



ELSEVIER

Contents lists available at ScienceDirect

Journal of Membrane Science

journal homepage: www.elsevier.com/locate/memsci

Stable and efficient composite anion-exchange membranes based on silica modified poly(ethyleneimine)–poly(vinyl alcohol) for electro dialysis

Ravi P. Pandey^{a,b}, Amit K. Thakur^a, Vinod K. Shahi^{a,b,*}^a Electro-Membrane Processes Division, CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Council of Scientific & Industrial Research (CSIR), Gijubhai Badheka Marg, Bhavnagar 364002, Gujarat, India^b Academy of Scientific and Innovative Research, CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Council of Scientific & Industrial Research (CSIR), Bhavnagar 364002, Gujarat, India

ARTICLE INFO

Article history:

Received 6 February 2014

Received in revised form

21 June 2014

Accepted 23 June 2014

Available online 15 July 2014

Keywords:

Anion exchange membrane

Chronopotentiometry

Permselectivity

Membrane conductivity

Electrodialysis

ABSTRACT

Anion exchange membranes (AEMs) have found numerous electrochemical applications because of their good conductivity and permselectivity. Herein, we are reporting a method to prepare silica modified poly(ethyleneimine) (SMPEI) with 3-Glycidoxypropyl-trimethoxysilan (GPTMS) by epoxide ring opening reaction. Stable AEMs of different compositions were prepared with SMPEI and a plasticizer poly(vinyl alcohol) (PVA) by acid catalyzed sol-gel followed by formal cross-linking. The reported method is simple and a green alternative for the preparation of AEM without the use of hazardous chemicals. Suitability of prepared AEMs for electro dialytic application was assessed by analyzing their physicochemical properties, stabilities under operating conditions, conductivity, electro-osmotic and chronopotentiometry studies. A highly suitable membrane, SMPEI/PVA-40, exhibited 55.32 mS cm^{-1} conductivity (in equilibrium with 0.04 N NaCl solution at 30°C), ion-exchange capacity (1.31 meq g^{-1}) and permselectivity (0.79) with good electro dialytic performance. Preparation protocols and properties of the reported composite AEM represent a promising starting point for architecting highly conducting and stable AEMs, but we have to study the trade-off between properties, stabilities and electro-osmotic mass drag before its commercial exploitation.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Positively charged quaternary ammonium tethered polymers have found numerous successful applications in fuel cells, flow batteries, water electrolyzers, electro dialysis (ED), and reverse electro dialysis [1–8]. Current state of knowledge, concerning structure–morphology–performance relationships of anion exchange membranes (AEMs),

Abbreviations: AEM, anion exchange membrane; IEM, ion exchange membrane; SMPEI, silica modified poly(ethyleneimine); ED, electro dialysis; CMME, chloromethyl methyl ether; DC, diluted compartment; CC, concentrated compartment; PEM, proton exchange membrane; IEC, ion exchange capacity; CEM, cation exchange membrane; PVA, poly(vinyl alcohol); TGA, thermo-gravimetric analysis; φ_w , volume fraction of water in the membrane matrix; χ^m , surface charge concentration; I , applied current density across the IEM; τ , transition time; P_s , membrane permselectivity; κ^m , ionic conductivity; A , surface area of membrane; DSC, differential scanning calorimetry; DMA, dynamic mechanical analyzer; SEM, scanning electron microscopy; E , energy consumption; CE, current efficiency

* Corresponding author at: Electro-Membrane Processes Division, CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Council of Scientific & Industrial Research (CSIR), Gijubhai Badheka Marg, Bhavnagar 364002, Gujarat, India. Fax: +91 0278 2566970.

E-mail addresses: vkshahi@csmcri.org, vinodshahi1@yahoo.com (V.K. Shahi).

<http://dx.doi.org/10.1016/j.memsci.2014.06.046>

0376-7388/© 2014 Elsevier B.V. All rights reserved.

is much less in comparison with that about proton exchange membranes (PEMs) [9,10]. Several AEMs based on different polymers, such as poly(2,6-dimethyl-1,4-phenylene oxide) (PPO), copolymer of chloromethylstyrene and divinylbenzene, PVDF-vinylbenzyl chloride, and poly(vinyl alcohol)-poly(1,3-diethyl-1-1-vinyl imidazolium bromide), are reported in the literature [11–15]. These AEMs were prepared via chloromethylation of polysulfone, poly(ether imide), and Cardo poly(ether sulfone)-based polymers using chloromethyl methyl ether (CMME) followed by amination with a tertiary amine [16,17]. In addition, different cationic groups such as imidazolium [18], phosphonium [19], guanidinium [20], sulfonium [21], and pyridinium moieties [22] were also screened for developing stable and efficient AEM. In general, preparation procedures of AEMs, especially chloromethylation and quaternary amination, are complicated and require potentially harmful chemicals such as chloromethyl styrene, different amines and pyridine, etc. [7,23,24] Thus, usage of an expensive and hazardous chemical dramatically increases the manufacturing cost of the AEM. However, the promising strategies for preparing efficient AEM, effect of hydrophobic and ionic clusters on membrane conductivity, and different experimental protocols to assess the suitability of AEM for electro-driven separation technologies are not yet clear.

