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Article

Ultrafast Self-Propelled Directional Liquid Transport on the Pyramid-Structured Fibers with Concave Curved Surfaces

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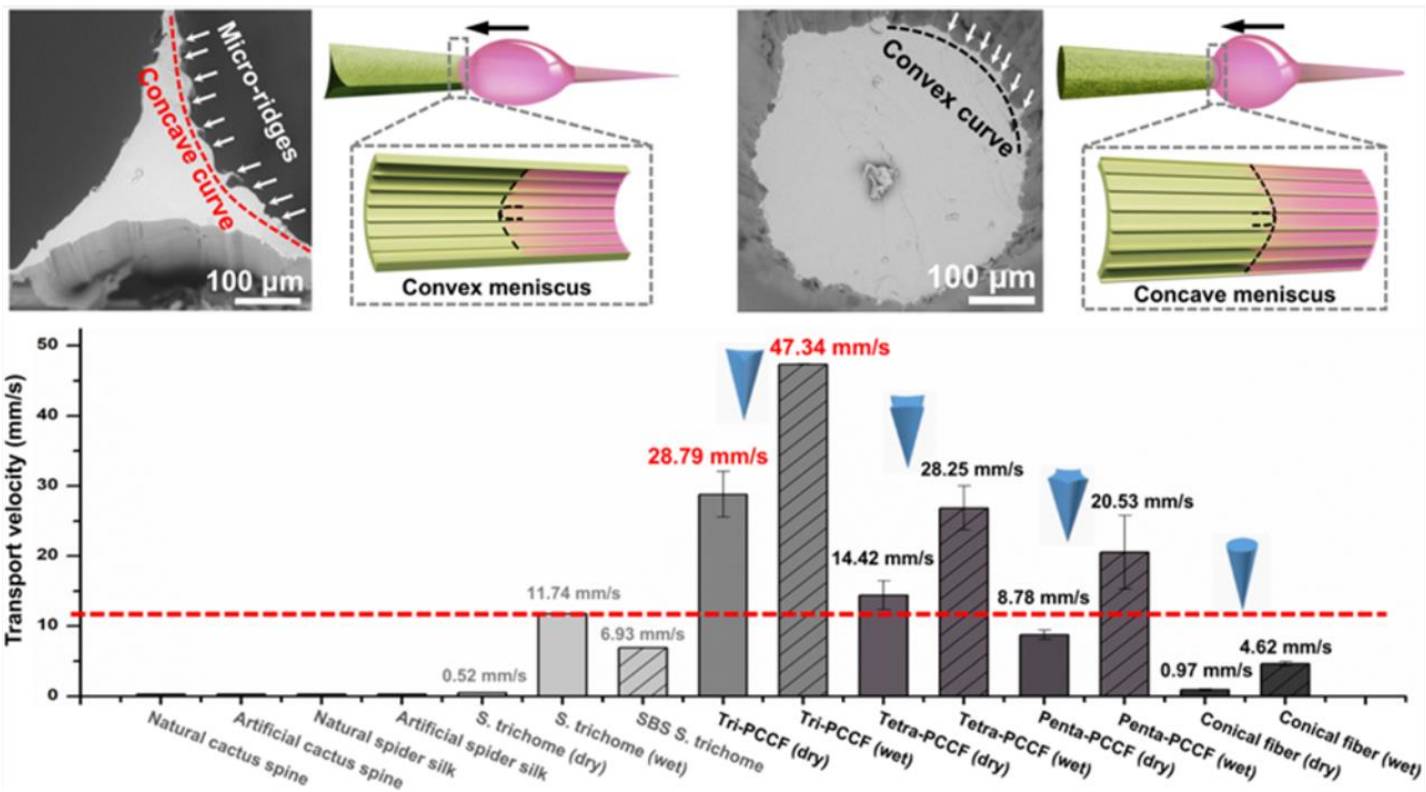


