Supporting Information

A Hybrid Bioinspired Fiber Trichome with Special Wettability for Water Collection, Friction Reduction and Self-Cleaning Behaviors

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References

Section S1. Synthesis and surface modification of Fe_3O_4 magnetic microspheres.

The Fe_3O_4 magnetic nanoparticle (NPs) was prepared according to the method as previous literature reported.[1] In brief, $FeCl_3.6H_2O$ (1.35 g) was slowly added into ethylene glycol (40 mL) by vigorous stirring, forming a uniform solution. And then, NaAc (3.6 g) and polyethylene glycol (MW = 4 000, 1.0 g) were dissolved in the solution and stirred for 20 min to obtain a homogeneous mixture. After that, the mixed solution was transferred into a teflonlined stainless-steel autoclave and then sealed to prevent the solution leakage, which was heated to 200 ℃ and maintained for 24 h with autogenous pressure. Finally, the mixture was cooled to ambient temperature, the black Fe_3O_4 NPs were collected by centrifuging for 5 min at 7000 rpm, washed with ethanol for three cycles to remove residual solvent, then fully dried at 60 ℃ for 6 h in air.

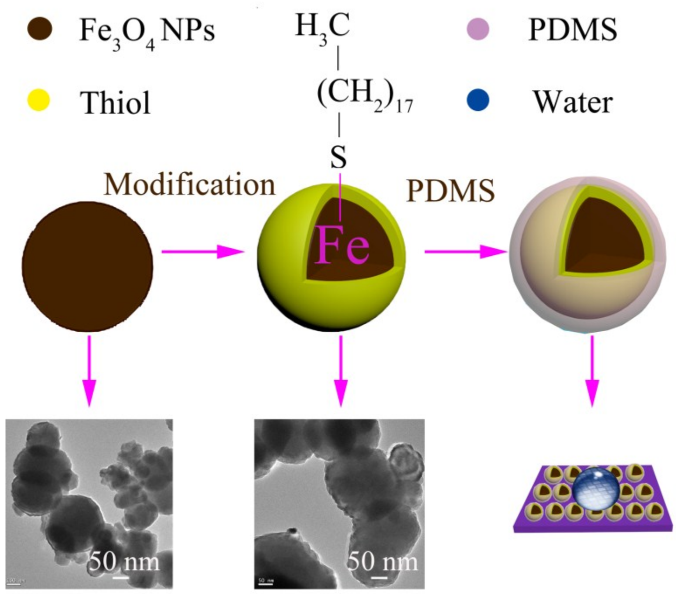

Figure S1. Surface modification of Fe_3O_4 NPs.

As shown in Figure S1, the as-prepared spherical Fe_3O_4 NPs (1.5 g) were dispersed in n-hexane (30 mL) solution which contained 1*H*,1*H*,2*H*,2*H*-perfluorodecanethiol (1.0 mM), and treated with the modification agent for 12 h at ambient temperature.[2] The resultant Fe_3O_4 NPs were harvested by a magnet and cleaned with ethanol for three times, removing the retained thiol. Lastly, the functionalizational nanoparticle was dried in a vacuum oven to obtained superhydrophobic Fe_3O_4 microspheres for the following experiments. A typical TEM image of as-prepared Fe_3O_4 NPs with the average diameter of about 300 nm, as shown in Figure S1. It was exhibited that the the modified Fe_3O_4 NPs show a regular morphology of a single nanoparticle, indicating that the modified Fe_3O_4 NPs as-prepared tended to loosely agglomerate owing to a lower surface free energy of the superhydrophobic Fe_3O_4 NPs.

Section S2. Fabrication of the bioinspired fiber trichome.

Polyester short plush fabric was degreased with ethanol and petroleum ether by Soxhlet extraction method, and washed with the distilled water to remove residual impurities. Then, the fabric dried at 60 ℃ in a drying oven. Finally, the fabric was cut into the strip specimen (50 × 5 mm) and wound around the plastic pipe with an inner diameter of 1.4 mm covered with holes, resulting that the bioinspired fiber trichome structures were prepared for the the following experiment (Figure S2).

