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Supporting information

Highly efficient water harvesting of bioinspired spindle-knotted microfibers with continuous hollow channel

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Supplementary Figures

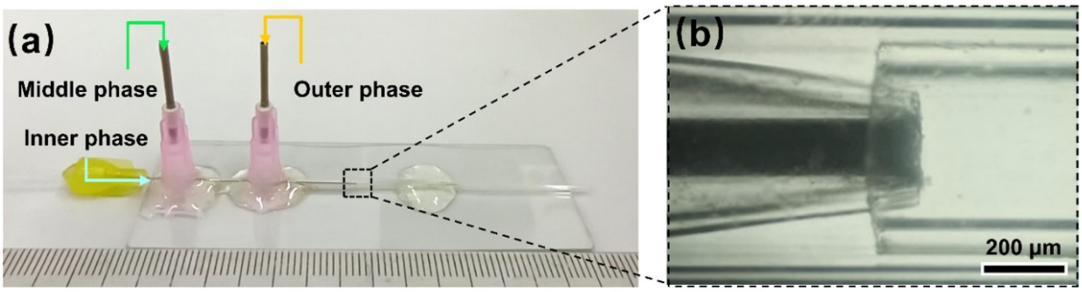


Fig. S1 Digital image of the device (a), and micrograph at the device cone (b).

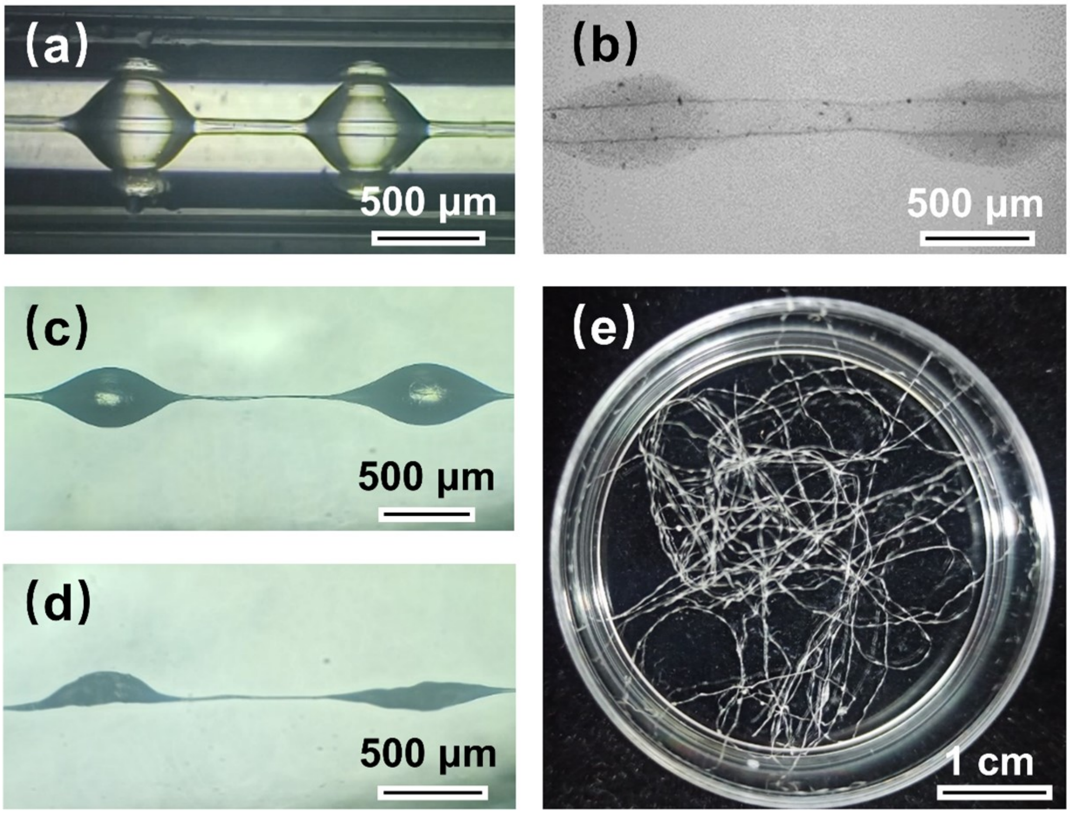
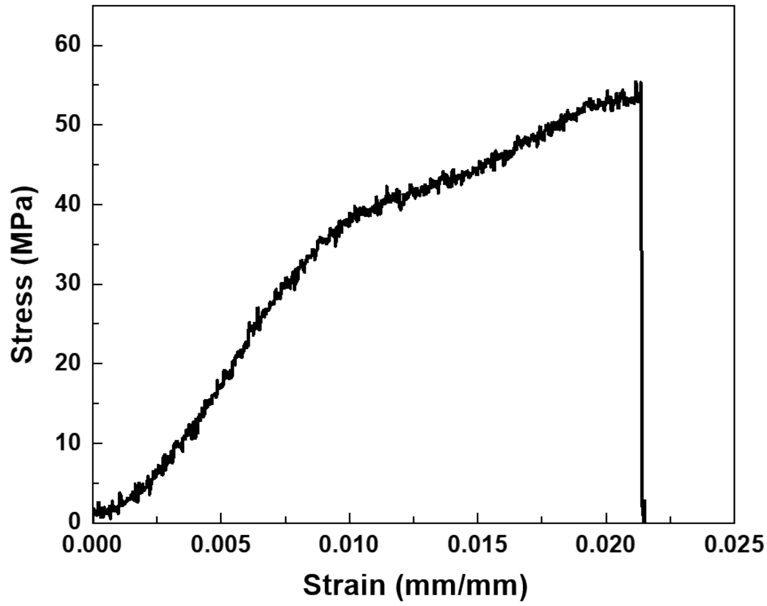


