Supporting Information

Two-Photon Polymerization of Butterfly Wing Scale Inspired Surfaces with Anisotropic Adhesion

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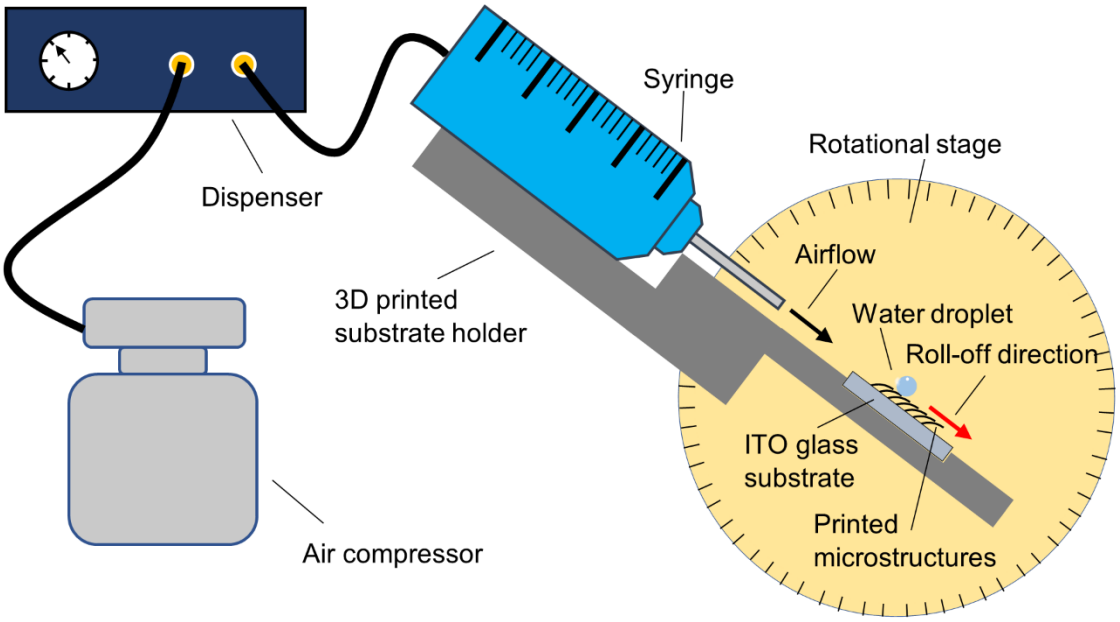


Figure S1. Experiment setup for roll-off pressure measurement (ROP). Stable airflow is generated 35 mm away from the edge of the printed microstructure surface, and the airflow direction is parallel to the roll-off direction. Water droplet is deposited on the edge closer to the nozzle, and the minimum required pressure to initial the droplet's movement along the roll-off direction is measured from 0° to 90°. Roll-against pressure (RAP) is measured with the same setup but the microstructure's roll-off direction is oriented against the direction of the airflow.

