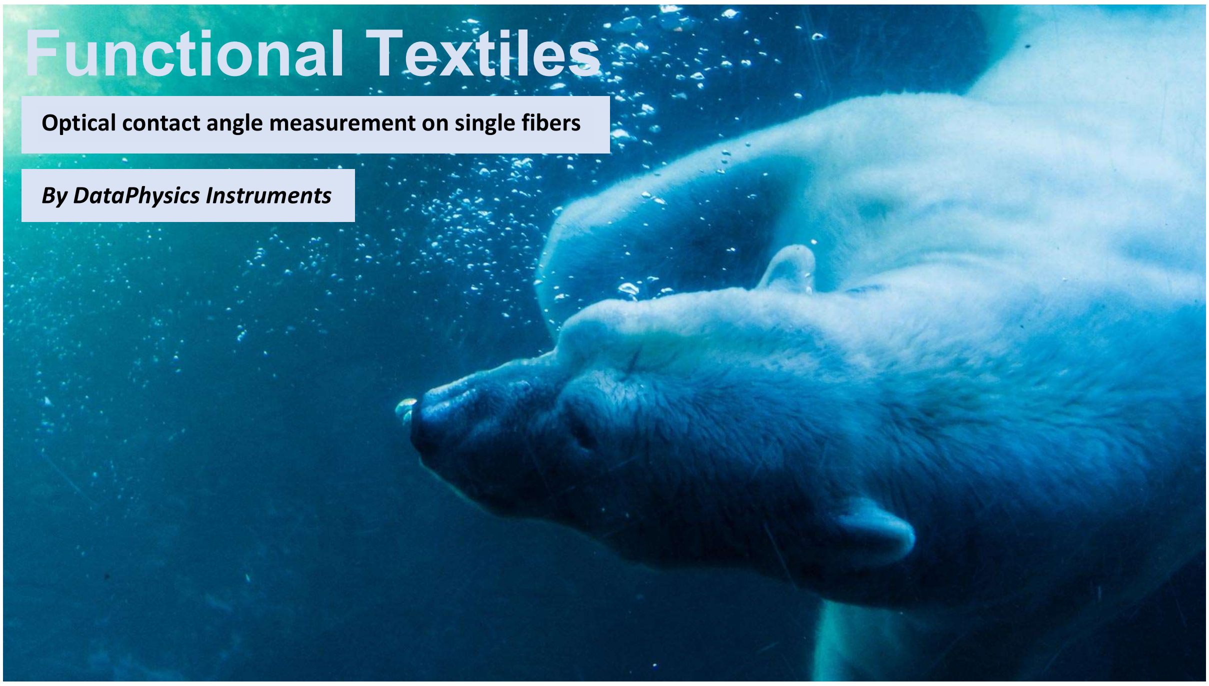
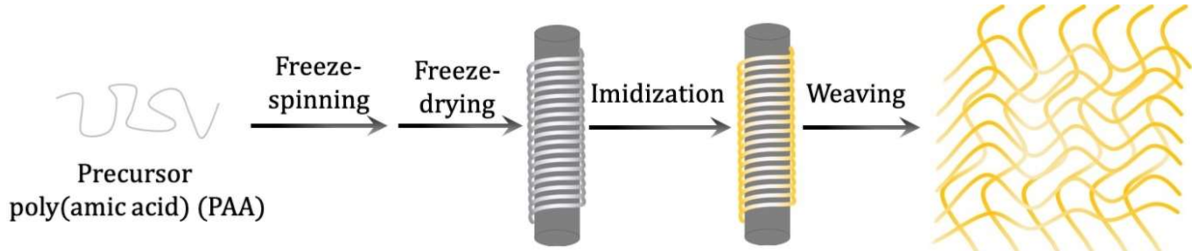
How contact angle measurements can help to develop multifunctional textiles inspired by polar bear fur.