Fig. S2 The evolution of hollow spindle-knotted microfiber: in capillary (a), before (b) and after solidification (c), after dehydration (d) and dehydrated microfibers in large quantities (e).



Specimen Diameter	Gage Length	Modulus	Offset Yield Stress	Max Engineering Stress
25 µm	20 mm	4.16 GPa	42.5 MPa	55.83 MPa

Fig. S3 The tensile test of hollow spindle-knotted microfiber.

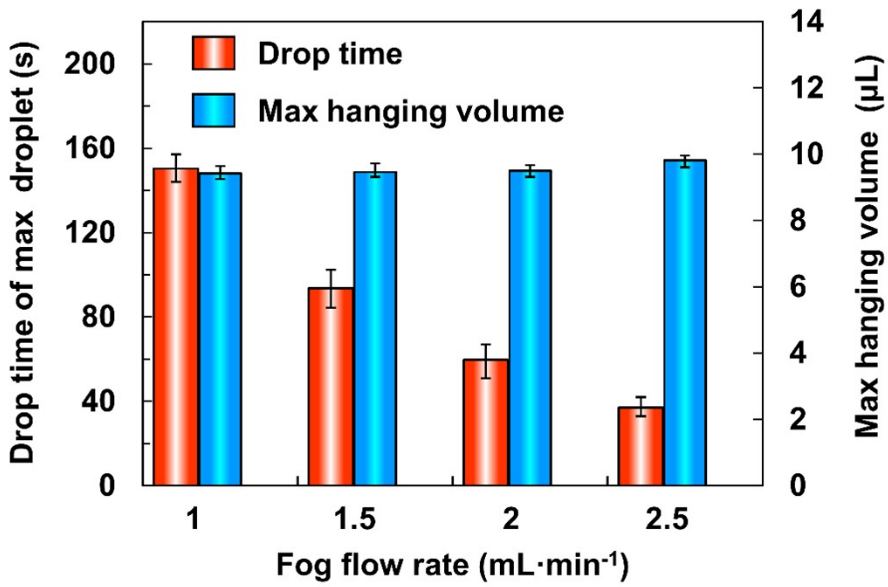


Fig. S4 The influence of the fog flow rate on the drop time and volume of maximum droplets.