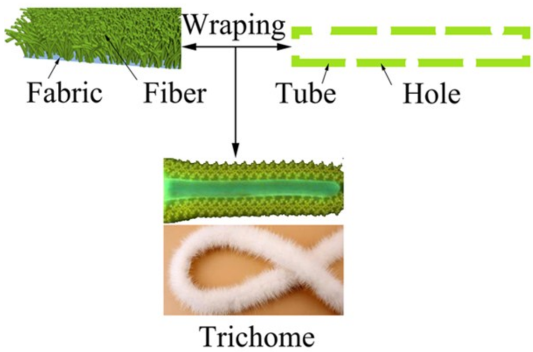

Figure S2. Fabrication process of the bioinspired fiber trichome.

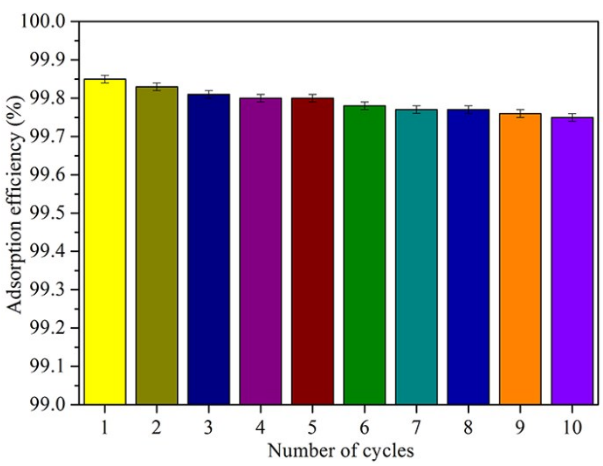

Figure S3. Oil adsorption performance of the caterpillar-inspired fiber trichome as a fuction of cycles by using n-hexane/water mixture.

Section S3. Fog harvesting experiment of the caterpillar-inspired fiber trichome.

The fog-harvesting capacity was tested by a laboratory-made humidifier system (Figure S4), and the water transferred from fog was weighted every 10 min over a period of 30 min, when no sample was settled in the fog-harvesting system, which was denoted as a blank sample to compare the water-harvesting ability. Then, the samples with micro-tip fiber array were sited on a perpendicular direction of the outlet of fog generator, which can eliminate the influence of the fog flow direction on the water motion, and the distance between the fog outlet was kept at 10 cm. A fog flow generated from humidifier was adjusted from 0.4 to 1.2 m/s, and maintained at the temperature of 25 °C, which can be kept a constant relative humidity of 80% in the fog chamber, according to the previous studies.[3] The process of fog harvesting of all as-prepared samples was recorded by using a digital camera (SONY DSC-HX200). In addition, the fog collection rate (FCR) can be described as:

$$FCR = (kx - k0)/S \qquad (2)$$

where k_x is the slope factor of the tested specimen, k_0 is slope of the blank sample, and S is the effective surface area of the tested sample. The FCR of the corresponding sample showed a approximate constant value, indicating that the fog harvesting capacity was a stable trend with the time.

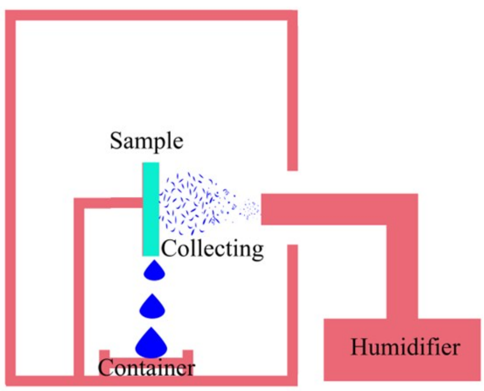

Figure S4. The schematic diagram of the laboratory-made humidifier system.

A fog droplet can be easily captured when the SHH fiber tip was exposed to fog flow with a certain speed, and then merged into the water droplets. For the SHH fiber wire, they can also show excellent capture capture performance, while extra energy was needed to capture the droplets to the SHH surface at at a certain extent.[4] The fog has to conquer the energy barrier in order to improve the fog capture capacity, and the energy relation can be expressed as the following:

$$E_k > E + W$$

where E_k is kinetic energy of the fog with a high initial velocity that generated from the humidifier, E is the barrier energy and W is viscous energy.The SHH fiber tip site could captured the fog droplets was quickly covered by a layer of water film when it was exposed to the flowing fog, which was similar to the thorn of the caterpillar for fog collection behavior.

