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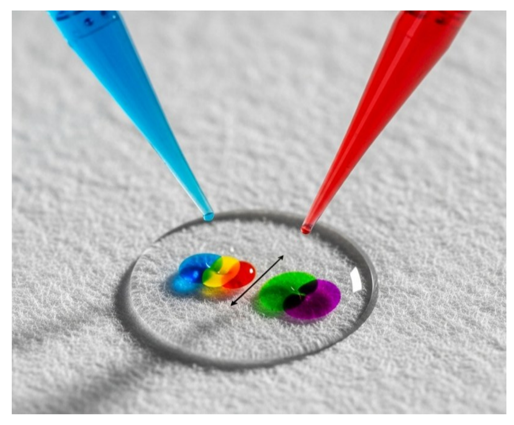

Fabrication of High-Adhesion Hydrophobic Filter Paper and Its Application as a Platform for Microscale Synthesis

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INTRODUCTION & AIM

Depending on their structure and surface chemistry, superhydrophobic (SHB) surfaces with water contact angles >150° exhibit either low or high-water adhesion [1]. Thus, SHB materials are characterized by two distinctive wetting regimes: the *lotus effect*, which yields low adhesion and self-cleaning capability, and the *rose petal effect*, which combines superhydrophobicity with strong water adhesion [1]. SHB surface with strong adhesion partially trap the droplet within hierarchical micro/nano structures, producing a *Cassie-impregnating* or *Wenzel-like* wetting state [2]. In such case, the droplet partially penetrates surface asperities, leading to increased solid-liquid interfacial area and contact-line pinning [3]. This kind of mixed-state wetting is responsible for their high adhesion and large contact angle hysteresis (CAH) [1].

The design and fabrication of SHB surfaces with strong adhesion mainly depends on the control of surface roughness and chemical composition. The fabrication can be attained through laser microstructuring, anodization, or nanoparticle assembly, followed by surface functionalization with low surface energy materials [4]. For example, laser-induced ZnO/Si "petal" morphologies sustain droplet adhesion even at 180° [5]. These surfaces are critical for applications that need stable droplet positioning and precise control such as microfluidics for droplet immobilization and manipulation, microreactors, and directional condensation [6-7]. Their tunable adhesion makes them ideal for biochips and smart wettability systems where droplets can be selectively trapped, merged, or released.

In the current study, we report the development of novel hydrophobic filter paper with strong adhesion properties for carrying out reactions inside microdroplets for microscale synthesis (20 – 30 μL). The fabricated filter paper was employed in the educational setting to carry out the polymerization of aniline inside a microdroplet instead of the traditional large-scale (50 – 100 mL) redox polymerization reaction.

METHOD

Nature-Inspired Design for Microscale Synthesis

The fabrication process is illustrated in **Fig. 1**. The fabrication process is green and use minimal amounts of materials and solvents. The process is composed of two alternating steps to modify the surface of the filter paper. The two steps can be repeated multiple times to control the adhesion and hydrophobic performance of the modified filter paper. The first step include dip-coating in iron oxide nanoparticle solution, whereas the second step includes the modification with low surface energy fatty acid. Both steps require post-drying to ensure the removal of solvents.