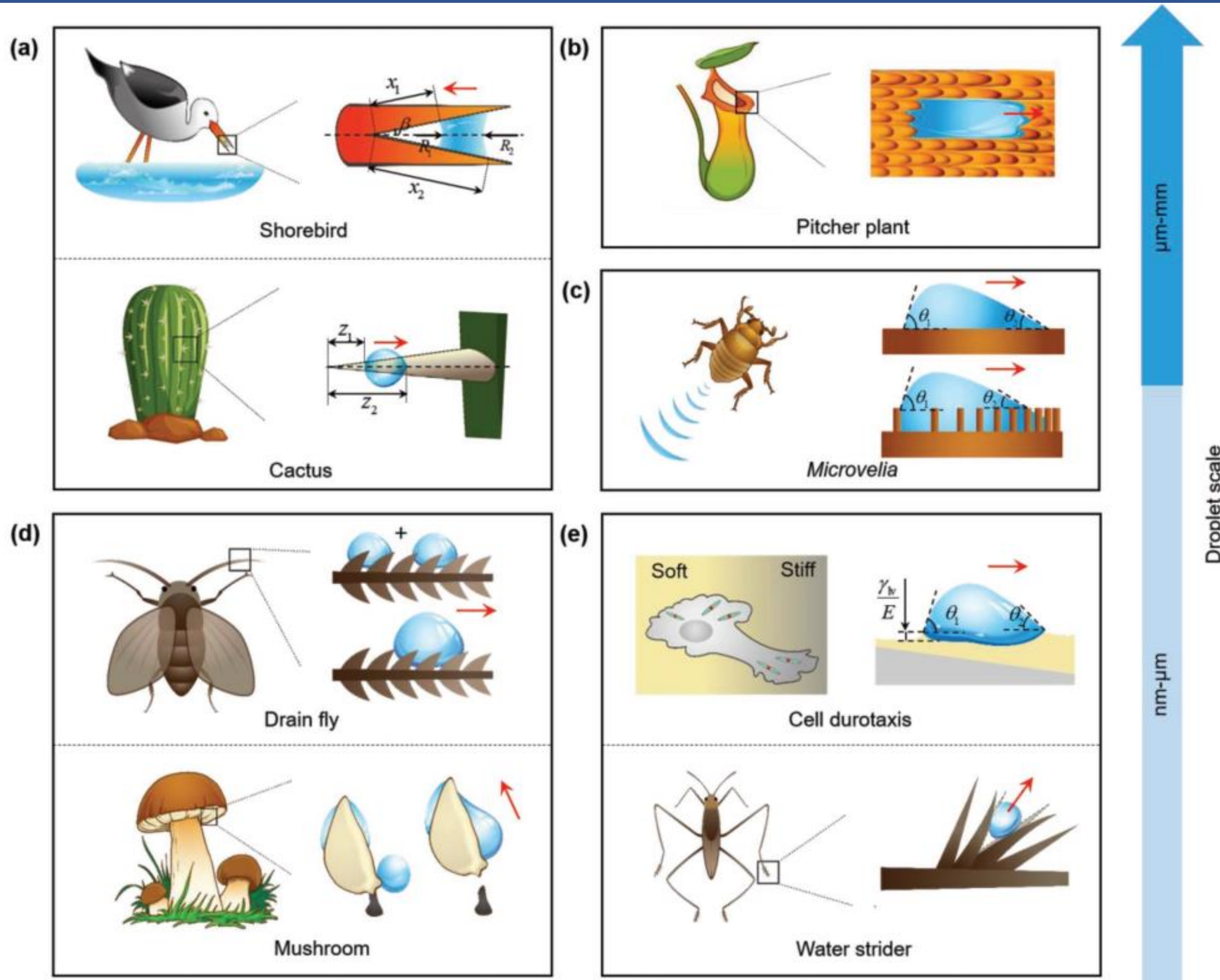
Paper presentation

32nd Group meeting

19-09-2020

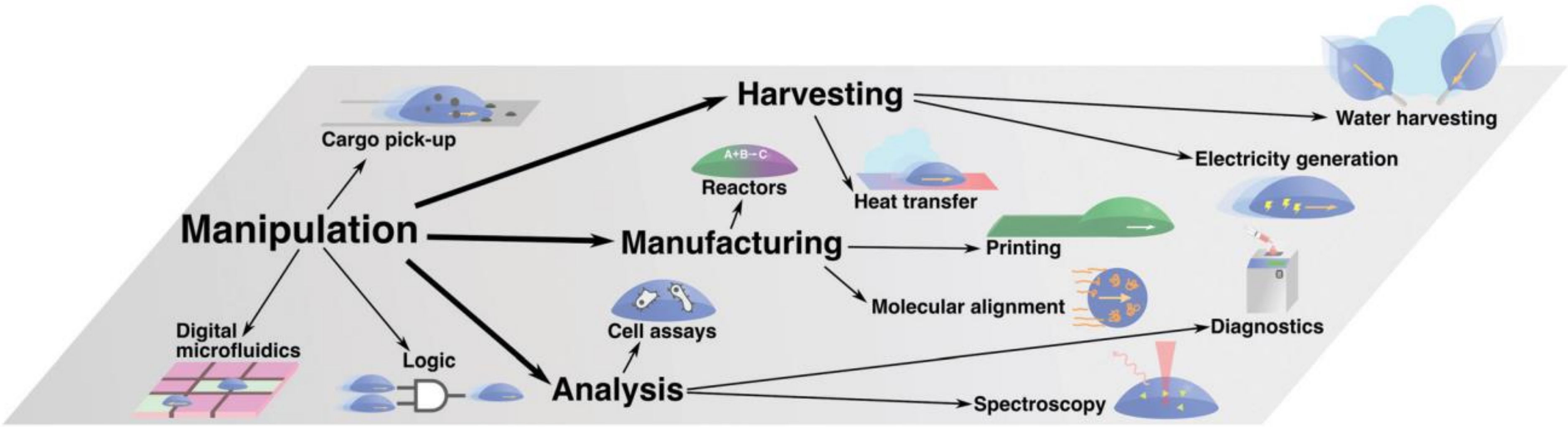
Ankit Nagar

Directional liquid transport in nature



Li, J.; Li, J.; Sun, J.; Feng, S.; Wang, Z *Advanced Materials* **2019**

Applications (Relevance to the group)



Malinowski, R.; Parkin, I.P.; Volpe, G. *Chemical Society Reviews* **2020**

Introduction

- Low transport velocity reported so far (ca. 3-30 μm/s).
- In this paper: A novel pyramid-structured fiber with concave curved surfaces (P-concave curved-fiber, PCCF), which enables ultrafast SDLT even on a dry surface.
- Maximum velocity for water on a tri-PCCF is up to ca. 28.79 mm/s, which is over 50 times and 2 times faster than that on a dry (ca. 520 μm/s) and a wet (ca. 11.74 mm/s) surface of a *S. trichome*, respectively
- A new perspective for fabricating open fibrous systems for both microfluidic and liquid manipulation.