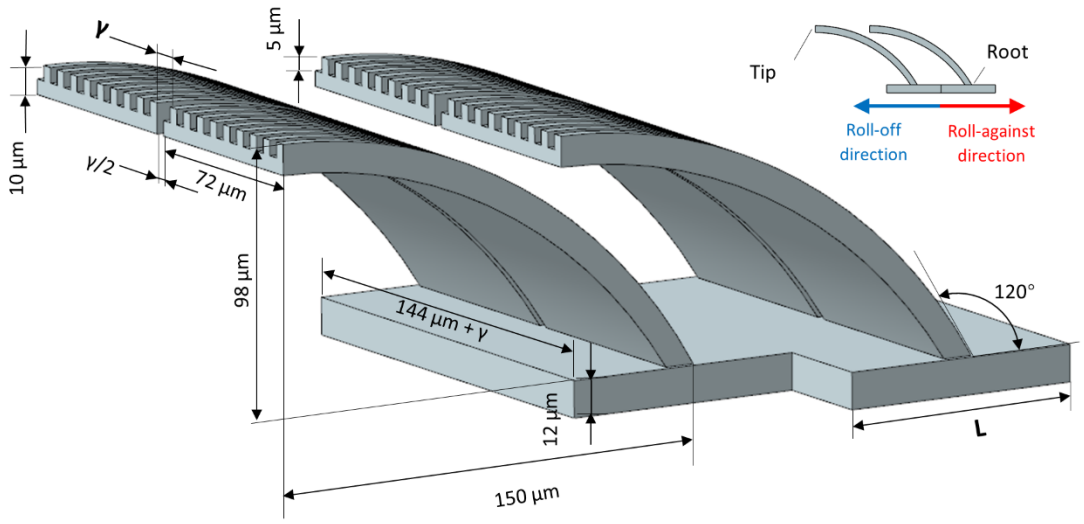


Figure S2. Computer-aided-design (CAD) models of microstructures inspired by butterfly wing's scales. The dimensions of the designed scale, such as arc length and width, are similar to the Morpho aega butterfly wing's scale. The lamella-stacking ridge nanostructure on the natural scale is simplified to a single ridge. The spacings of the curve structures and ridge structures, namely base length (L) and grating pitches (γ), are varied from 4 µm to 12 µm and 70 µm to 90 µm, respectively.

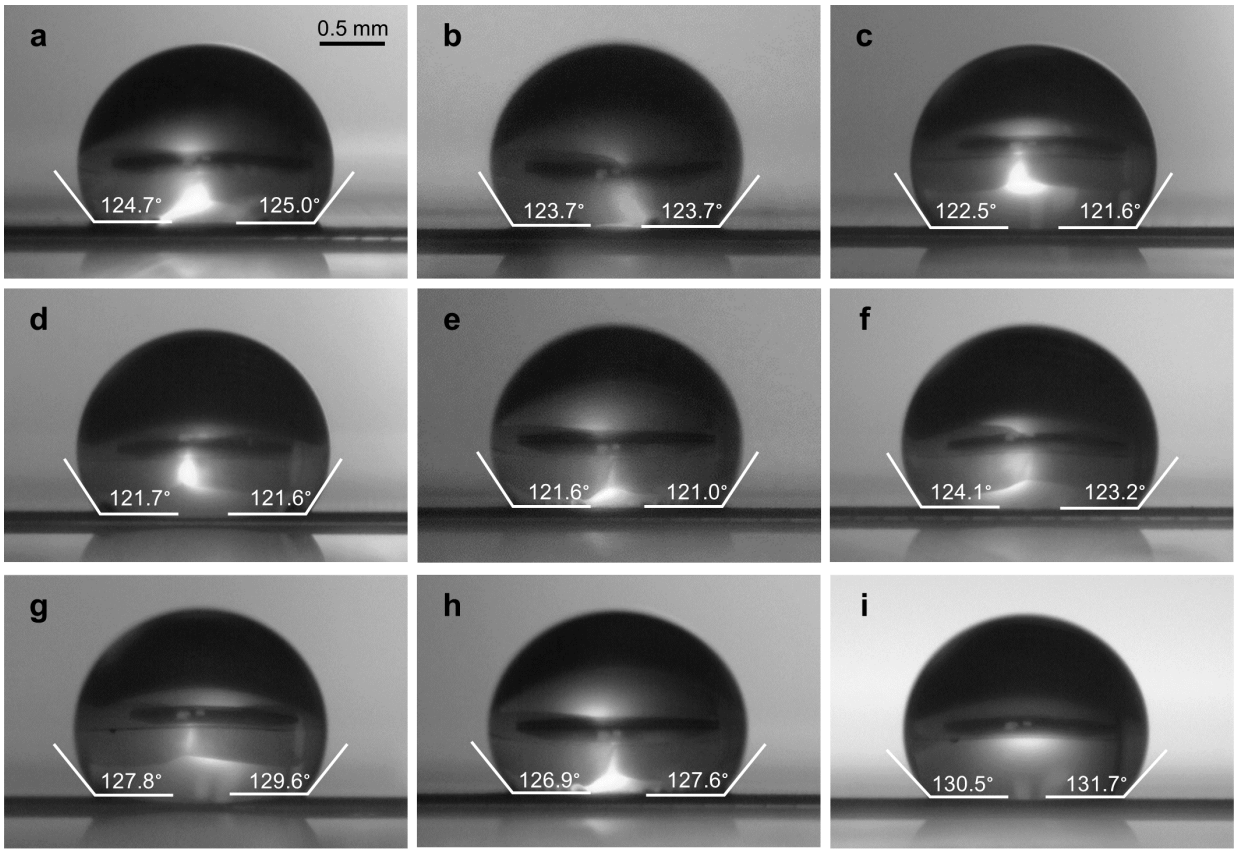


Figure S3. Contact angle of water on Parylene-N coated microstructure design with (a) γ = 4 μm and L = 70 μm, (b) γ = 4 μm and L = 80 μm, (c) γ = 4 μm and L = 90 μm, (d) γ = 8 μm and L = 70 μm, (e) γ = 8 μm and L = 80 μm, (f) γ = 8 μm and L = 90 μm, (g) γ = 12 μm and L = 70 μm, (h) γ = 12 μm and L = 80 μm, and (i) γ = 12 μm and L = 90 μm.

