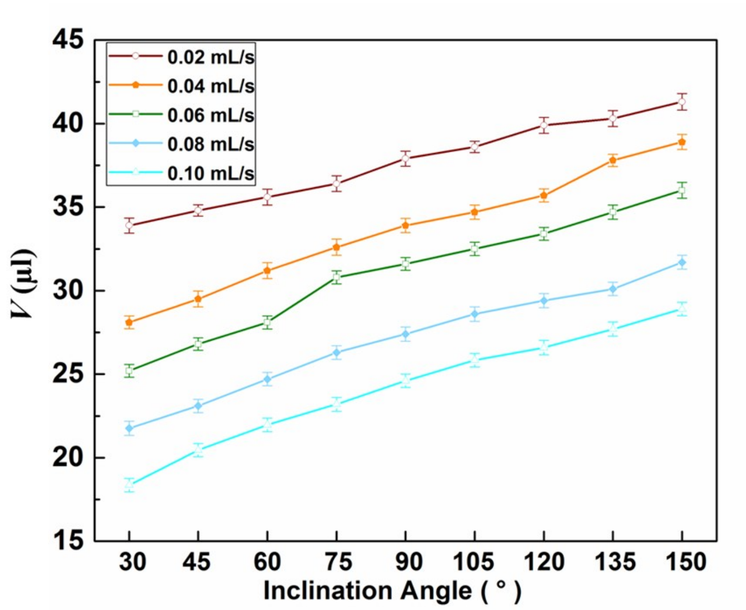

Fig. S7 Drop volume as a function of ratchets' inclination angle at varied injection speeds. Drop volume, V, as a function of ratchets' inclination angle β for injection speed varied from 0.02, 0.04, 0.06, 0.08, to 0.10 ml/s. The inclination angle α of the substrate is 45°. The hydrophilic-superhydrophobic boundary width is 2 mm.

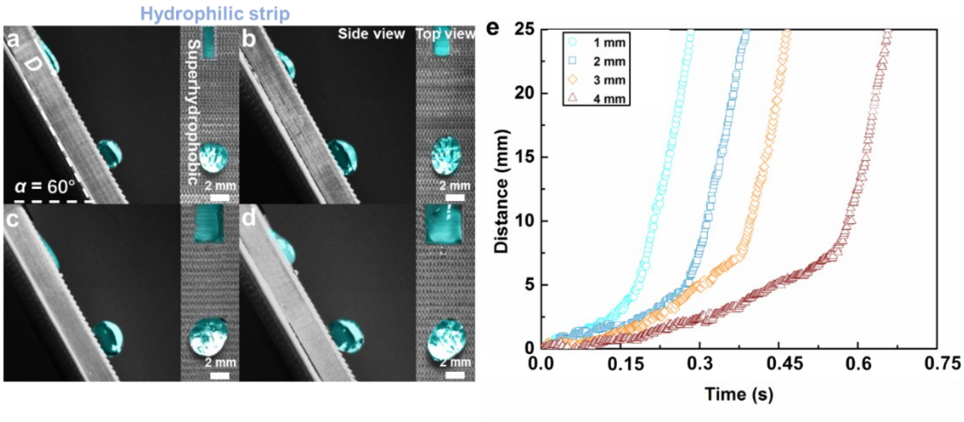

Fig. S8 Relationship between drop emission and boundary width. (a) The inclination angle α of the substrate is 60°. The ratchets tilted angle β is 30°.The hydrophilic strip with is 1 mm with injection speed of 0.04 ml/s. The left image and right image are from side view and top view, respectively. **(b) - (d)** varying the hydrophilic-superhydrophobic width from (b) 2 mm, (c) 3 mm to (d) 4 mm, the size of projectile drop increases. **(e)** Drop position along the surface x as a function of time for the image in (a) - (d).

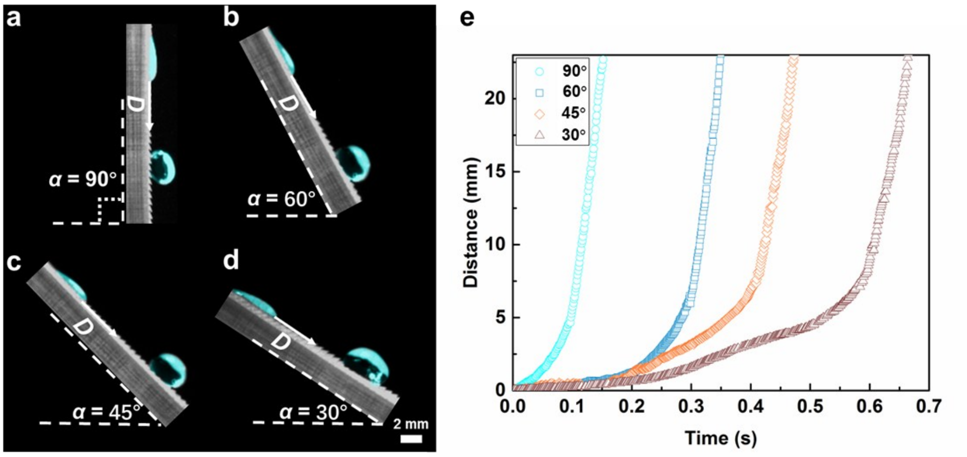

Fig. S9 Relationship between drop emission and substrate inclined angle α. (a) The inclination angle α of the substrate is 90°. β is 30°. The hydrophilic strip with is 2 mm with injection speed of 0.04 ml/s. **(b) - (d)** Varying α from (b) 60°, (c) 45° to (d) 30°, the size of projectile drop increases. **(e)** Drop position along the surface x as a function of time for the image in (a) - (d).