Pyramid-structured fibers

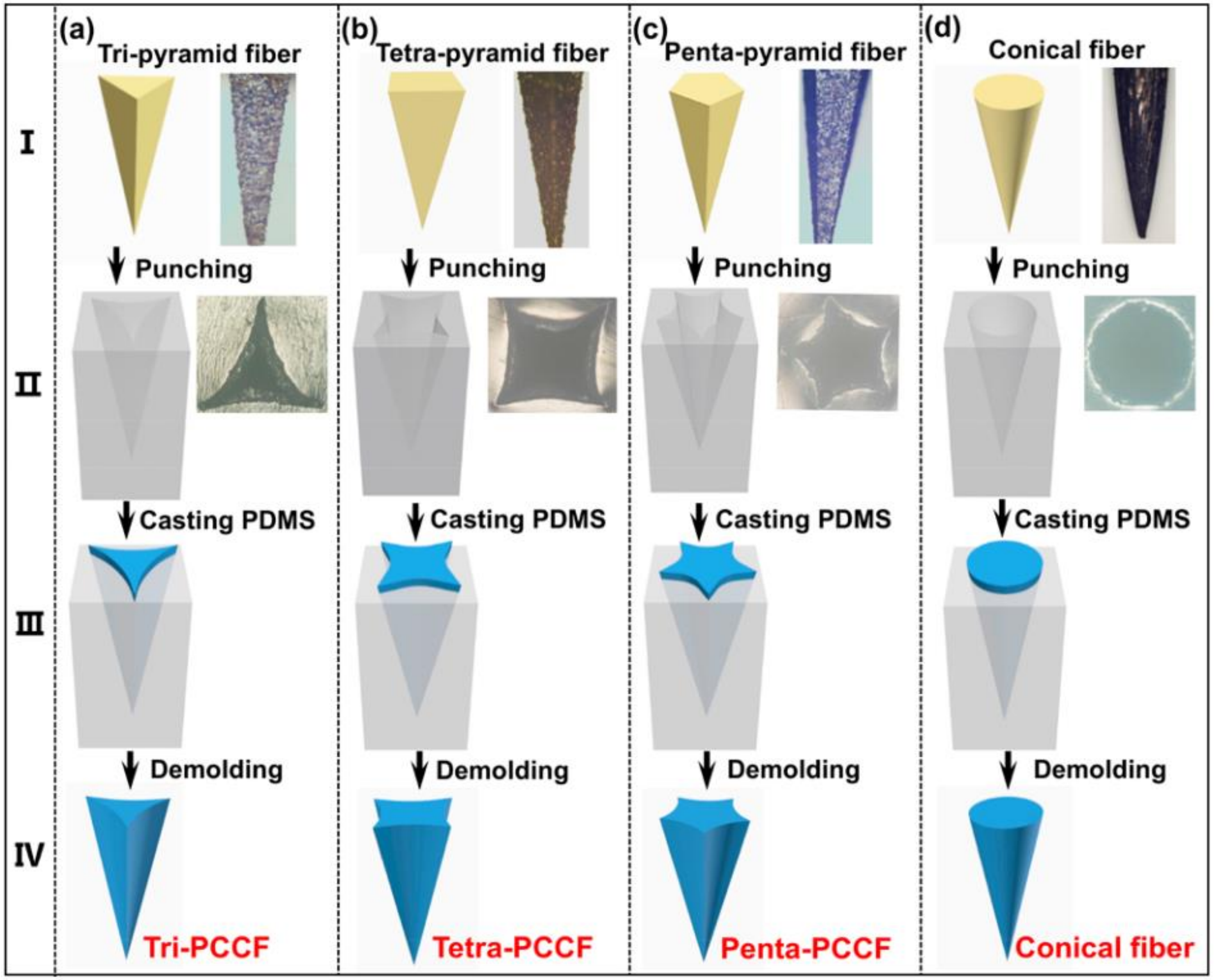


Figure 1. Schematic diagram for the PCCFs fabrication process, including steps of punching a structured hole on a soft PE substrate using the pyramid structured needles, casting PDMS solution on the substrate, and demolding. As a result, the tri-PCCF (a), tetra-PCCF (b), penta-PCCF (c), and conical fiber (d) were prepared. (Insets) Optical pictures of the needles and the cross-section image of the structured hole in PE substrate.

