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Polyvinylidene fluoride-based loose nanofiltration membrane with graphene oxide intercalation for efficient desalination of small organic molecules

摘要

有机物小分子与无机盐的分离对实现工业废水资源化利用至关重要。通过对三种不同氧化石墨烯 (GO) 掺杂方式制备的纳滤膜进行通量、截留率及有机小分子和无机盐分离测试，得到以 GO 和多巴胺 (DA) 涂层形成的 PDA-GO 插层的方式效果最好，从而制备了一种新型的疏松纳滤膜材料 (PVDF/PDA-GO-TFN)，旨在提高有机小分子和无机盐分离性能的同时增强膜表面的稳定和抗污染性能、降低“trade-off”效应。本研究探明了形成 PDA-GO 插层的最优条件和在此基础上界面聚合的最佳组合。通过 SEM-EDS、AFM 以及 FT-IR 确定了插层结构的产生。PVDF/PDA-GO-TFN 疏松纳滤膜纯水通量高达 10.45 L/(m2·h·bar)，对标准物 PEG 2000 的截留率高达 88%，对无机盐 NaCl、Na2SO4 的截留率分别低至 11% 和 6.8%。通过对膜表面接触角 (亲水性)、荷电性 (Zeta 电位) 以及孔径 (BET) 进行相关性分析，确定分离机理为 Donnan 效应和空间位阻效应。经过四个循环有机小分子和无机盐混合溶液冲洗过滤后，膜的 FRR 均值为 99.06%，表明膜抗污染能力较强，且通过 SPSS 对无机盐截留率进行显著性差异分析，指出膜稳定性能优异。综上，PVDF/PDA-GO-TFN 膜材料的制备为高效分离有机小分子和无机盐纳滤膜的制备提供新思路。

关键词

氧化石墨烯; 多巴胺; 疏松纳滤膜; 有机废水脱盐

Abstract

The separation of small organic molecules and inorganic salts is crucial for achieving industrial wastewater resource utilization. Through flux, rejection rate, and separation tests of small organic molecules and inorganic salts using nanofiltration membranes prepared by three different doping methods of graphene oxide (GO), it was found that the method of forming a PDA-GO interlayer using GO and a dopamine (DA) coating performed the best. Consequently, a novel type of loose nanofiltration membrane material (PVDF/PDA-GO-TFN) was prepared, aiming to improve the separation performance of small organic molecules and inorganic salts, enhance surface stability and anti-fouling properties of the membrane, and reduce the “trade-off” effect. This study identified the optimal conditions for forming the PDA-GO interlayer and, on this basis, the best combination for interfacial polymerization. The formation of the interlayer structure was confirmed by SEM-EDS, AFM, and FT-IR. The pure water flux of the PVDF/PDA-GO-TFN loose nanofiltration membrane reached as high as 10.45 L/(m2·h·bar), the rejection rate for the standard PEG 2000 molecule was as high as 88%, and the rejection rates for inorganic salts NaCl and Na2SO4 were as low as 11% and 6.8%, respectively. By performing correlation analysis on surface contact angle (hydrophilicity), charge (Zeta potential), and pore size (BET) of the membrane, it was determined that the separation mechanism is the Donnan effect and steric hindrance effect. After four cycles of washing and filtration with a mixed solution of small organic molecules and inorganic salts, the average FRR of the membrane was 99.06%, indicating strong anti-fouling ability. In addition, a significance analysis of the inorganic salt rejection rate using SPSS showed that the membrane has excellent stability. In summary, the preparation of PVDF/PDA-GO-TFN membrane material provides a new approach for the efficient separation of small organic molecules and inorganic salts by nanofiltration membranes.

Keywords

Graphene oxide; Dopamine; Loose nanofiltration membrane; Desalination of organic wastewater

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