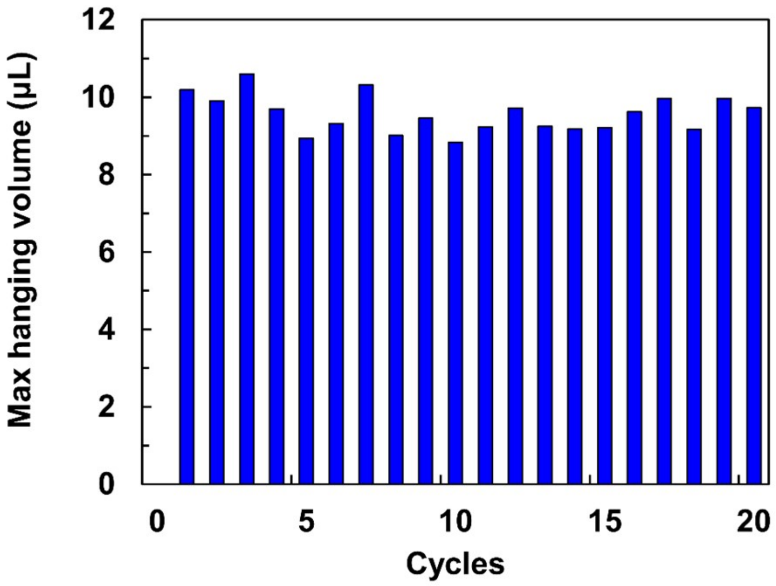


Fig. S5 The durability of hollow spindle-knotted microfibers.

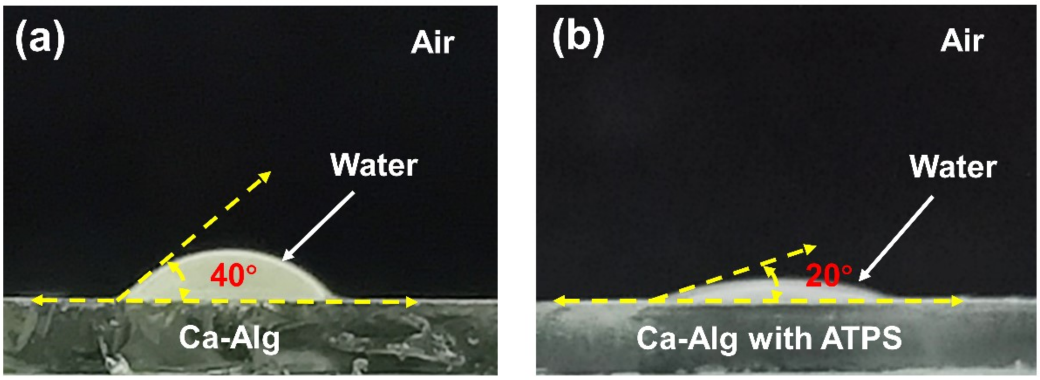


Fig. S6 Wettability of surface. The surface is covered by Ca-Alg (a), and Ca-Alg with ATPS (b).

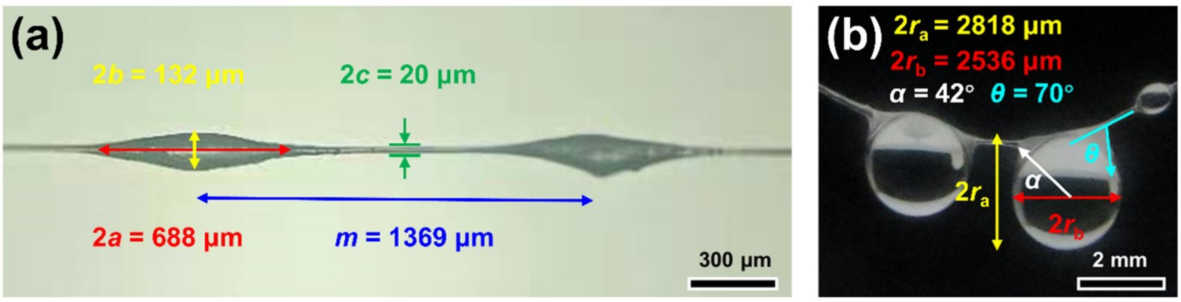


Fig. S7 The maximum volume of droplet collected by the domain knots. a) The volume of knots, b) the maximum volume of droplet.

Supporting analysis I

The length of three phase contact line (TCL) when droplet detach from microfiber:

The TCL is composed of two lines and two half ellipse, when droplets hanging on two spindle knots of solid spindle-knotted microfiber. The perimeter of an ellipse is $2\pi b + 4(a - b)$, the perimeter of a half-ellipse is equal to $\frac{1}{2}\times[2\pi b + 4(a - b)] + 2b$, the length of two lines can be written as $2(m - a)$. The length of TCL outside the microfiber (L_o) can be expressed as:[1]

$$L_o \approx 2\times\{\frac{1}{2}\times[2\pi b + 4(a - b)] + 2b\} + 2(m - a) = 2m + 2\pi b \quad (1)$$

where L is the length of the three phase contact line (TCL). m is the distance between adjacent knots, a is the major semi-axis of knots b, is the minor semi-axis of knots.