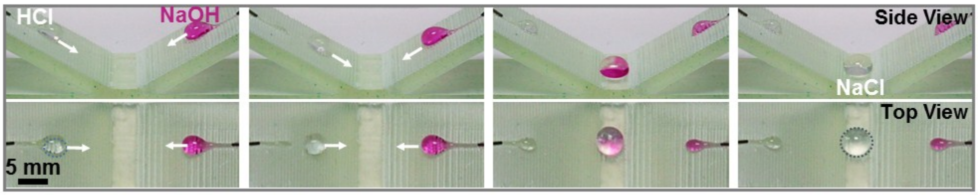

Fig. S10 Asymmetric ratchets regulated drop reactions. Hydrochloric acid solution and NaOH solution transport along the arrays and form two drops with volume ratios of 1:1 to react at the center. The substrate remains robust after contacting with acidic solution.

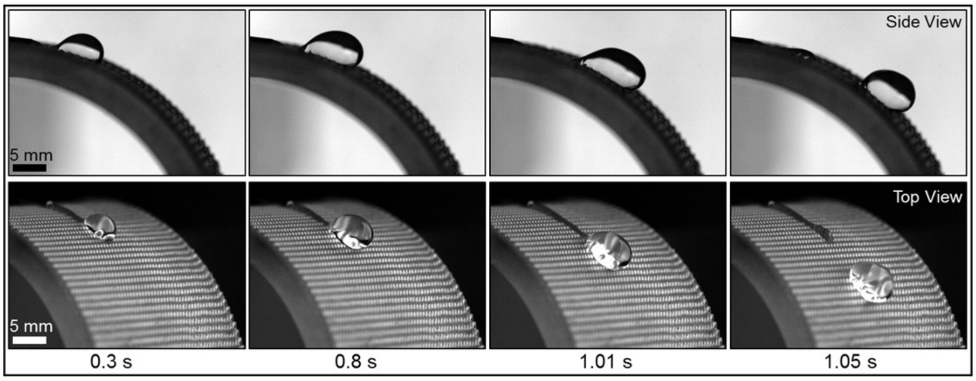

Fig. S11 Drop emission on the curved surface. The optical image of the prepared curved sample with a radius curvature of 2.5 cm.

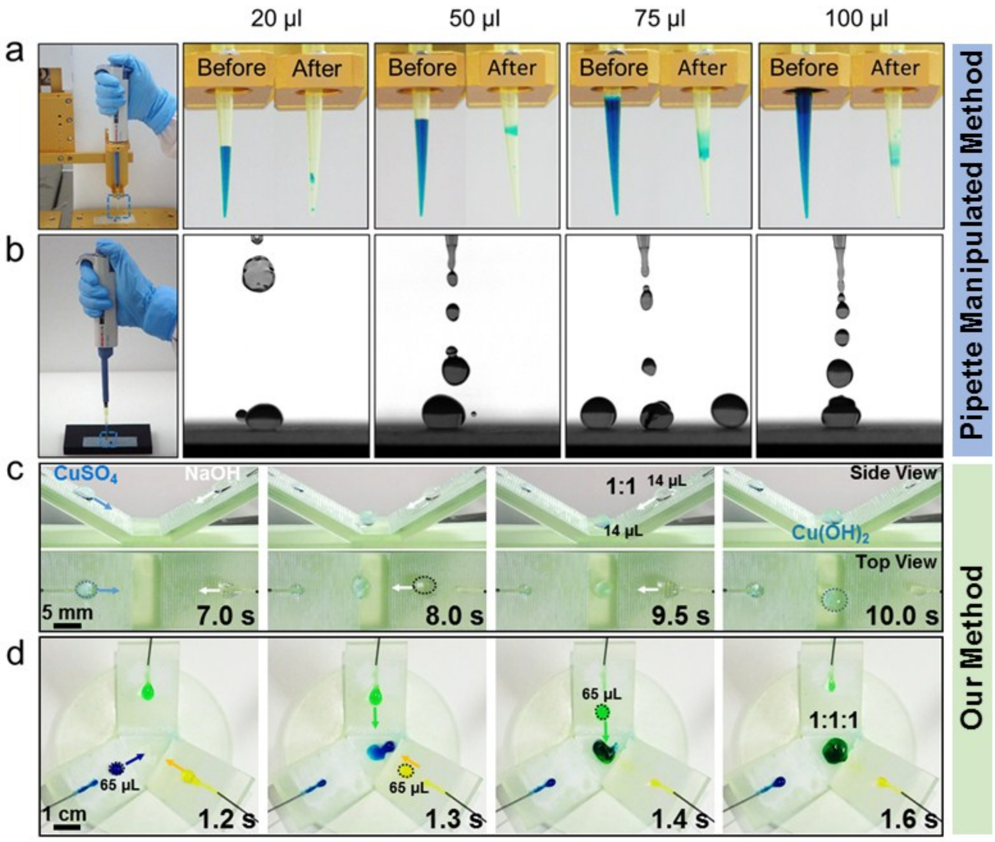

Fig. S12 Pipette manipulated liquid drops transfer compared with drop manipulation on bamboo mimetic surface. a, b The pipette dripping process of dripping drops with differnet set sizes 20 μl ,50 μl, 75 μl, 100 μl. **(a)** There is residue water in the pipette needle. **(b)** The injected liquid splits into small droplets. **(c)**,**(d)** A whole droplet of varied volumes can be ejected by asymmetric micro-ratchets wettability boundary.