2017 International Bionic Innovation Competition

Peristome-Mimetic Curved Surface for Spontaneous and Directional Separation of Micro Water-in-Oil Drop

Abstract

Inspired by ants that on the water covered peristome surface would helplessly slip on its surface. Here we report that instead of the “plug and go” separation model, tiny water-in-oil droplets can be separated into pure water and oil droplets through “go in opposite ways” on the curved peristome-mimetic surfaces in milliseconds without energy input. Furthermore, the spontaneously uni-directional transportation of the separated droplets is achieved on the curved peristome-mimetic surface.

Methods

Guided by the natural designed structures of the peristome surface, here, we develop peristome mimetic curved surface by a 3D printing process and use it to separate tiny water-in-oil droplets. Digital light processing (DLP) three dimensional printing is used in our experiment to fabricate the inverse template of the peristome-mimetic surface. Without the need of the chemical modification or resin changing, the peristome-mimetic surfaces with low or high surface energies can be easily prepared through replication.

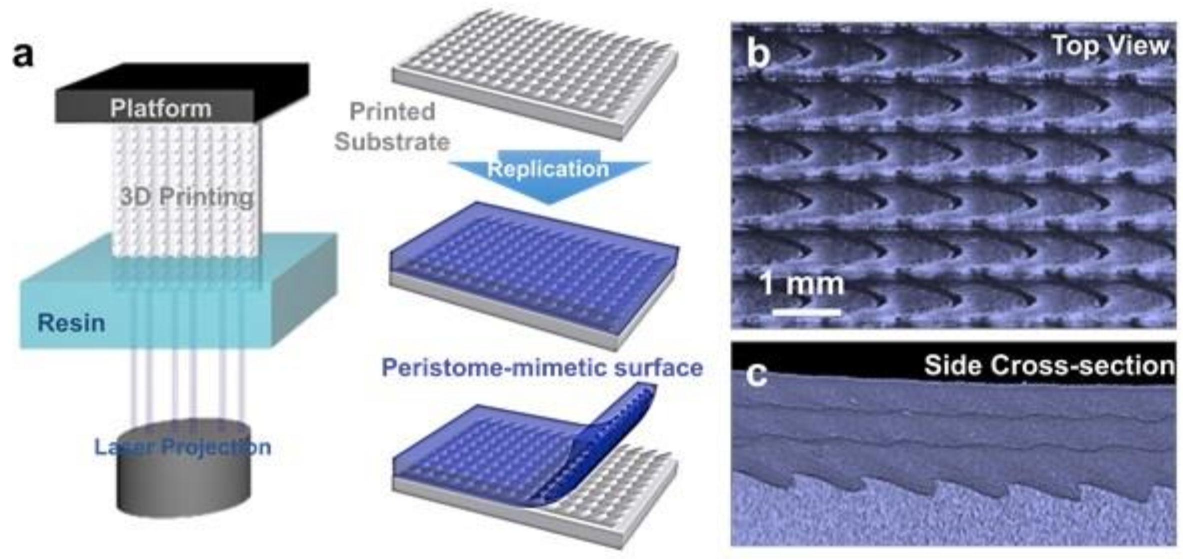

Fig. 1 The fabrication process. a, The inverse template is first fabricated by 3D printing. PDMS or PVA is then casted onto the printed substrate. Getting off the replica, the flexible peristome-mimetic film is finally prepared. **b,** Stereoscopic image of the peristome-mimetic surface, indicating that arch-shaped cavity structures arrayed into a pattern. **c,** Side cross-sectional views from the micro-CT observation.

Liquid spreading behaviour

Peristome-mimetic PDMS surface shows hydrophobic with a water contact angle of 105° and superoleophilic with an hexadecane contact angle of less than 10°. Selective liquid transportation behavior is demonstrated by the high speed movie sequences when a water-in-hexadecane drop impacts on the peristome-mimetic PDMS surface. Even though the mass density of n-hexadecane, 0.77 g·cm-3, is lower than that of water, which is 1.03 g·cm-3, the oil would occupy the liquid-solid contact interface first, then uni-directionally spreads on the PDMS surface. In contrast to the directional wetting of the oil phase, water phase transforms into a hemi-sphere shape and keeps its position at the rare side of the oil strip just below the nozzle.