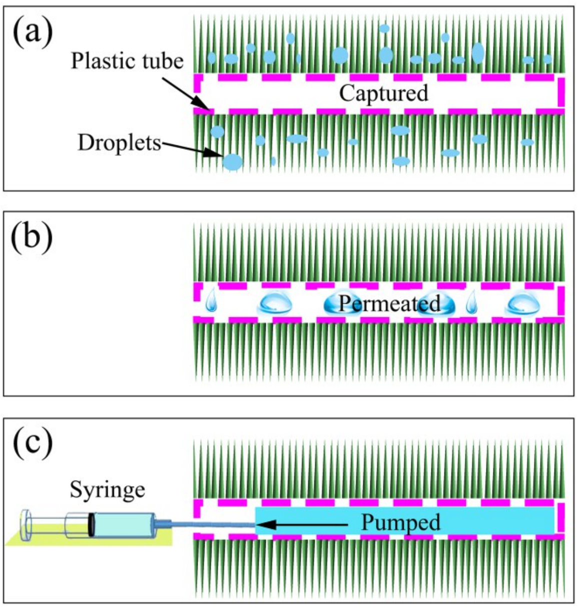

Figure S5. The schematic diagram of the continuous water transport of the caterpillar-inspired fiber trichome.

The structure of the fiber trichome is is composed of a cluster of hairlike fibers, and a fiber has an average diameter of about 0.5 μm, and the length is 3.5 mm. The superhydrophilic fiber region can be marked as “SHH tip”, and the superhydrophobic fiber region is denoted as “SHB middle”, underneath the fiber is fiber parenchyma for absorbing water, which is labeled as “SLIPS” in Figure S5.

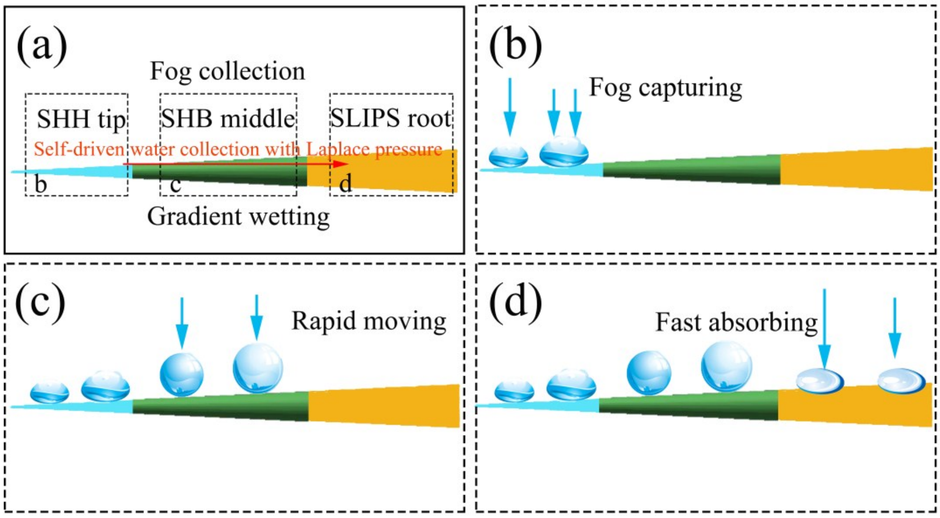

Figure S6. The structure of the caterpillar-inspired fiber trichome with gradient wetting.

Section S4. Tribology properties test of the earthworm-inspired fiber trichome.

