Progressing from Outside to Inner Side: Inside-Out Isoporous Hollow Fiber Membranes

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Isoporous block copolymer membranes are promising candidates for ultrafiltration applications by providing high surface porosity along with specific retention properties.[1-2] The first isoporous flat sheet membranes were prepared using the self-assembly of block copolymers in combination with non-solvent induced phase separation (SNIPS).[3] In a subsequent work, the isoporous surface was developed on the outer surface of block copolymer hollow fibers.[4] The self-sustainable geometry of HFM provides a higher effective surface area per unit volume. In particular, the well-controlled flow hydrodynamics in the lumen, easy back flushing and cleaning make the inside-out HFM more fascinating as compared to outside-in HFM.[5] In our recent work, a novel inside-out isoporous HFM was prepared using the dry-jet wet spinning technique.[6]

Polystyrene-*block*-poly(4-vinylpyridine) (PS-*b*-P4VP) diblock copolymer was dissolved in a mixture of solvents, e.g., *N*,*N*-dimethylformamide (DMF), tetrahydrofuran (THF) and *1*,*4*-dioxane (DOX). Nitrogen (N_2) gas flow was used to initiate the microphase separation on the fiber lumen of block copolymer solution and the self-assembled structure was trapped by providing water flow in the lumen of the hollow fiber.

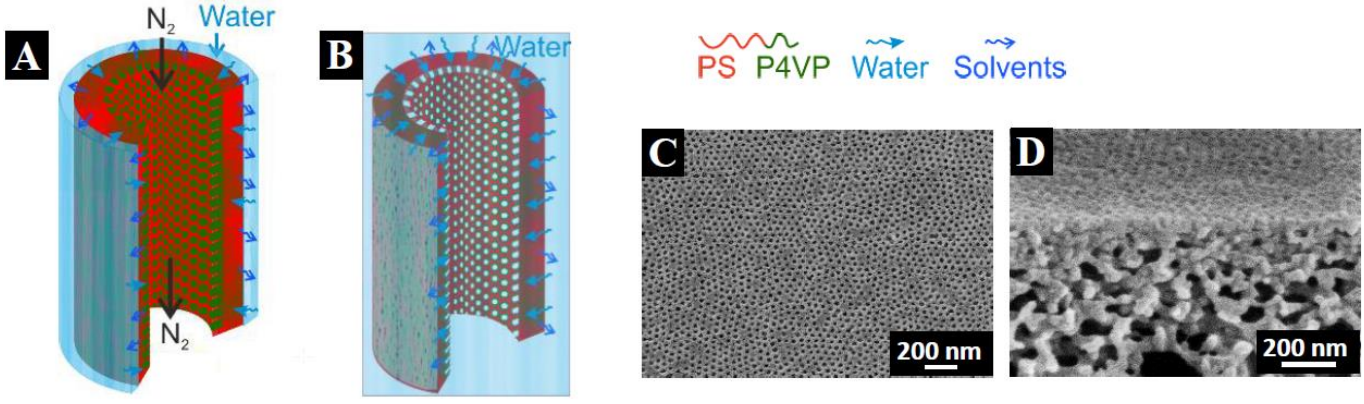


Figure 1. Schematic diagram displays the SNIPS process on the inner surface, the self-assembly of block copolymers (A), followed by non-solvent induced phase separation (B). The SEM micrographs represent inner surface (C), and the cross-section near inner surface (D) of an inside-out HFM.

In this work, the structure formation is controlled by gas flow, which makes the system more complex as compared to flat sheet and outside-in membranes. Moreover, a variation in the polymer solution and the parameters governing evaporation time and rate of evaporation like flow rate and time of flow of each fluid, size of lumen, environmental conditions etc. change the structural features. The influence of these parameters on membrane morphologies are investigated by scanning electron microscopy (SEM). Further, the morphological behavior will be correlated to small-angle X-ray scattering (SAXS) measurements. The novel inside-out isoporous HFM shows promising pure water flux $\geq$ 300 L m^{-2} h^{-1} bar^{-1} (at 2 bar, dead end-mode).

The key to this development is the ability to control the kinetics of macromolecules on the inner surface of the hollow fibers with a diameter of less than 1 mm. The approach may offer valuable perceptions for the fabrication of inside-out isoporous HFM also using different block copolymers. Furthermore, the emerging membranes offering high selectivity and permeability can be applicable for numerous ultrafiltration separation applications, mainly water filtration and hemodialysis.

References

1. Abetz, V., Isoporous Block Copolymer Membranes. *Macromol. Rapid Commun.* **2015,** *36* (1), 10-22.
2. Clodt, J. I.; Bajer, B.; Buhr, K.; Hahn, J.; Filiz, V.; Abetz, V., Performance study of isoporous membranes with tailored pore sizes. *J. Membr. Sci.* **2015,** *495*, 334-340.
3. Peinemann, K.-V.; Abetz, V.; Simon, P. F. W., Asymmetric superstructure formed in a block copolymer via phase separation. *Nat. Mater.* **2007,** *6* (12), 992-996.
4. Radjabian, M.; Koll, J.; Buhr, K.; Vainio, U.; Abetz, C.; Handge, U. A.; Abetz, V., Tailoring the morphology of self-assembled block copolymer hollow fiber membranes. *Polymer* **2014,** *55* (13), 2986-2997.
5. Baker, R., *Membrane Technology and Applications, 2nd Edition*. John Wiley & Sons: **2004**.
6. Sankhala, K.; Koll, J.; Radjabian, M.; Handge, U. A.; Abetz, V., A Pathway to Fabricate Hollow Fiber Membranes with Isoporous Inner Surface. *Advanced Materials Interfaces* **2017,** *4* (7), 1600991.