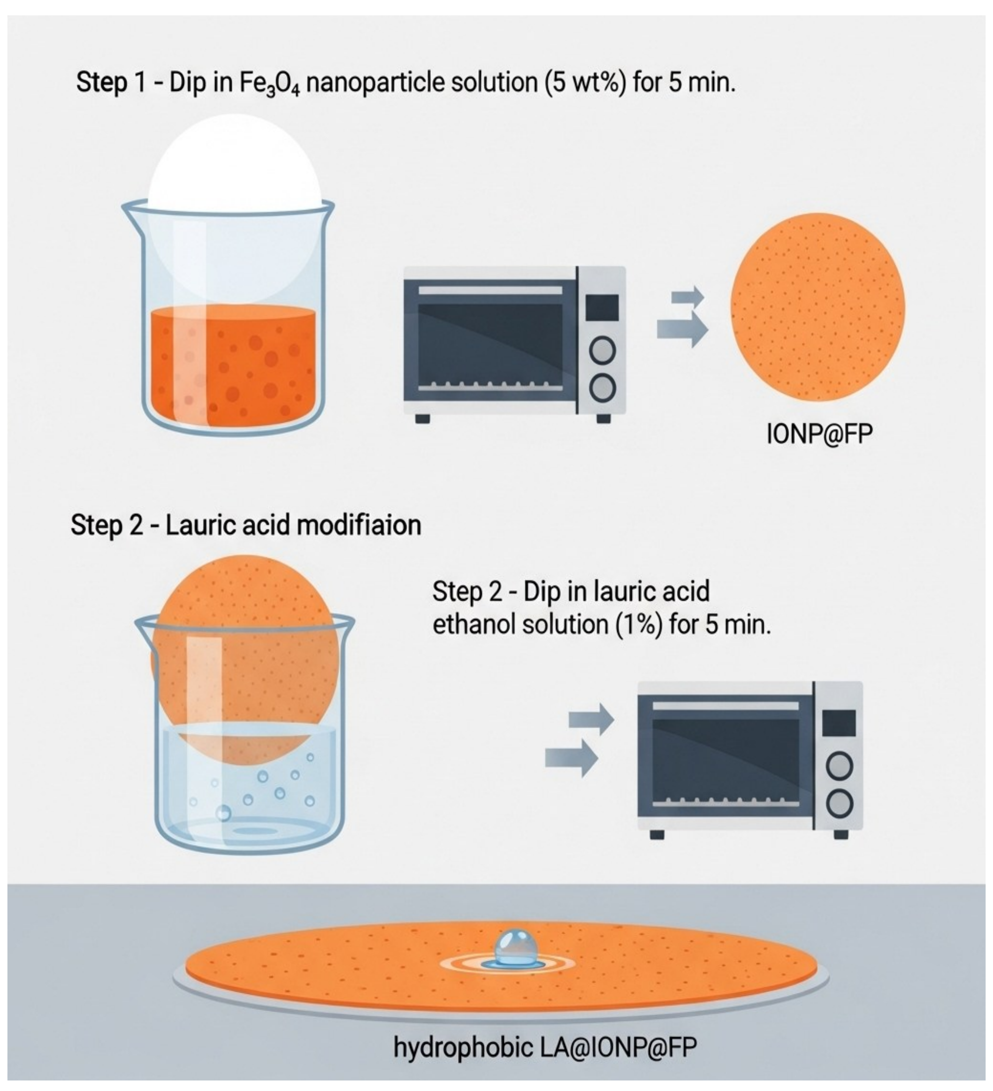

Figure 1 Schematic illustration for the two-step fabrication of HB filter paper.

RESULTS & DISCUSSION

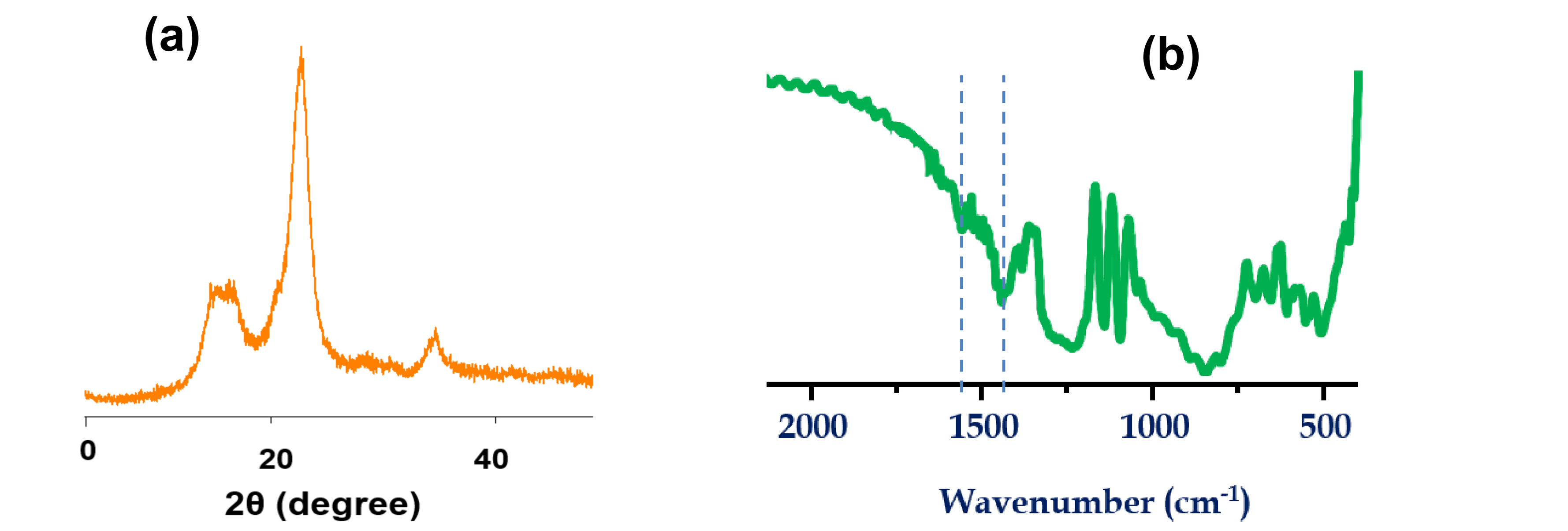

Figure 2 (a) XRD of the modified HB paper, and (b) FTIR of the modified HB paper.

