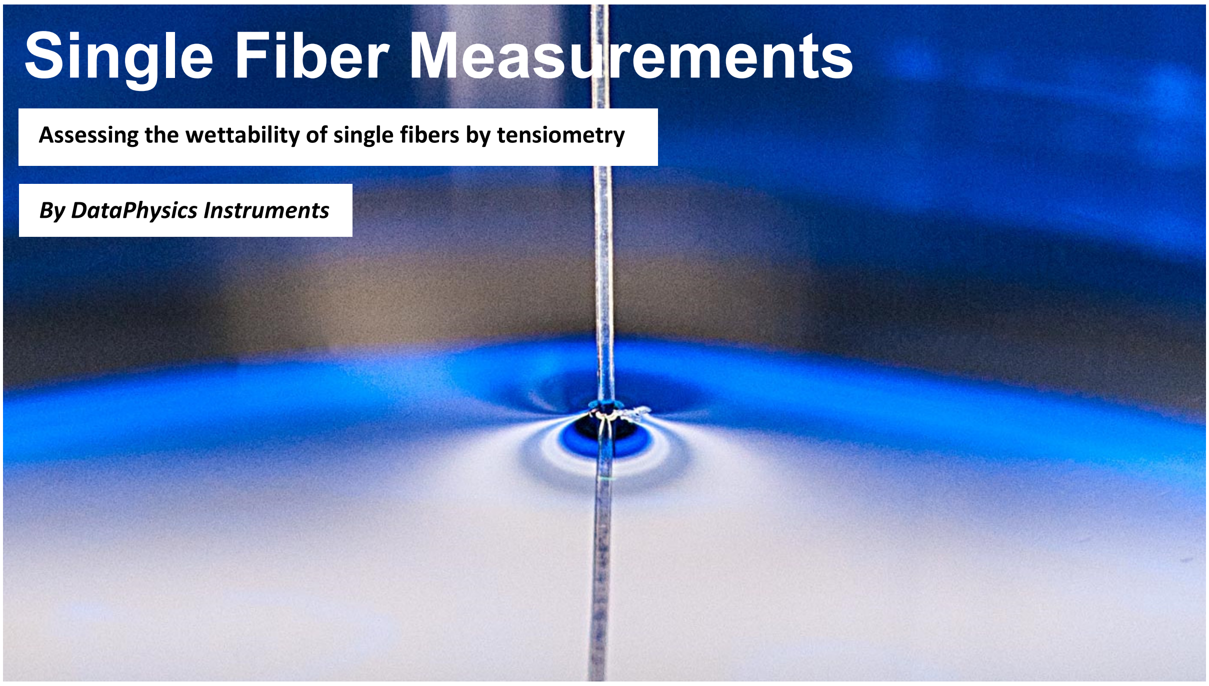
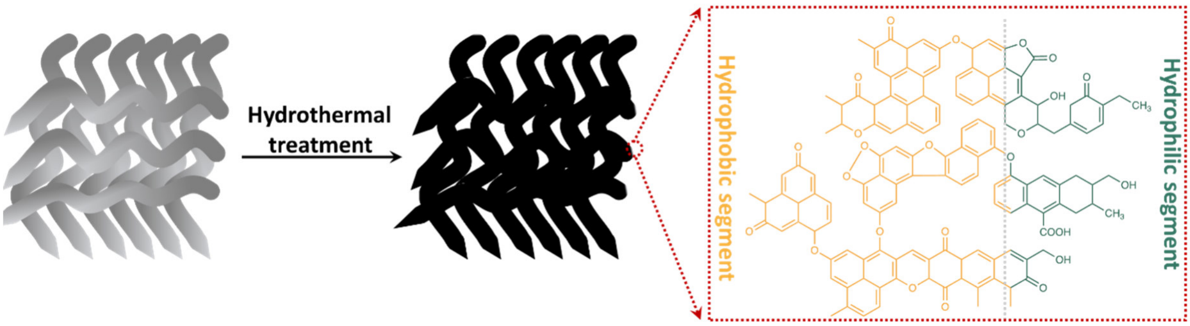
How single fiber measurements can help to develop materials for waste- and seawater purification.