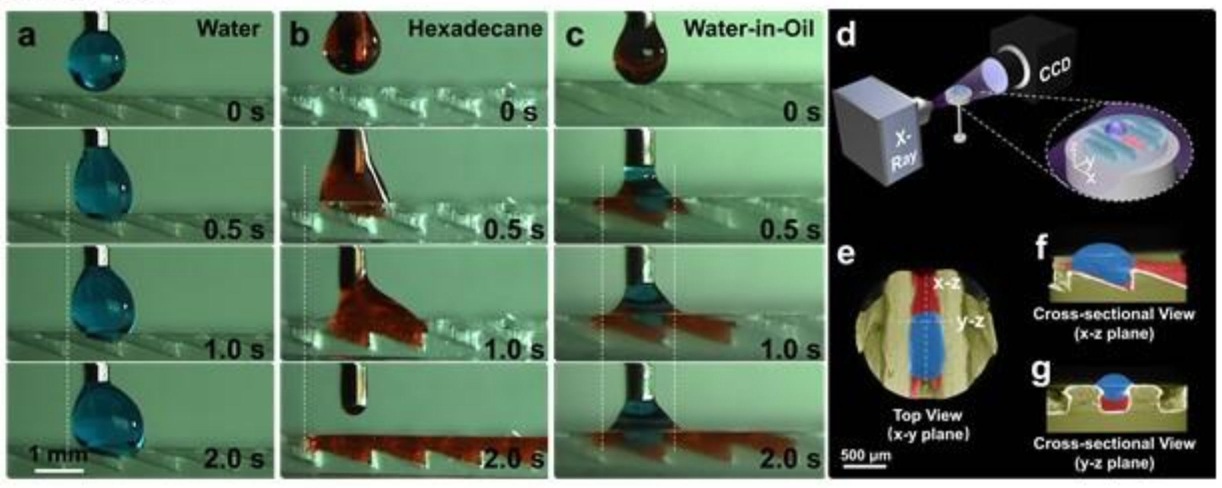

Fig. 2 The selective wetting behaviour of liquid on the peristome-mimetic surface. a-c, Time-lapse images of the water, hexadecane, water-in-hexadecane drops' spreading behaviour on the peristome-mimetic PDMS surface. d-f, 3D micro-observation of the selective liquid directional transportation on the peristome-mimetic surface.

Oil-water seperation

A novel oil-water separator based on double curved plates is devised to separate tiny oil-water mixture drops. we placed two curved peristome-mimetic surfaces with the structured sides face to face, oil would transport along the bottom surface in one direction and water spreads in another direction, just after the water-in-oil droplet contacted the surface. Controlling the parameters of the peristome-mimetic surfaces, our device can spontaneously separate, for the first time, several microliters sized water-in–oil droplets into controllable sized pure oil and pure water droplets with volumes ranging from nanolitres to microliters in controlled speeds even within milliseconds.

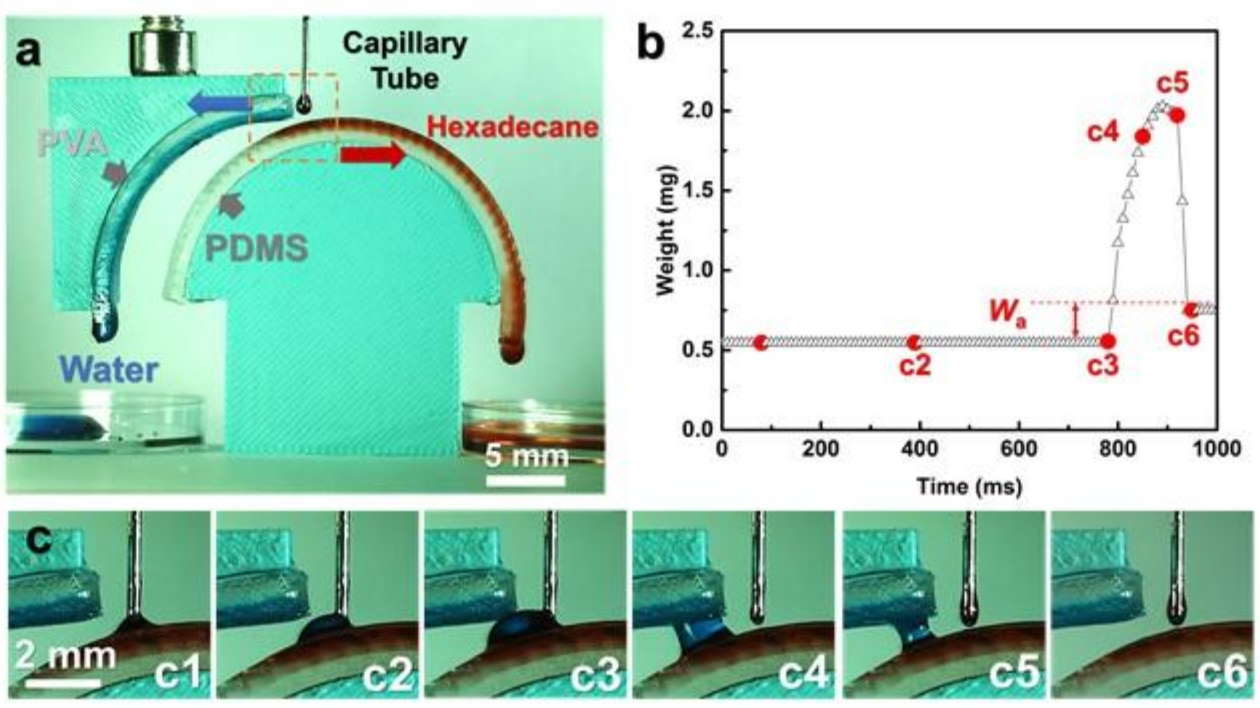

Fig. 3 Nano-liter scaled water-oil separation on the curved PDMS and PVA peristome-mimetic surface. a, Optical images depicting the experimental setup of the water-oil separation device. **b,** High sensitivity microbalance system recording the force during the separation process. **c,** Time lapse images showing the process of nano-liter water separated from oil coated PDMS surface and transporting on the PVA surface.

Publications

1. Uni-Directional Transportation on Peristome-Mimetic Surfaces for Completely Wetting Liquids, Angew. Chem.-Int. Edit., 2016, 55(48), 14988-92.

2. Peristome-Mimetic Curved Surface for Spontaneous and Directional Separation of Micro Water-in-Oil Drop, Angew. Chem.-Int. Edit., 2017, early online.