The friction reducing and wear-resistance property of the earthworm-inspired fiber trichome can be evaluated by the tribological property of the corresponding fabric composite. The tribological properties of fabric samples were tested by using a MMQ-05G pin-on-disk tester (Jinan Yihua Tribology Testing Technology Co. Ltd, China) at ambient conditions (temperature: T = 25 ℃, relative humidity: 40%), the schematic diagram of the friction tribometer was shown in Figure S7.[5] Here, note that a round shape fabric sample is carried out to analyze the tribological property instead of the earthworm-inspired fiber structure. In the pin-on-disk tribometer, a stationary round head AISI-1045 pin can slide against the fabric composite sample that was adhered on a rotating steel disk (Ra = 0.45 μm) with or without PFPE lubricant. The steel pin with the diameter of 4.5 mm was fixed in a chuck of load arm the fixture as the friction counterface, and the distance from which to the roating axis is 10 mm, and polished with 400, 800, and 1000 grade metallographic abrasive paper successively to obtain the surface with a roughness Ra = 0.15 μm, and then washed with acetone before measurement. During the friction experiment, the round shape sample (diameter: Ø = 30 mm) was attached on the disk, which was driven for 50 min with a rotate speed of 280 r/min and a applied load of 10 N. A force transducer connected to the pin was employed to measure the frictional torque when the friction sliding was conducted, then friction coefficient (*f*) could be directly obtained from a friction-measure system controlled by computer software. Meawhile, the wear performance was obtained at the end of each test, which can be calculated as the following equation:

$$\omega = V\cdot(PL)^{-1}$$

where ω (m^3 $(N\cdot m)^{-1}$) denotes the wear rate, V (m^3) is the volume loss of the wear groove that is measured by a micrometer (precision: 0.001 mm), P (N) is the applied load, and L (m) is the friction distance.

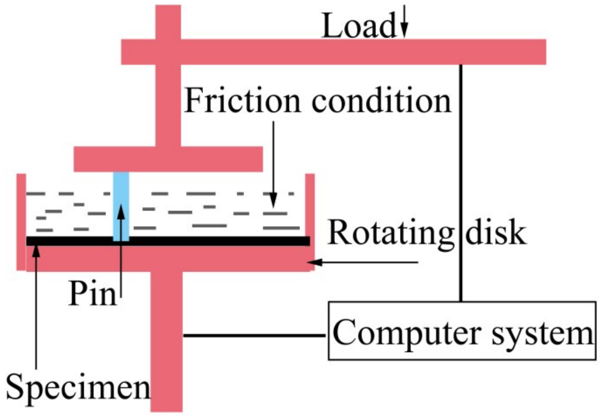

Figure S7. The schematic diagram of the friction testing device.

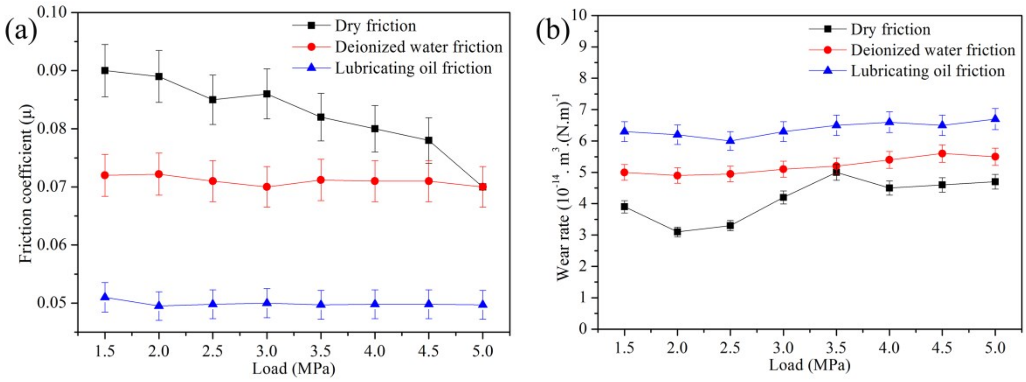

Figure S8. The value of friction coefficient (a) and wear rate (b) of the fabric sample at the different applied load.

The friction surface morphology of sample and the chemical change of counterpart pin were characterized by a scanning electron microscope (SEM, JSM–5600LV) that is equipped with an energy-dispersive X-ray spectrum (EDS). Each specimen was carried out three times experiment, and the mean value of f and ω was used. The same friction measurement procedure was followed as above except that the friction conditions was kept at the wet PFPE lubricant-bathed sliding instead of dry.

