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Evaluation of cellulose acetate membrane with carbon nanotubes additives

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ABSTRACT

Cellulose acetate (CA)/carbon nano tubes (CNT) membranes were prepared using phase inversion method by dispersing different ratio of carbon nano-materials in CA casting solution. Different polymer to solvent ratios examined for enhancement of membrane desalination. The influence of differentiation in CA and CNT ratio on the morphology and thermal stability were investigated using scanning electron microscopy and thermogravimetric analysis (TGA). Also, Permeation performance of the prepared membranes was evaluated. Morphology results showed that CA membrane porosity decreased with increasing polymer ratio. The membranes pure water flux was increased by the addition of nano-carbon materials. The optimum polymer to solvent ratio for accepted desalination performance was 25:75.

The presence of carbon nanotubes (CNT) in the optimum membrane enhanced the salt rejection markedly to 96% as well as the pure water flux has been improved. The optimum membrane in the presence of CNT has convenient thermal stability with accepted water content percent and swelling percent.

Introduction

One of the main proportions to world population growth and economic development is water limitation finite resources which considered as one of the most concern problems to scientists [1]. Although different polymeric materials used for membrane preparation, cellulose acetate (CA) considered as the most common membrane materials used for water application due to its natural characteristics [2,3], low cost, extraordinary potential flux [4–7], long life time, less clean requirement and minimal fouling membrane via its high hydrophilicity [8–10]. Hybrid (organic-inorganic) membranes such as nanofiltration [11], ultrafiltration [12] and reverse osmosis (RO) [13] received a lot of interest in the past few years. In 1960s, Reid and Breton reported 98% and 0.01 L/m^2 h salt rejection and water permeation for reverse osmosis membrane, respectively [14]. By utilization of cellulose acetate (CA) membrane salt rejection and water permeation were improved up to 99% and 14.6 L/m^2 h [15]. Although long-known good mechanical strength of CA polymer makes it the best choice in membranes fabricating [16,17], reverse osmosis and gas separation [18,19] the lack of reactive functional groups on the polymer, chemical resistance, high pressure requirement and transportation is one of the major disadvantages of CA membrane. So, several investigations converged on effect of changing different parameter such as solvents and non-solvents [20–25] and the effect of different pore formers [26–33] on membrane performance applied. Blending of 2–hydroxyethyl methacrylate with CA membrane as an initiated polymer improve biofouling resistance by 24%, also nanoparticals modification such as ZnO assembling cellulose acetate/ZnO bactericidal nano-composite membrane [34,35]. Another researches observed that flux, salt rejection and mechanical strength enhanced dramatically by insertion of polyhedral oligomeric silsesquioxane (POSS) nanoparticle into cellulose acetate membrane [36]. On the other hand, organoclay nanofillers indicate more thermal stability than TiO_2 during presence in CA membrane [37,38]. However, all the above studies indicate that nano-technology offers opportunities for enhancement of membrane desalination performance since it propose alternative polymeric materials as additives or precursor [39]. Various studies focused on

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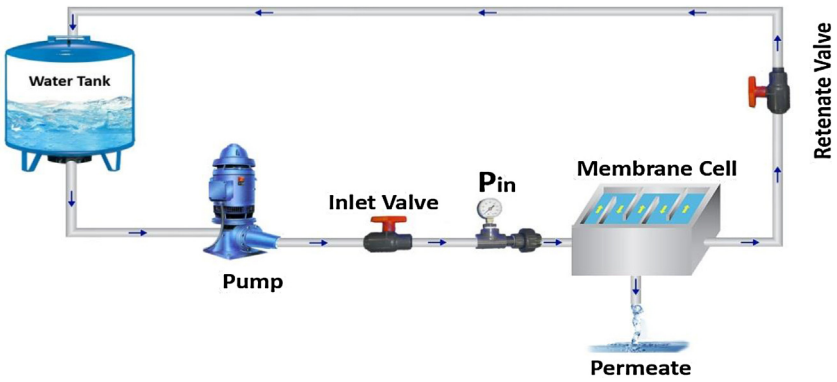