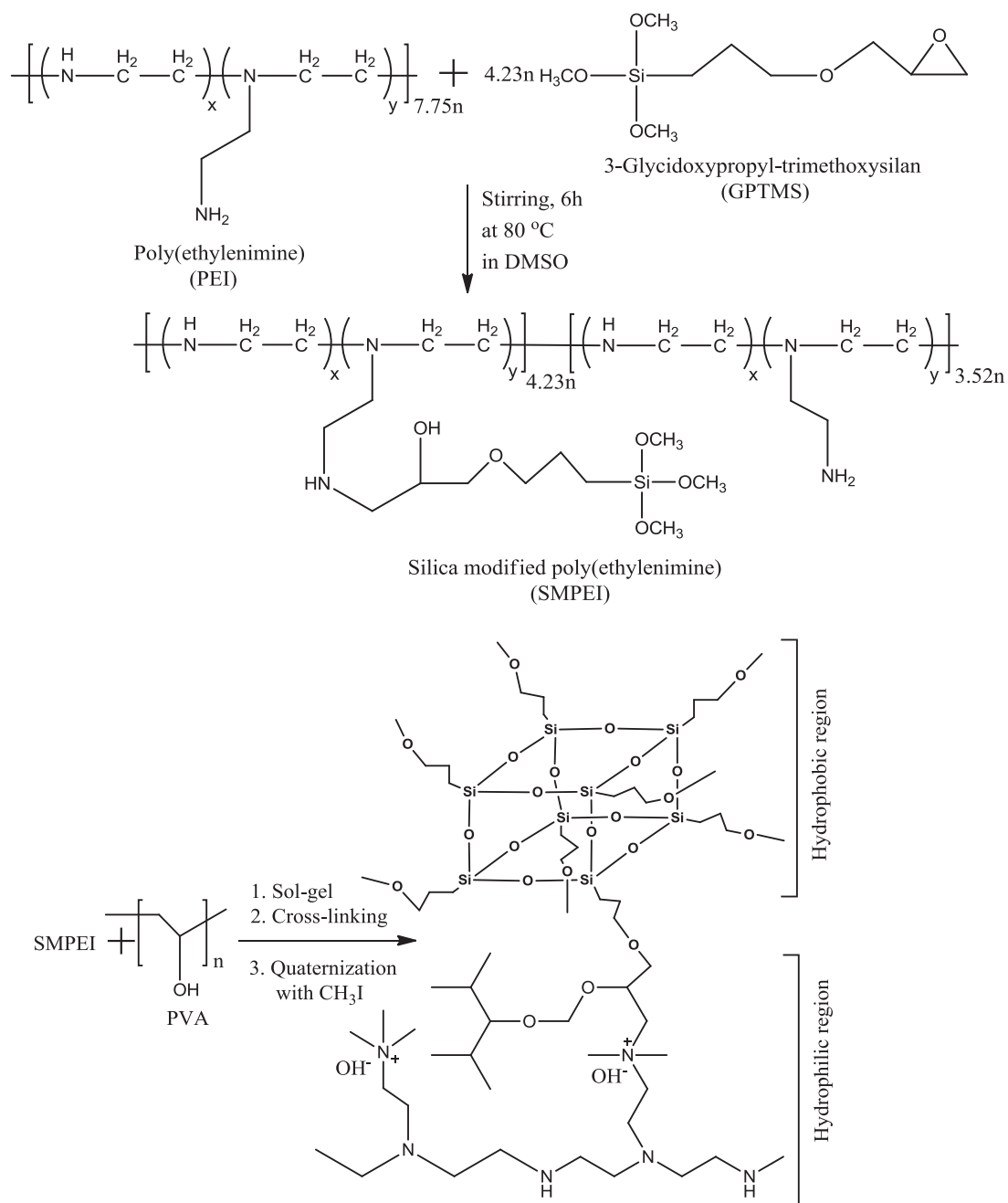
Hydrophobic and ionic clustering in membrane morphology is a key factor for enhanced ion conductivity, which was validated in the case of cation-exchange membranes such as Nafion and sulphonated polymers [25]. Ionic clustering contributes to the formation of hydrophilic channels for the fast diffusion of water and conduction of ions through the membrane, while hydrophobic clusters contribute toward phase separation and stabilities of ion-exchange membranes [10,26]. To facilitate the formation of ionic and hydrophobic clusters, different strategies such as grafting of polymer chain, usages functionalized monomer or block copolymers were adopted [3,7,27]. To solve these problems, attention was rendered for developing organic–inorganic composite membrane forming materials because they combine attractive properties of organics and inorganics [7,27–29]. Therefore, to design stable and efficient membranes by eco-friendly preparation protocols with suitable hydrophobic and ionic clustering responsible for good conductivity is extremely important for next-generation materials.

For developing high performance AEMs with superior morphology, conductivity, stability and scalable synthetic steps, herein we disclose a novel route for producing silica-modified poly(ethylenimine) (SMPEI) and membrane preparation methodology by acid catalyzed sol–gel using poly(vinyl alcohol) (PVA) as a plasticizer. Detailed physicochemical and electrochemical properties of SMPEI/PVA membranes were analyzed to assess their suitability for ED.

2. Experimental

2.1. Materials

Poly(ethylenimine) (PEI, 50 wt% solution in water), and 3-Glycidoxypropyl-trimethoxysilan (GPTMS) were obtained from Sigma Aldrich Chemicals. Poly(vinyl alcohol) (PVA, Mw: 125,000; degree of polymerization: 1700, degree of hydrolysis: 88%), methyl



Scheme 1. Schematic reaction route for the preparation of SMPEI/PVA composite AEMs.

Download English Version:

<https://daneshyari.com/en/article/633522>

Download Persian Version:

<https://daneshyari.com/article/633522>

[Daneshyari.com](https://daneshyari.com)