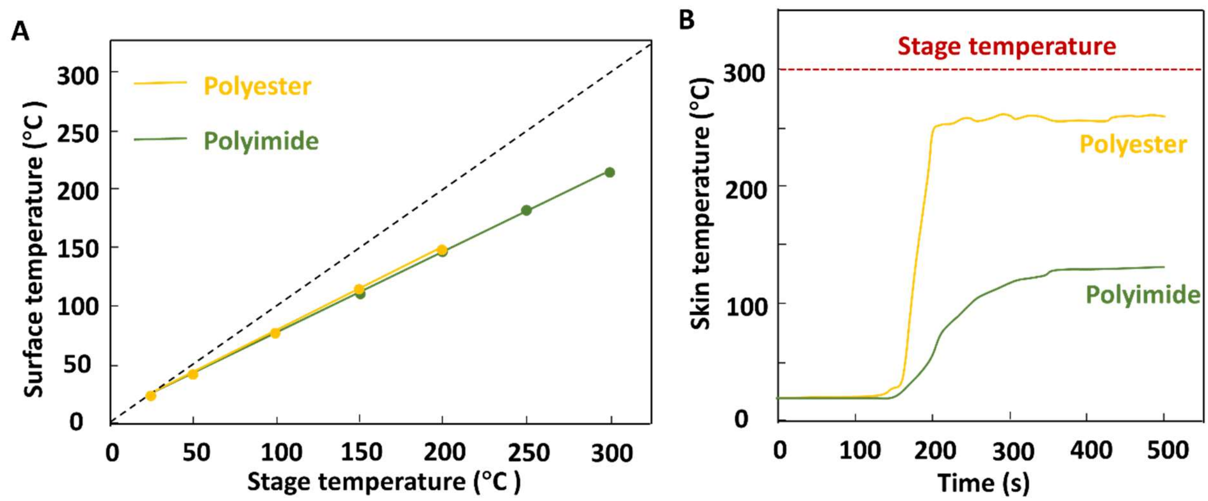
When exposed to an extremely hot environment, maintaining body temperature plays a crucial role for human health. For example, workers in the metallurgy, mining, or glass industry need special equipment to protect themselves from excess heat, thus keeping their productivity and reducing the risk of heat-related illness. However, their mobility will be largely limited due to the heaviness and specific requirement of the currently used complex equipment. There is an urgent need to design smart protective clothing with excellent thermal insulating performance and heat tolerance for workers. As a basis material, polyimide with its high heat-resistant (even up to 500 °C) seems attractive but it has a poor mechanical strength due to high porosity. One of the best examples for a perfect balance between wearability and thermal insulating properties is polar bear hair. Inspired by it, Yujie Wang and team have recently reported an aerogel textile woven with porous polyimide fibers to mimic the complex microstructure of polar bear hair which is characterized by a well-defined hierarchical architecture featured as aligned shell and randomly porous core.

In this work, the authors used a freeze-spinning method to generate aligned porous structures of synthetic fibers (**Picture 1**), which is quite challenging when using other currently available techniques like melting spinning, electrospinning and templating. By controlling the pore size the mechanical strength of polyimide fibers could be drastically improved. When the freezing temperature during freeze-spinning process decreased from -30°C to -196 °C, the average pore size of the fiber would decrease from 70 ± 9.3 μm to 25 ± 8.4 μm. After mechanical tests, they chose the fibers with a medium pore size (40 ± 9.7 μm) and an aligned porous structure for further weaving operation, because this fibers group showed the highest strength, modulus, and the largest elongation.