Surface characterization

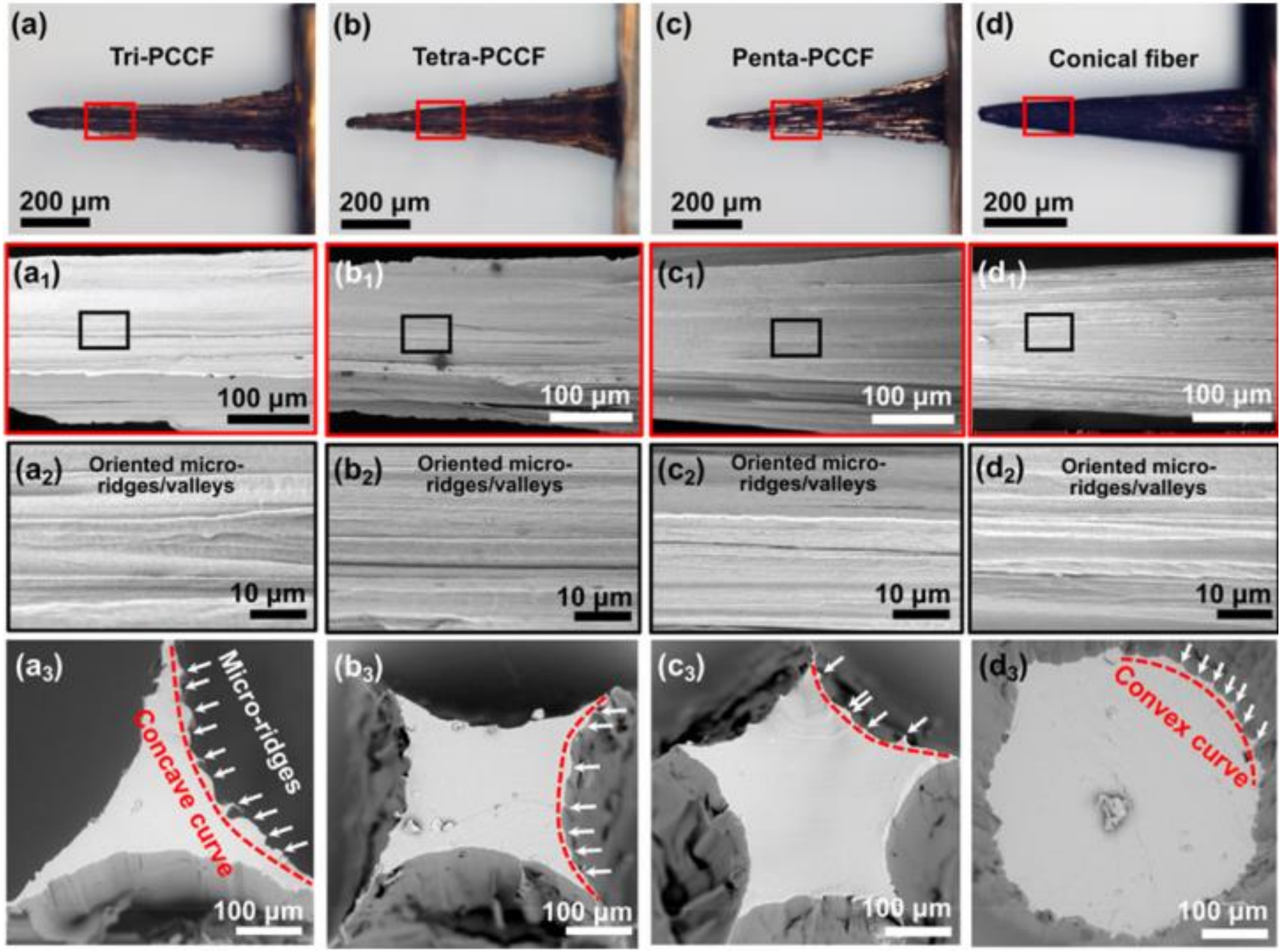


Figure 2. Microstructural characterization of the as-prepared PCCFs. (a-d) Optical images show typical tapered structures with a length of ca. 2.0 mm. (a1-d1, a2-d2) Side-view SEM images under different magnifications, and (a3-d3) cross-section SEM images show both the concave curved surfaces and the microridges/valleys microstructures.