With the fast development of economy and society, pollution like discharged organic solvent or water/oil emulsions seriously affect our ecological environment and human health. Solar steam generation, as one of the most efficient ways of purification, has drawn more and more attention to sea- and wastewater purification. Most photochemical materials are however physiochemical instable in presence of organic solvents. This lack drives the research on photothermal materials with a long-term stability and good resistance to organic solvent or salt water that also have the capability to pump water or organic solvents out during the purification process. Up to now, commercial carbon fibers have caught scientists' eyes due to the following advantages: high mechanical strength, excellent chemical resistance, thermal stability and light weight. Notably, carbon fibers possess enough capillary force to pump water or solvents during the purification process. Unfortunately, they have an extremely poor solar absorption and polar solvent absorption due to their dense surface and low polar contribution to the surface energy. To improve their solvent affinity, Tiantian Li et al. recently have reported a hydrothermal carbonization method to fabricate carbon fibers with a rough structure and a high degree of polar functional groups on the surface to increase wettability.

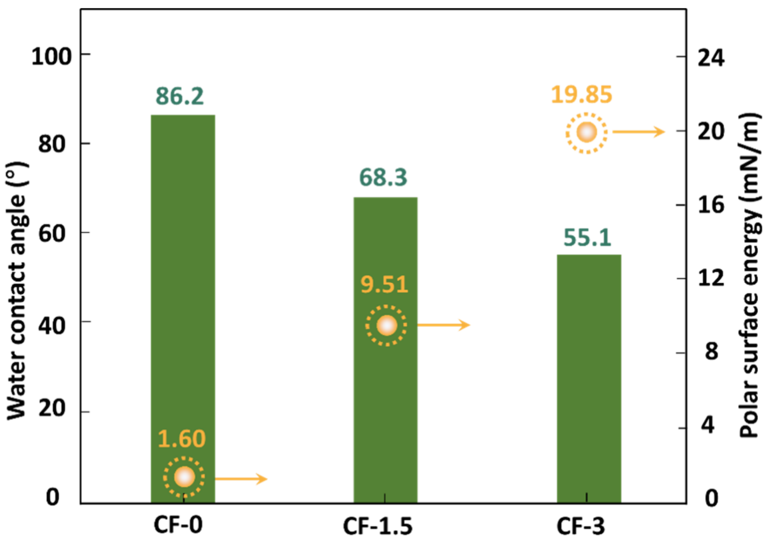
In this work, the researchers fabricated hydrothermal carbon layers by introducing multiple functional groups on the surface, as shown in **Picture 1**. First, they treated the carbon fibers by hydrothermal carbonization of glucose with different concentrations (1.5 wt%, 3 wt%) at

200 °C, and produced materials named CF-1.5 and CF-3, respectively. The pristine carbon fibers as control group were named CF-0. After the glucose dehydrated, polymerized and condensed, the aromatic amphiphilic macromolecules with carboxyl, carbonyl and hydroxyl groups would form micelles and attach to the carbon fibers surface via hydrophobic interaction **(Picture 1)**.



Picture 1: *Carbon fiber hydrothermal carbonization procedure.*

After treatment, the neat and smooth surface (CF-0) would change to rough and fuzzy ones (CF-1.5 and CF-3). For composition analysis, the three samples all contained oxygen and carbon elements. But the oxygen/carbon ratio and C–O and C=O groups amount would increase after treatment—which would greatly improve water wettability and polar surface energy of the carbon fibers **(Picture 2)**.