During the water collection process of hollow spindle-knotted microfiber, droplets hanging on the fiber outside, and the hollow channel is sweep by water, forming water column inside. Liquid menisci formed in the hollow channel create attraction force due to the presence of a capillary bridge. Assuming the channel is horizontal, the TCL inside the microfiber (L_i) is composed of two lines and two circles, which can be expressed as: [2]

$$L_i \approx 2m + 4\pi c \quad (2)$$

Where c is the axis of joints.

Supporting analysis II

Droplet detach from single microfiber:

Sufficiently large droplets detach from the microfibers when the capillary forces cannot balance with gravity. The gravity of droplet can be expressed as:

$$G = \rho g v \quad (3)$$

where ρ, v are the density, volume of droplet, g is the gravitational acceleration.

When droplets hanging on fibers, the capillary force can be expressed as:

$$F = \gamma L \cos\theta \tag{4}$$

where γ is the surface tension of water droplets, L is the length of the three phase contact line. θ is the apparent contact angle of water droplet and fiber surface.

The component force of capillary force in the vertical direction can be expressed as:

$$F = \gamma L \cos\theta \sin\alpha \tag{5}$$

where α is the off axis angle.

When the capillary force is balance with gravity, the maximum volume can be expressed as:

$$V_m = \frac{\gamma\cos\theta\sin\alpha}{\rho g} L \tag{6}$$

According to the equation 1, the maximum volume of solid spindle-knotted microfiber can be expressed as:

$$V_m = \frac{\gamma\cos\theta\sin\alpha}{\rho g} L \approx \frac{\gamma\cos\theta\sin\alpha}{\rho g} (2m + 2\pi b) \tag{7}$$

According to the equations 1 and 2, the maximum volume of hollow spindle-knotted microfiber can be expressed as:

$$V_m = \frac{\gamma\cos\theta\sin\alpha}{\rho g} L \approx \frac{\gamma\cos\theta\sin\alpha}{\rho g} (4m + 2\pi b + 4\pi c) \tag{8}$$

Supporting analysis Ⅲ

Maximum volume of droplet captured by single hollow microfiber：

We can evaluate the maximum volume of droplet captured by hollow microfiber in Supplementary Fig. 6, The maximum volume of droplet in theory can be calculated by the equation (7): $\gamma \approx 7.2\times10^{-2}$ N M^{-1} at 25°C, $\rho = 1$ g cm^{-3}, $g = 10$ N kg^{-1}, $\theta = 70°$, $\alpha = 42°$, $m = 1369$

μm, $2a$ = 688 μm, $2b$ = 132 μm, $2c$ = 20 μm.

$$V_m = \frac{\gamma \cos\theta \sin\alpha}{\rho g} L \approx \frac{\gamma \cos\theta \sin\alpha}{\rho g} (4m + 2\pi b + 4\pi c)$$

$$= \frac{7.2 \times 10^{-2} \times 10^{-3} \times cos70° \times sin42°}{1 \times 10^{-3} \times 10 \times 10^{-3}} \times (4 \times 1.369 + 2 \times \pi \times 0.066 + 4 \times \pi \times 0.01)$$

$= 9.90$ μL

Droplet volume is calculated by $V = \frac{4}{3}\pi r_a r_b r_c$, where r_a is semi length of major axis ($2r_a$ = 2818 μm), $r_b = r_c$ is semi length of minor axis($2r_b = 2r_c$ = 2536 μm).

$$V = \frac{4}{3}\pi r_a r_b r_c = \frac{4}{3} \times \pi \times 1.407 \times 1.268 \times 1.268 = 9.48\ \mu L$$

The theory data 9.90 μL agree with the experimental data 9.48 μL very well.

References

1 Y. Hou, Y. Chen, Y. Xue, Y. Zheng and L. Jiang, *Langmuir*, 2012, **28**, 4737-4743.

2 R. Shi, Y. Tian, P. Zhu, X. Tang, X. Tian, C. Zhou and L. Wang, *ACS Appl. Mater. Interfaces*, 2020, **12**, 29747-29756.