In situ transport behavior

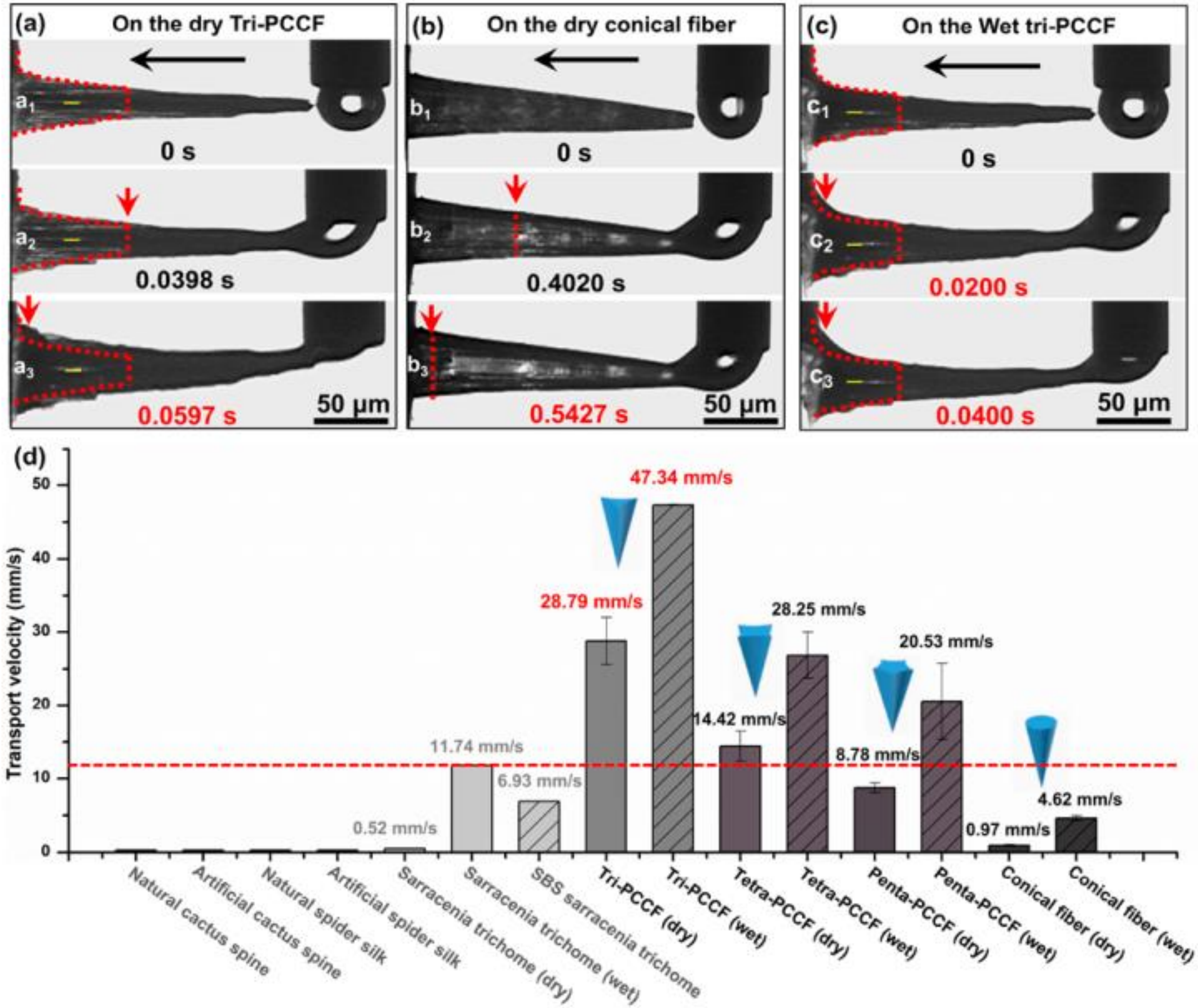


Figure 3. In situ SDLT behavior on (a) a dry surface of the tri-PCCF, (b) a dry surface of the conical fiber, and (c) a wet surface of the tri-PCCF. (d) Summary of the SDLT velocity on different substrates: gray characters indicate the reported value in references, and others are from this work.