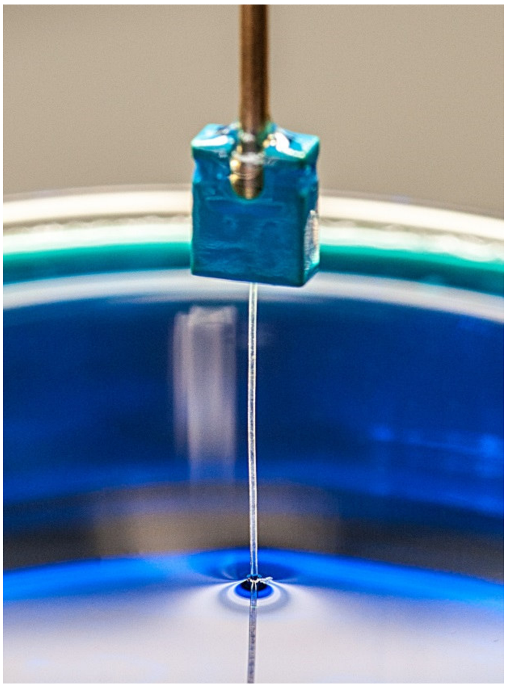


Picture 2: *Single fiber water wettability and polar surface energy for CF-0, CF-1.5 and CF-3.*

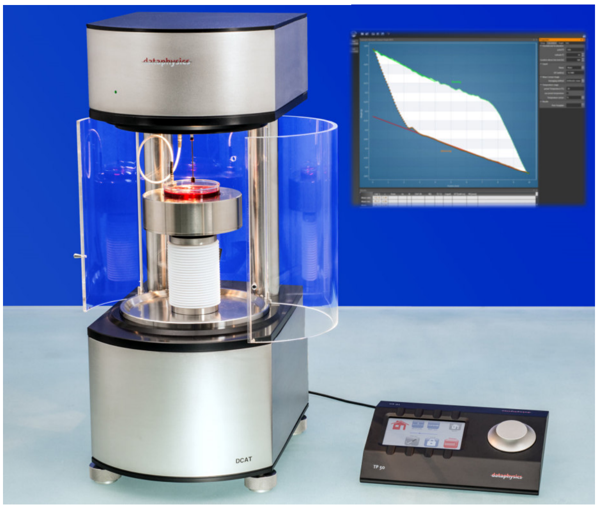
To further study the effect of hydrothermal treatment on the single fiber water wettability and polar surface energy, the researchers conducted measurements by using the Dynamic Contact Angle measuring devices and Tensiometer DCAT from DataPhysics Instruments. The water contact angles of CF-0, CF-1.5 and CF-3 were 86.2°, 68.3° and 55.1° respectively, indicating that the water contact angle would decrease with increasing glucose concentration. The polar surface energy of CF-3 (19.85 mN/m) was 12.4 times higher than that of CF-0, and 2.1 times higher than that of CF-1.5. Overall, the introduction of carboxyl groups (–COOH) and hydroxyl groups (–OH) greatly improved both properties.

Single Fiber Wettability Studies

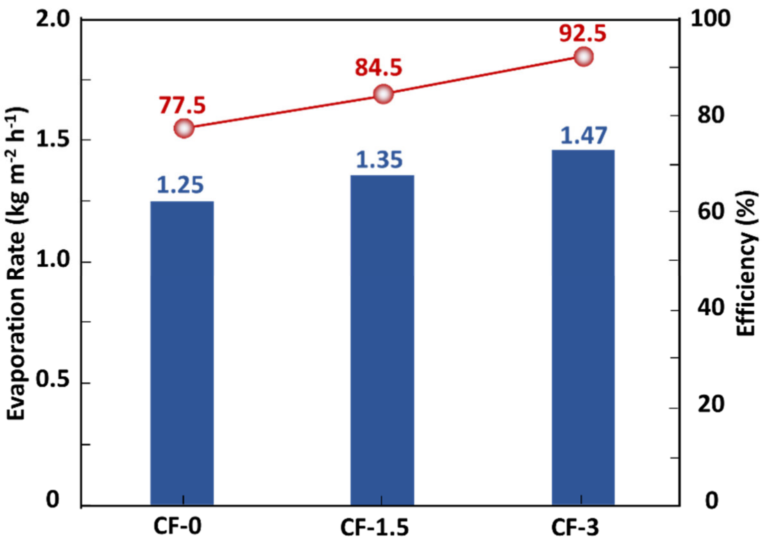
The **wettability of single fibers** can be studied with a **tensiometer** using the Wilhemly-Method by immersing the fiber in the testing liquid of interest and slowly rising and lowering it. This causes a **wetting and dewetting** of the fiber surface and the mass of the lamella that forms is recorded by the tensiometer. From this data the dynamic wettability can be assessed as quantified by **dynamic contact angles**. From these dynamic contact angles the **surface free energy** and thus the **surface polarity** can be calculated.



