Environmentally friendly amino sulfonic acid zwitterion grafted 2D MXene ($Ti_3C_2T_X$) robust composite membranes with improved permeability and self-cleaning properties

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Abstract

The development of chemically and mechanically stable nanocomposite membranes with high permeability and self-cleaning properties is important for various wastewater treatment applications. Two-dimensional MXene ($Ti_3C_2T_X$) nanomaterials have attracted increasing research interest in various applications, including membrane-based separation technologies for wastewater treatment. In the current research, MXene was modified by bio-inspired polydopamine coating based on the oxidation and self-polymerization of dopamine monomer. Then the MXene modified with PDA was sulfonated with taurine (TA, amino acid with $–SO_3H$ group) according to Michael addition or Schiff base reaction. The composite membrane was prepared by incorporating MXene-TA nanocomposite into polyethersulfone (PES) via a non-solvent-induced phase separation (NIPS) process. Morphology and surface properties of the TA-MXene nanocomposite and the fabricated composite membranes were characterized by FT-IR, XRD, contact angle, zeta potential, SEM, TEM, and AFM. The incorporation of TA-MXene nanocomposite particles into the PES improved the porosity, mean pore radius, hydrophilicity, and tensile properties of the developed hybrid membranes. The flux of the developed PES/TA-MXene membrane was nearly 3.1 times higher than in pristine PES membrane. The rejection rates of three representative species of natural organic matter (NOM) in raw water (HA, NA, and BSA) were above 93%. The abundant functional groups and negative charge on the MXene-TA surface also enhanced dye separation (83%) while maintaining high water flux. In both NOM and dye separation tests, the PES/TA-MXene membrane showed the best flux recovery ratio (FRR), reversible fouling ratio (R_r), and low irreversible fouling ratio (R_{ir}), indicating its self-cleaning properties. In addition, the composite membrane has significant chemical stability, as demonstrated by its high corrosion resistance during long-term treatment with 2M HCl and oxidant (NaOCl) solutions. This study provides a new MXene nanocomposite for the development of high-performance composite membranes along with self-cleaning properties.

Keywords: Two-dimensional MXene, Eco-friendly sulfonated MXene nanocomposites, Hydrophilicity, High permeability, Self-cleaning.