Transport mechanism

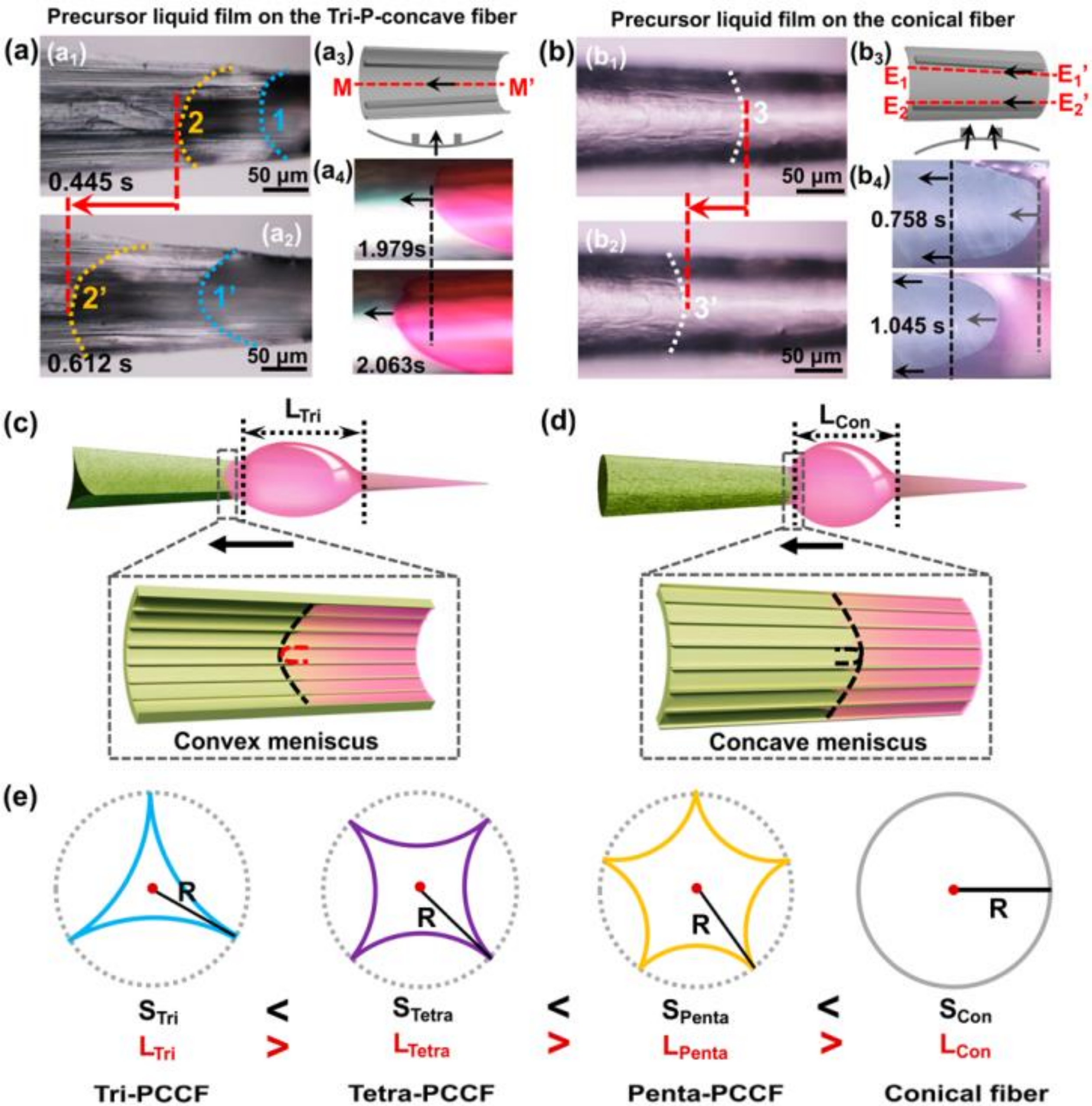


Figure 4. Mechanism of the ultrafast SDLT behavior on the PCCF. (a) Advancing meniscus of the liquid on the PCCF shows typical convex shape, as monitored using the artificial concave curved surface with oriented ridges. (b) Advancing meniscus of liquid on the conical fiber shows typical concave shape, as monitored using the artificial convex curved surface with oriented ridges. (c, d) Schematic cartoon of the selfpropelled liquid droplet on (c) the tri-PCCF and (d) the conical fiber, where the length (L) covered by the liquid was indicated as L_{Tri} and L_{Con}, respectively. (e) Cross-sectional image of the tri-, tetra-, and penta-PCCF and the conical fiber.