Picture 1: *Scheme of biomimetic polyimide fiber and textile preparation process.*

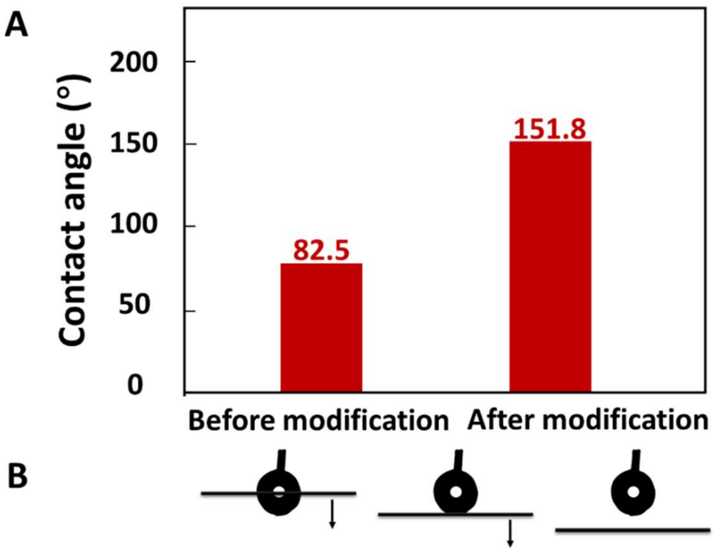
To study the thermal insulating performance and heat tolerance, the researchers applied both polyimide their aerogel textile and a commercial polyester textile (control group) on the same hot stage to compare their surface temperature. As shown in **Picture 2A**, at 25 °C, the average surface temperatures of polyimide and polyester textiles were 23.4 and 23.6 °C respectively; at 300 °C, the polyester textile melted while the polyimide textile still kept its thermal insulating property (average surface temperature 210.5 °C).



Picture 2*: (A) The surface temperatures of both textiles against the stage temperature (dotted line) (B) Temperature of both the polyester and polyimide finger-cots*

Furthermore, they demonstrated their potential as thermal protective clothing for workers who often contact molten metal splashes. **Picture 2B** shows that before touching the hot stage at 300 °C, both polyester and polyimide finger-cots remained at 19 °C (room temperature); after touching, the temperature of polyester finger-cots rapidly increased to around 262 °C with melting phenomenon, while the temperature for polyimide finger-cots increased much slower until 132 °C. In addition, after touching for 3 min, the polyester finger-cot was completely destroyed while the polyimide finger-cot did not change too much. As a whole, polyimide textile showed better thermal insulating performance and heat tolerance than a commercial polyester textile.

Moreover, the researchers illustrated the multifunctionality of modified polyimide textiles. Contact angles measurements were taken by an optical contour analysis system OCA 50AF from DataPhysics Instruments to compare the wettability before and after modification. The data shows that the modification greatly improved the hydrophobicity of polyimide fibers with an increase of water contact angles from 82° to 151° (**Picture 3A**). There is no obvious water residue when pulling the fiber out of a water droplet indicating that the fiber surface is superhydrophobic and has a low hysteresis of water (**Picture 3B**). This improves the resistance to both alkali and acid solutions. In addition, acid solutions easily damage unmodified polyimide textiles while the modified material stayed intact.



Picture 3: *(A) The contact angles of polyimide fibers before and after surface modification; (B) pulling out the polyimide fiber surface from a water droplet.*

Overall, the authors creatively fabricated excellent thermal insulating clothing inspired by polar bear hair by using freeze-spinning technology. Due to the hierarchical microstructure and intrinsic high temperature resistance, polyimide aerogel textile showed great thermal insulating performance even at 300 °C. In addition, polyimide aerogel textile can be easily multifunctionalized, thus possessing good resistance to both acid and alkali and thermoregulating capability.

An optical contour analysis system OCA 50AF (DataPhysics Instruments GmbH, Germany) was used in this research.

For more information, please refer to the following article:

Multifunctional polyimide aerogel textile inspired by polar bear hair for thermoregulation in extreme environments; Yujie Wang, Ying Cui, Ziyu Shao, Weiwei Gao, Wei Fan, Tianxi Liu, Hao Bai; *Chemical Engineering Journal,* **2020**, 390, 124623; DOI: 10.1016/j.cej.2020.124623