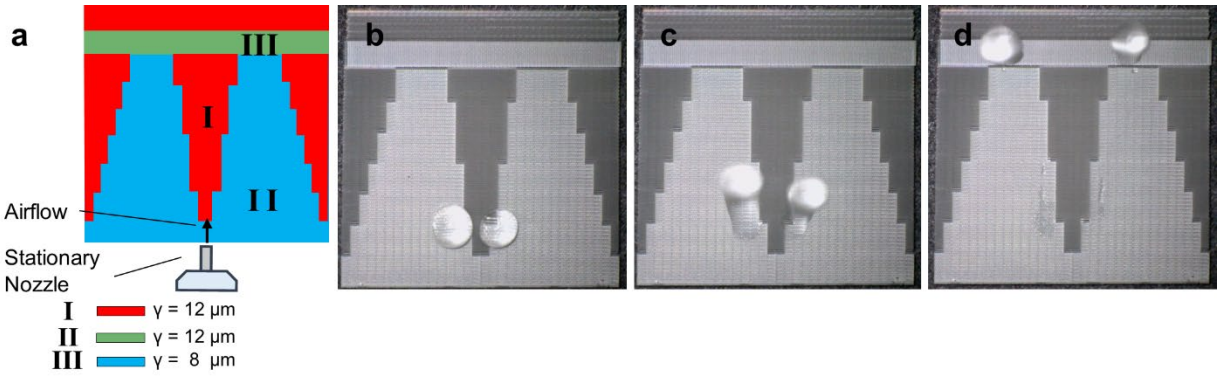


Figure S4. Airflow from a stationary nozzle transports water droplets. (a) The stationary nozzle is positioned at the center of the printed microstructures and 35 mm away from the edge of Region II. (b) Two water droplets are deposited on the printed surface close to the center segment of Region I. (c) The droplets move along the edge of the center segment of Region I due to the moment restriction of Region I and the increased degree of airflow dispersion away from the nozzle. (d) The droplets stop at Region III due to the moment restriction of the rectangular segment of Region I.

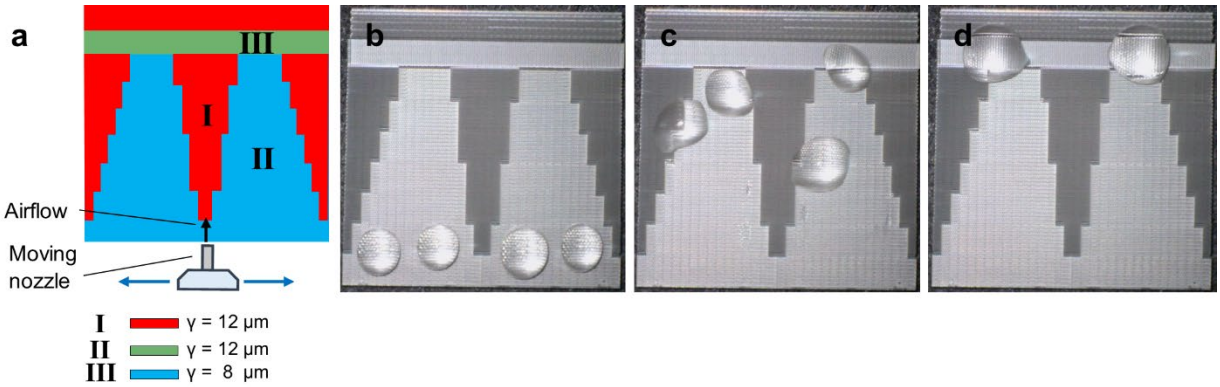


Figure S5. Airflow from a moving nozzle transports water droplets. (a) The nozzle is positioned 35 mm away from the edge of Region II and moves along the edge. (b) Four water droplets are deposited near the edge of Region II. (c) The deposited water droplets are transported along the edge of the triangular segments of Region I. (d) Droplets accumulate together as the width of Region II decreases and stop at Region III due to the moment restriction of the rectangular segment of Region I.

Table S1. Water contact angles of bare glass, non-coated artificial scale microstructure, Parylene-N coated glass, and the coated microstructure with different design parameters (refer to Figure S3).