Effect of conicity and curvature

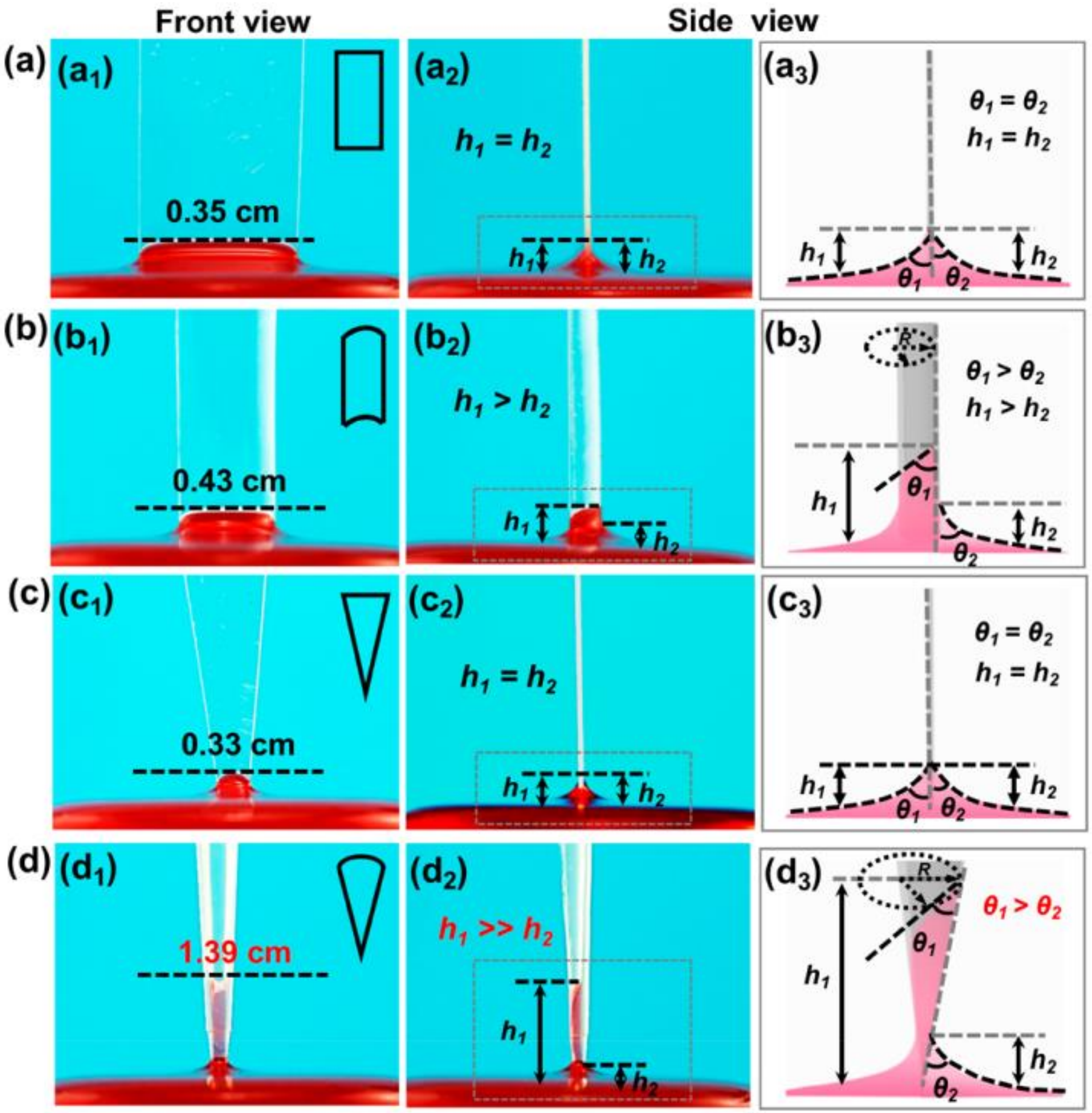


Figure 5. Effect of the conicity and curvature of the substrate on the capillary rise behavior for (a) the rectangular plate, (b) the concave curved rectangular plate, (c) the conical plate, and (d) the concave curved conical plate. Front view (a_1-d_1) and side view (a_2-d_2) show different capillary rise height on different substrates. Maximum height was observed on the concave curved conical plate (d). (a_3-d_3) Schematic cartoons. For both concave curved substrates (b, d), the heights on two sides of the plate are different ($h_1 > h_2$, $h_1 \gg h_2$).