The modified HB paper was characterized by XRD and FTIR to verify the chemical composition. As shown in **Fig, 2a**, the HB paper exhibits the typical XRD peaks for the cellulose . The modification does not affect the crystallinity of the paper due to the tiny adsorbed/ incorporated materials which does not alter the crystalline structure of the cellulose. As shown in **Fig. 2b**, the FTIR spectrum of the HB paper shows the peaks related to iron oxide NPs and lauric acid complex with distinctive peaks of the coordinated carboxylic acid groups at 1450 cm^{-1} and 1575 cm^{-1}. Hence, the modified HB filter paper shows the characteristics of cellulose backbone embedded within with the iron oxide NPs and low surface energy fatty acid molecules which resulted in water contact angle of 146°.

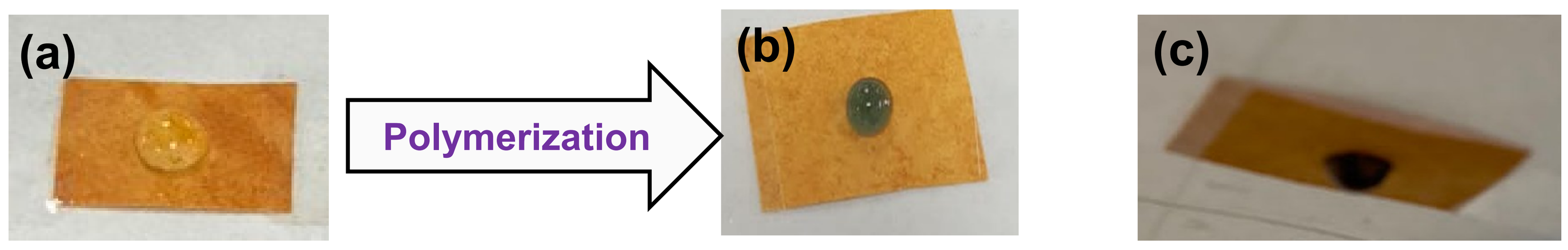

Figure 3 Application of the HB filter paper as a device for microscale synthesis; (a) reagents are added on the top of the filter modified HB paper, (b) after few minutes, the reaction started inside the microdroplet; and (c) at the end of the reaction, the paper was inverted upside down to demonstrate the strong adhesion performance of the HB paper.

Fig. 3 illustrates the application of HB paper as a versatile platform for microscale synthesis. A small droplet containing the reaction reagents was carefully placed on the surface of the HB paper, forming a stable microreactor, **Fig. 3a**. The reaction gradually proceeded within the confined droplet over several minutes, indicating the ability of the HB surface to localize and sustain liquid phase reactions without significant spreading or absorption, **Fig. 3b**. The HB paper was inverted to demonstrate the strong adhesion of the droplet to its surface, confirming the high surface stability and controlled wettability of the HB paper, **Fig. 3c**. This behaviour highlights the potential of HB paper as a simple, low-cost, and efficient platform for conducting microscale reactions or screenings, especially in green chemistry and portable analytical applications

CONCLUSION

This study demonstrates the fabrication of a hydrophobic filter paper with strong water adhesion through a simple and environmentally friendly two-step process involving iron oxide nanoparticles and fatty acid modification. Structural and chemical analyses (XRD and FTIR) confirmed the preservation of cellulose crystallinity and effective surface modification. The resulting material exhibited a water contact angle of 146°, indicating enhanced hydrophobicity and droplet retention. Its practical application as a microreactor for the polymerization of aniline verified its ability to localize reactions within stable microdroplets without leakage or spreading. The developed hydrophobic paper provides a low-cost, portable, and sustainable platform for microscale synthesis, supporting green chemistry and educational laboratory application

REFERENCES

1. Chen, X. et al. *Facile adhesion-tuning of superhydrophobic surfaces between "lotus" and "petal" effect and their influence on icing and deicing properties.* **ACS Applied Materials & Interfaces**, 2017.
2. Bormashenko, E. et al. *Wetting transitions on biomimetic surfaces: From lotus to rose petal effect.* **Langmuir**, 2013.
3. Liu, Y. et al. *Functional Superhydrophobic Surfaces with Spatially Programmable Adhesion.* **Polymers**, 2020
4. Zhang, M. et al. *Fabrication method of highly adhesive superhydrophobic surface based on laser chemical composite process.* **Chinese Patent CN113275223B**, 2023.
5. Li, X. et al. *Hierarchical "rose-petal" ZnO/Si surfaces with reversible wettability reaching complete water repellence without chemical modification.* **Applied Physics A**, 2023.
6. Wei, J. et al. *Roles of adhesives in forming mechanically robust superhydrophobic coatings.* **Chemical Science**, 2025.
7. Yong, J., Chen, F., Fang, Y., et al. *Bioinspired design of surfaces with special wettability for liquid manipulation.* **Advanced Materials Interfaces**, 2017.