Fig. 1. Scheme diagram of the water permeation experiments set-up.

additives to membrane desalination such as carbon nanotubes (CNTs) which increase water flow inside it [40–43]. Choi et al. found that the addition of CNT to polysulfone membrane might enhance the water flux by increasing CNT weight percentage to 1.5 wt% then water flux decreased [44]. This may be attributed to that by increasing CNT wt%, the hydrophilicity and pore sizes increases until reach threshold (1.5 wt%) [45]. Accordingly, addition of carbon nanotubes considers as a great development to overcome the restrictions of polymeric membranes and enhances membrane properties such as developing higher water permeability and salt rejection rate [46,47].

In this work, we investigate the effect of polymer concentration in the membrane matrix and the addition of CNT on the membrane performance towards water desalination. The optimum membrane properties were estimated.

Experimental

Materials

Cellulose diacetate was provided from Aldrich and utilized as the precursor to prepare CA membrane. Acetone of analytical grade and Multi-walled CNT (diameter ≈ 140 nm, length ≈ 7 microns) were purchased from Sigma and STREM chemicals, respectively. All chemicals were used as received without any further modifications.

Methods

The blank CA, C1 and C2 membranes were prepared by polymers to solvent wt% ratios (CA: Acetone) 20:80 and 25:75, respectively. Accordingly, the mixtures were casted on a glass plate and immediately immersed in tap water bath up to one hour at 20 ± 2 °C to get free standing CA membrane. Finally, after drying, the prepared membranes were annealed for 10 min at 80 °C for approximately 10 min. Different concentrations of CNT 0.01, 0.03 and 0.05 wt% were added to the polymeric solution to prepare the composite membranes in the same way.

Characterizations

Scanning electron microscopy (SEM)

The cross section morphology of the membranes was studied using scanning electron microscopy of Model Quanta 250 FEG. The membranes were cryogenically fractured in liquid nitrogen before using for SEM to give clear cross section; the cross section was coated with thin film of gold. The prepared sample was mounted on brass plates with double-side adhesive tape in a lateral position. Top, bottom and cross section images for each sample were obtained.

Thermal properties

The thermal stability of the membranes was measured using thermal gravimetric analyzer (Q 600). 5–10 mg of the sample was

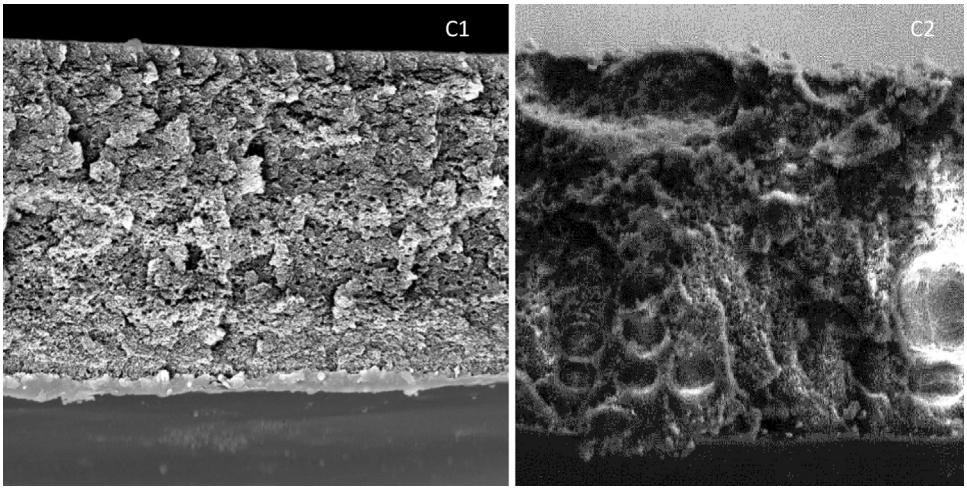

Fig. 2. SEM images of C1 and C2.