The **DCAT 25 and 25SF** from DataPhysics Instruments are the ideal choice for single fiber measurements.

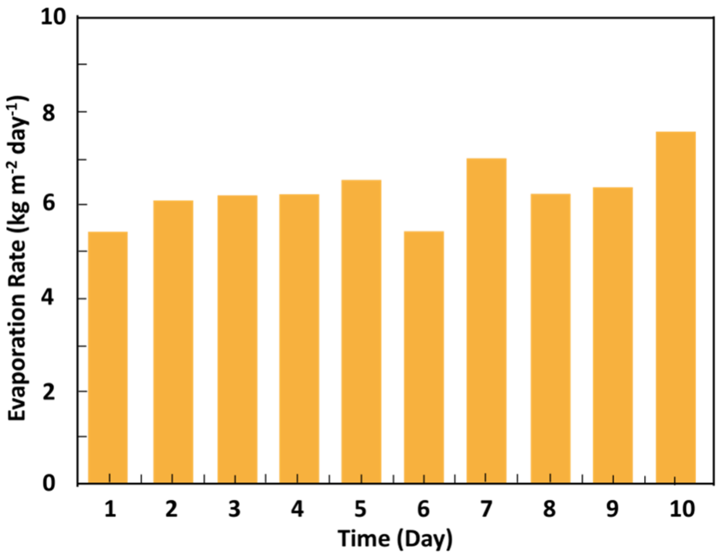


Furthermore, the authors tested the solar absorption ability of all three samples. Due to the rougher surface, the absorption ability of CF-3 (~93.0%) is highest (**Picture 3**). They also built a small-scale module with PS foam as insulator and tested the simulated seawater purification performance revealing that CF-3 has the highest evaporation rate of 1.47 kg/m^2 per hour **(Picture 3)**.



***Picture 3**: Evaporation rate and efficiency under sun illumination.*

They attributed the better performance to three advantages of this solar steam generation system: improved wettability for water supply by higher capillary forces (due to a hierarchical surface), higher solar absorption due to reduction of sunlight reflection, and minimized conduction heat loss. Hence, they chose CF-3 as the model material, and applied it for various solution purifications such as highly concentrated seawater, oil-in-water emulsion and dyed organic solution. For seawater, they found the average water production over ten consecutive days from seawater was as high as 5.4 kg/m^2 per day due to the outstanding anti-salt property of CF-3 (**Picture 4**); For oil-in-water emulsion, the evaporation rate was 1.25 kg/m^2 per hour and the oil content of the distilled water was only 11.9 ppm. For dyed organic solution, the evaporation rate was 0.98 kg/m^2 per hour and the dyes could be easily removed. Moreover, they did not see any deterioration of tensile strength for CF-3 after immersion into organic solvent or concentrated salt solution for 10 days.



Picture 4: *Collected water out of simulated Dead Sea water under natural sunlight.*

In summary, the authors illustrated a novel purification system based on modified carbon fibers with increased polar surface energy and sunlight absorption which can efficiently purify various polluted solutions and pump water and organic solvent by enhanced capillary force. Notably, these materials have a good long-term stability even immersed in organic solvent or highly concentrated salt water. This solar steam generation system holds a considerable promise of being applied for purifying polluted liquid and satisfying the daily drinking water demands in the future.

The Dynamic Contact Angle measuring devices and Tensiometer DCAT (DataPhysics Instruments GmbH, Germany) was used in this research.

For more information, please refer to the following article:

Ultra-robust carbon fibers for multi-media purification via solar-evaporation; Tiantian Li, Qile Fang, Xianfeng Xi, Yousi Chen, Fu Liu; *J. Mater. Chem. A,* ***2019****, 7, 586*; DOI: 10.1039/c8ta08829b