



# The Role of Asymmetric Wettability Fibrous Membranes in Modern Biotechnology

Mingyu Chen\*

Department of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai, China

## DESCRIPTION

Asymmetric wettability fibrous membranes have emerged as innovative materials at the intersection of biotechnology and material science, appealing researchers with their unique properties and diverse applications. These membranes exhibit distinct wetting behaviors on opposite sides, offering personalized solutions to numerous biological and medical challenges. Their preparation involves sophisticated techniques aimed at engineering fibrous structures with differential surface energies, enabling specific control over their wetting characteristics. This article explores the innovative methods used to create these membranes and their expansive range of applications across various fields.

The establishment of preparing asymmetric wettability fibrous membranes lies in electrospinning, a versatile and widely adopted technique for fabricating fibrous materials with high surface area-to-volume ratios. Electrospinning allows researchers to complicatedly control parameters such as fiber diameter, porosity, and surface morphology. By employing different polymer solutions and varying electrospinning conditions, membranes can be engineered to possess one hydrophilic (water-attracting) side and one hydrophobic (water-repelling) side. This controlled asymmetry is important for their intended applications, enabling specific fluid manipulation and substance transport dynamics within biological systems. Various strategies are employed to achieve asymmetric wettability in these membranes. One effective method involves utilizing a dual-spinneret electrospinning setup, where two distinct polymer solutions are concurrently spun onto a rotating collector. This dual-deposition process ensures that fibers with different surface chemistries are deposited on opposing sides of the membrane. Alternatively, post-treatment techniques such as plasma treatment or surface coating can selectively modify the wettability of one side of the membrane after electrospinning, enhancing its functionality for specific applications.

The resulting membranes boast a host of advantageous properties. Their high porosity and expansive surface area facilitate efficient mass transfer, making them ideal for applications in tissue engineering and drug delivery systems. In tissue engineering, these membranes replicate the natural extracellular matrix, promoting cell attachment and proliferation. The hydrophilic side supports cell adhesion and growth, while the hydrophobic side acts as a barrier to control cell migration, thus guiding the formation of functional tissue constructs. Moreover, in wound healing, the membranes' asymmetric wetting properties enable controlled release of therapeutic agents, adopting optimal healing environments while minimizing the risk of infection. Drug delivery systems benefit significantly from these membranes' capabilities. They can be engineered to achieve targeted and sustained release of drugs, enhancing therapeutic efficacy and reducing side effects. By incorporating drugs directly into the fibers during electrospinning or by coating them with drug-loaded nanoparticles, researchers can ensure preferential release towards the hydrophilic side, where direct contact with target tissues is desired. This targeted delivery mechanism holds potential for improving treatment outcomes across various medical conditions.

Beyond biomedical applications, asymmetric wettability fibrous membranes find utility in environmental remediation and biosensing technologies. Their unique surface properties enable efficient separation of substances based on their affinity for water. For instance, these membranes can selectively filter oil from water, a capability crucial for environmental cleanup efforts. In biosensing, their high surface area and differential wetting properties enhance the sensitivity and specificity of sensors. Functionalizing the hydrophilic side with specific biomolecules allows for precise detection of target molecules, while the hydrophobic side minimizes non-specific interactions, thereby improving sensor accuracy.

Exciting advancements also extend to the field of smart textiles and microfluidics. By integrating these membranes into fabrics,

**Correspondence to:** Mingyu Chen, Department of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai, China, E-mail: mingchen@usst.edu.cn

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researchers can create textiles with enhanced functionalities such as moisture management and controlled release of active compounds. In microfluidics, the membranes' differential wetting properties enable detailed control over fluid flow, enabling the development of miniaturized devices for biological assays and diagnostics. These applications underscore the versatility and transformative potential of asymmetric wettability fibrous membranes across diverse fields. Looking ahead, ongoing research continues to refine the fabrication techniques and explore novel materials for these membranes. Advances in 3D printing and nanotechnology hold potential for creating more complex and functional membrane structures. The integration of biopolymers and composite materials may further

expand their applicability, offering personalized solutions for specific biomedical and environmental challenges.

In conclusion, asymmetric wettability fibrous membranes represent an innovative class of materials with intense implications for biotechnology and medicine. Their ability to specifically control fluid interactions, coupled with their diverse range of applications from tissue engineering to environmental cleanup, underscores their transformative impact. As research continues to push the boundaries of material science, these membranes are poised to revolutionize various fields, offering new possibilities for innovation and improving outcomes in healthcare and beyond.