Samples	Position	Contact angle [°]				Average
ITO-coated glass	Left	39.5	39.2	39.1	39.3	39.3
	Right	38.8	39.3	38.9	39.1	39.0
ITO-Parylene-N coated glass	Left	92.1	92.2	92.2	92.4	92.3
	Right	91.2	91.6	92.0	92.3	91.8
Non-coated structure	Left	91.2	92.2	92.1	91.7	91.8
	Right	92.2	91.2	91.6	91.1	91.5
γ = 4μm & L=70 μm	Left	124.7	124.9	124.9	125.5	125.0
	Right	125.0	125.2	125.9	125.9	125.5
γ = 4 μm & L=80 μm	Left	123.7	123.8	124.2	124.3	124.0
	Right	123.7	123.7	124.1	124.6	124.0
γ = 4 μm & L=90μm	Left	122.5	122.6	122.9	123.0	122.8
	Right	121.6	121.8	122.1	122.6	122.0
γ = 8 μm& L=70μm	Left	121.7	122.3	122.4	122.6	122.3
	Right	121.6	121.7	121.8	121.9	121.8
γ = 8μm & L=80μm	Left	121.6	121.7	121.8	121.9	121.8
	Right	121.0	121.2	121.3	122.4	121.5
γ = 8μm & L=90μm	Left	124.1	124.4	124.6	124.8	124.5
	Right	123.2	123.5	124.1	124.1	123.8
γ = 12μm & L=70μm	Left	127.8	128.3	128.4	128.6	128.3
	Right	129.6	130.0	130.2	130.3	130.0
γ = 12 μm & L=80 μm	Left	126.9	127.0	127.9	128.1	127.5
	Right	127.6	128.0	128.1	128.3	128.0
γ = 12 μm & L=90 μm	Left	130.5	130.6	131.3	131.6	131.0
	Right	131.7	132.0	132.1	132.2	132.0

Table S2. ROP and RAP of Parylene-N coated microstructures with different design parameters measured at 0°, 30°, 60°, and 90° of rotation.

Rotary angle	Grating pitches (γ) [μm]	4			8			12		
	Base length (L) [μm]	70	80	90	70	80	90	70	80	90
0°	ROP [psi]	10.1	9.3	7.9	13.8	12.0	10.0	11.2	10.4	9.8
		10.2	9.4	8.1	14.1	12.2	10.1	11.3	10.5	10.0
		10.4	9.5	8.3	14.2	12.5	10.3	11.4	10.7	10.2
	RAP [psi]	2.4	3.7	4.3	1.9	2.3	4.5	1.8	1.7	1.0
		2.5	4.0	4.5	2.1	2.5	4.8	2.0	1.8	1.2
		2.7	4.3	4.6	2.2	2.6	5.0	2.2	2.0	1.4
30°	ROP [psi]	7.8	7.2	7.1	11.9	10.8	7.3	9.7	9.3	8.8
		8.0	7.5	7.2	12.0	11.0	7.5	9.8	9.4	9.0
		8.1	7.6	7.3	12.2	11.1	7.6	10.0	9.5	9.2
	RAP [psi]	2.0	3.1	3.8	1.6	2.1	4.0	1.3	1.4	0.9
		2.1	3.2	4.0	1.7	2.2	4.1	1.6	1.5	1.0
		2.2	2.3	4.1	1.9	2.3	4.3	1.7	1.6	1.1
60°	ROP [psi]	7.3	7.1	6.9	10.6	9.9	7.0	8.0	7.5	7.4
		7.5	7.2	7.0	10.8	10.0	7.2	8.1	7.7	7.5
		7.6	7.3	7.1	10.9	10.2	7.3	8.2	7.9	7.6
	RAP [psi]	1.5	2.6	3.2	1.0	1.9	3.3	1.2	1.0	0.7
		1.6	2.7	3.4	1.2	2.0	3.4	1.5	1.2	0.8
		1.7	2.8	3.5	1.4	2.1	3.6	1.6	1.4	0.9
90°	ROP [psi]	7.0	5.8	5.4	9.7	7.8	6.3	7.4	7.1	7.0
		7.1	6.0	5.5	9.8	8.0	6.5	7.5	7.3	7.1
		7.3	6.1	5.6	10.0	8.1	6.6	7.6	7.5	7.3
	RAP [psi]	1.0	2.0	2.3	0.7	1.6	1.9	1.1	0.8	0.2
		1.1	2.3	2.5	0.8	1.8	2.0	1.3	0.9	0.3
		1.2	2.4	2.6	1.0	2.0	2.2	1.4	1.0	0.4

Note:
ROP - minimum required air pressure to move a water droplet in roll-off direction.
RAP - minimum required air pressure to move a water droplet in roll-against direction.