6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Self-healing super-hydrophobically coated fiber prepared by plasma treatment

Ying Guo[1,2],Peiru Zhang[1,3], Xuanying Guo[1,2],Chenzi Lu[1,2], Jianjun Shi[1,2]

[1] College of Science, Donghua University, China,[2]Magnetic Confinement Fusion Research Center, Ministry of Education of the People's Republic of China, [3] State Key Laboratory for Modification of Chemical Fibers and Polymer Materials, College of Materials Science and Engineering, Donghua University, Shanghai 201620, China

Corresponding Author E-mail: guoying@dhu.edu.cn

Superhydrophobic（SH） fabrics show great potential for use in functional gear, clothing, and other applications; however, the introduction of toxicity and degraded wearing comfort restrict their applications. However, SH fabrics are not durable against laundering where the surface coatings can be easily destroyed by abrasion[1]. Uniform wrinkles are created due to the surface instability of PDMS coating induced by Ar-plasma generated gradient crosslinking. Both the surface topographies of the wrinkles and the viscoelasticity of the underlying compliant layer endowed the treated fabrics with extraordinary super-hydrophobicity durability, withstanding 800 standard laundries or 1000 rubbing cycles under 44.8kPa. Additional, SH fabrics are self-healable after heating or plasma treatment. Our approach paves a new way to design ultra-durable and fluorine-free fabrics by engineering soft skins on fabric fibers with periodic sub-micron surface topography and modulus gradient.

As illustrated in Figure 1a, the preparation of SH fabrics involves two steps: dip-coating of PDMS precursor and radio frequency capacitively-coupled Ar-plasma (RF-CCP) treatment. Figure 1b demonstrated the evolution of wrinkle morphologies at different plasma treatment time. The surface topography is just like the soft earthworm which is wrapped by periodically wrinkled skin (Figure 1c). After 80 s treatment, a high aspect-ratio fold pattern was formed, which gradually smoothed out after longer treatment.

The Ar plasma treated PET fabric exhibited exceptional laundering durability, maintaining super-hydrophobicity after at least 800 cycles according to a standard procedure (AATCC 61-2006-2A); even after 1500 laundering cycles, WCA was still as high as ~145° and the sliding angle (SA) was ~ 20°. Our PDMS wrinkle coated PET fabric is even superior than fluorine-containing material coated fabrics in terms of washing durability. To elucidate the reason behind the unprecedented laundering performance of our fabrics, we imaged the PDMS coated PET fibers after laundering.

To quantitatively explore the mechanical failure mechanism and self-healing behaviors of wrinkled PDMS coating on fibers, we performed dry mechanical rubbing based on the AATCC 8-2007 colorfastness method with high pressure of 44.8 kPa (ISO 105-X12:2001)4 for accelerating coating damage, while normally 12 kPa was used for abrasion test. Ar-plasma treated fabric exhibits a WCA of ~152° and SA of ~9° after 1000 rubbing cycles, while SH fabric coated by conventional, thermally crosslinked PDMS lost their super-hydrophobicity after 200 rubbing cycles. These results are consistent with the partial damage of the stiff layer and retainment of compliant PDMS layer on gradient PDMS coated fibers. Together, the winkled surface and gradient PDMS coating provide mechanisms to alleviate stress concentration, leading to high durability in laundering and the daily abrasion.

References

[1] Deng, B. et al. Laundering Durability of Superhydrophobic Cotton Fabric. Adv. Mater. 2010; 22, 5473-5477

[2] Chen,T.L.et al. Bioinspired Durable Super-hydrophobic Surface from a Hierarchically Wrinkled Nanoporous Polymer. ACS Appl Mater & Interfaces. 2019; 11, 40875-408

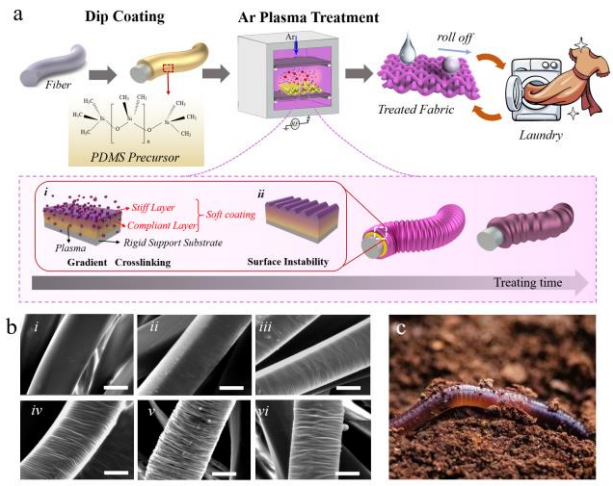

Figure1 a, Schematic illustrations for the fabrication of SH fabric and formation of winkled PDMS on fibers via Ar-plasma treatment. b, SEM images showing surface wrinkle patterns of treated fibers at different Ar-plasma treatment time, i: 0 s, ii: 20 s, iii: 40s, iv: 60 s, v: 80s, vi: 120 s. Scale bars: 10 μm. c, Photograph of a soft wrinkled earthworm showing excellent robustness against soil.