

Electro-Responsive 3D printed Nanocomposite Membranes Based on Polypyrrole for Tunable Separation and Anti-Fouling Applications

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Electro-responsive membranes offer a promising platform for developing adaptive separation systems capable of dynamic fouling control and targeted selectivity. This study presents the fabrication and functionalization of polypyrrole (PPy)-based nanocomposite membranes with tunable structural and surface properties designed for use in challenging industrial wastewater streams. The membranes are fabricated using both methods of 3D printing and electrochemical polymerization, enabling the creation of perforated architectures with pore sizes tunable between 2–50 nm through optimization of polymerization conditions and carbon nanotube (CNT) support layering. The membranes incorporate graphene oxide (GO) and DBS⁻ dopants to enhance conductivity, mechanical integrity, and hydrophilicity. A key feature of these membranes is their reversible wettability, controlled through external voltage application, allowing the surface to switch between hydrophilic and less hydrophilic states. This dynamic surface control, along with the electroactive gating behavior of PPy, significantly enhances anti-biofouling performance, particularly against organic and biological contaminants. Targeted applications include the treatment of food industry and petrochemical wastewater, where biofouling and high organic load often challenge conventional membranes. The proposed system is being developed as a pretreatment step for reverse osmosis (RO), aiming to reduce membrane fouling, extend RO membrane life, and lower operational costs. This work contributes to the advancement of stimuli-responsive membrane systems tailored for industrial use, combining smart material behavior with scalable fabrication strategies. Currently, a conductive membranes were successfully fabricated using photopolymerization with pore size range 100nm-180nm.

Figures

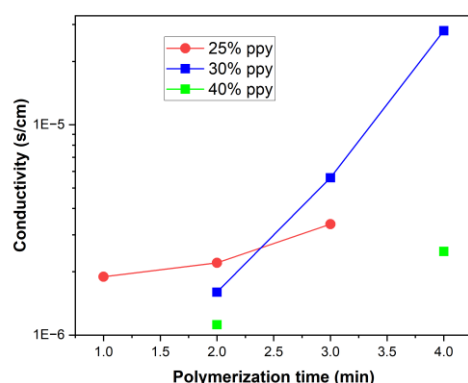


Figure 1: Conductivity measurements of the composites