Underwater ultrafast transport of oil

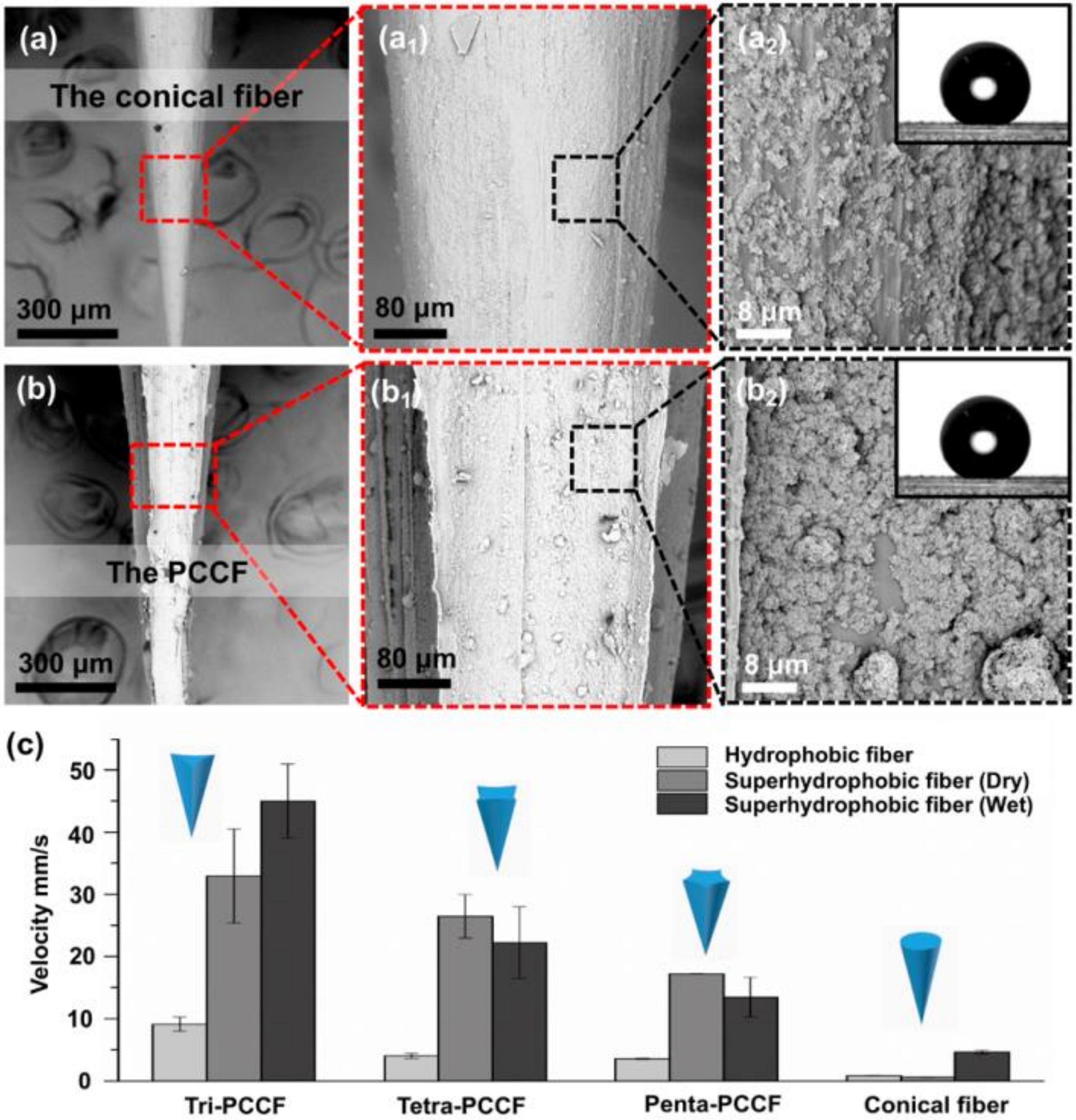


Figure 6. Ultrafast SDLT behavior for the oil of 1,2-dichloroethane on the PCCFs underwater. Surface structural characterization of (a) the superhydrophobic conical fiber and (b) the superhydrophobic PCCF. (c) Summarized velocities of SDLT of oil underwater on the dry and wet superhydrophobic PCCFs.

Conclusions

- Novel structured fibers, characterized by the concave curved surfaces and the surface-oriented microridges/valleys, which enabled ultrafast SDLT.
- Maximum velocity of liquid transport even on a dry tri-PCCF can reach a rather high value of ca. 28.79 mm/s.
- The velocity is even faster on the wet PCCF with a value of up to 47.34 mm/s.
- It is proposed that the capillary rise imparted by the concave curved surfaces and the oriented micro- ridges/valleys accelerates the SDLT, while the F_L induced by the tapered structure determines the liquid transport direction.