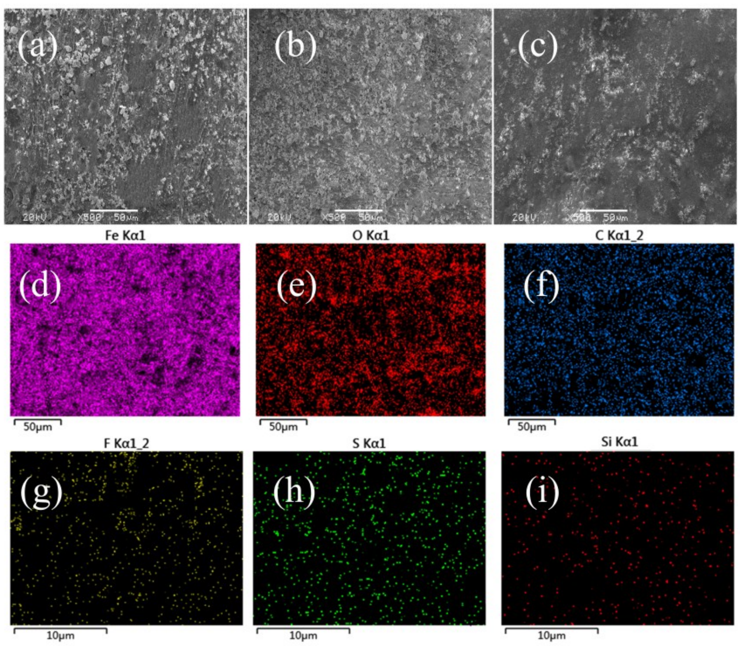

Figure S9. SEM images of the counterpart pins in the various friction medium condition: (a) dry friction, (b) distilled water-bathed friction, (c) oil-bathed friction and (d-i) EDS spectrum of the (c).

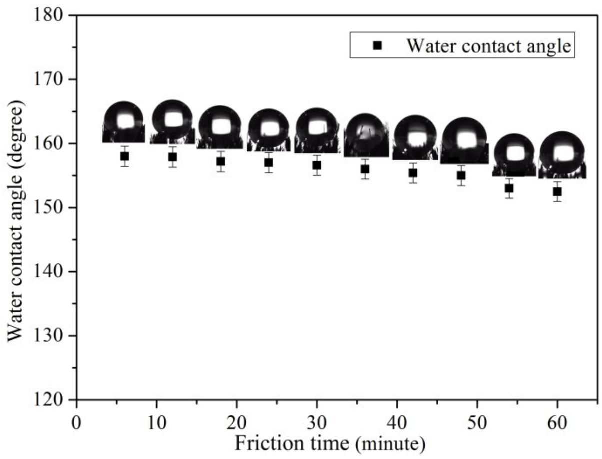

Figure S10. The value of water contact angle of the fabric worn surface as a function of friction time.

Section S5. Antifouling properties test of the earthworm-inspired fiber trichome.

Based on the related self-cleaning mechanism, [6] the antifouling effect of fiber trichomes can be tested by the alizarin red of water-solubility powder as contaminant (Figure S11), and the lubricating oil was injected by a syringe into the plastic tube, which is similar to the self-cleaning effect of the alive earthworm in the living environment.

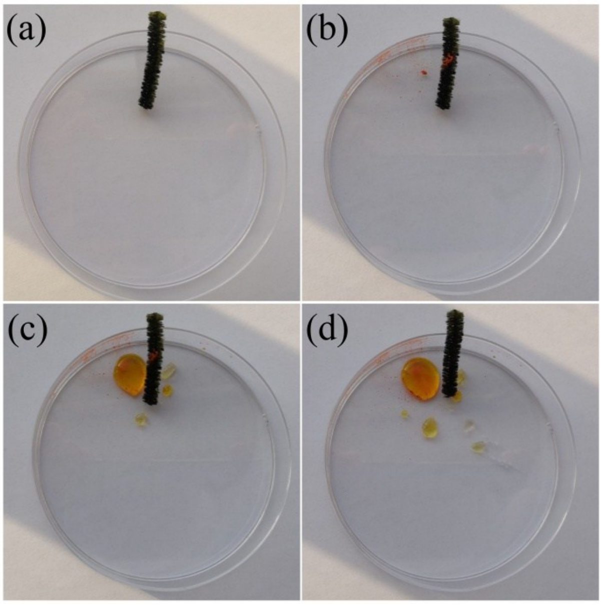

Figure S11. The self-cleaning characteristics of the earthworm-inspired fiber trichome.

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