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Fabrication of Conducting Nanochannels Using Accelerator for Fuel Cell Membrane and Removal of Radionuclides: Role of Nanoparticles

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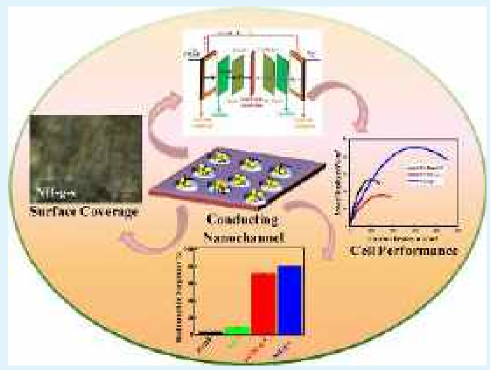

ABSTRACT: Latent tracks in pure polymer and its nanohybrid are fabricated by irradiating with swift heavy ions (SHI) (Ag^{+}) having 140 MeV energy followed by selective chemical etching of the amorphous path, caused by the irradiation of SHI, to generate nanochannels of size ∼80 nm. Grafting is done within the nanochannels utilizing free radicals generated from the interaction of high-energy ions, followed by tagging of ionic species to make the nanochannels highly ion-conducting. The uniform dispersion of two-dimensional nanoparticles better controls the size and number density of the nanochannels and, thereby, converts them into an effective membrane. The nanoparticle and functionalization induce a piezoelectric β-phase in the membrane. The functionalized membrane removes the radioactive nuclide like $^{241}Am^{+3}$ (α-emitting source) efficiently (∼80% or 0.35 μg/cm^2) from its solution/waste. This membrane act as a corrosion inhibitor (92% inhibition efficiency) together with its higher proton conduction (0.13 S/m) ability. The higher ion-exchange capacity, water uptake, ion conduction, and high sorption by the nanohybrid membrane are explored with respect to the extent of functionalization and control over nanochannel dimension. A membrane electrode assembly has been fabricated to construct a complete fuel cell, which exhibits superior power generation (power density of 45 mW/cm^2 at a current density of 298 mA/cm^2) much higher than that of the standard Nafion, measured in a similar condition. Further, a piezoelectric matrix along with its anticorrosive property, high sorption characteristics, and greater power generation makes this class of material a smart membrane that can be used for many different applications.

KEYWORDS: *PVDF nanohybrid, functionalization, radionuclide separation, corrosion, energy*

■ INTRODUCTION

Polymeric membranes exhibit a high efficiency toward many industrial applications such as air purification, water filtration,[1] sensor, ion transport, and energy production using a green technology.[2−4] Apart from these applications, their separation technology is a fundamental aspect from the chemical industries and academic viewpoints.[5,6] Among the separation methods, radioactive waste treatment is of prime importance, especially in nuclear power plants and health departments, including in the field of cancer cell imaging.[7−9] Recently, the separation and sensing of radioactive sources from aqueous/waste solution are of prime importance. Ion-exchange membranes (IEMs) have received much attention because of their easily portable, ambient temperature operation, light-weight, and high power density.[10−12] The membrane-driven technologies provide a clean and affordable source of energy for portable and stationary electronics. Recent developmental works are focusing on fuel cells as they are found to be suitable as alternative fossil fuels to avoid increasing environmental pollution.[13,14] A suitable way to figure out such kind of issue is the advancement of ion-exchange membrane (IEM), which is the key component of any electrochemical system such as batteries, electrochemical sensors, fuel cells, and solar cells including ion/charge carrier exchange/transport phenomena.[15,16] The exchange and complexing tendencies of the membrane are introduced through grafting of the polymer backbone using different monomers, followed by functionalization by means of ionic species, such as sulfates, phosphate, chlorides, etc.,[17−19] best suitable for cationic and quaternary ammonium, phosphonium ions, etc. as anionic membranes.[20,21] These ionic species also facilitate the transport/sorption of ions through the membrane.[22] This membrane is used as electrolyte in the fuel cell technology that works as the barrier

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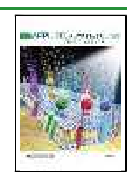

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