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Lithium-Irradiated Poly(vinylidene fluoride) Nanohybrid Membrane for Radionuclide Waste Management and Tracing

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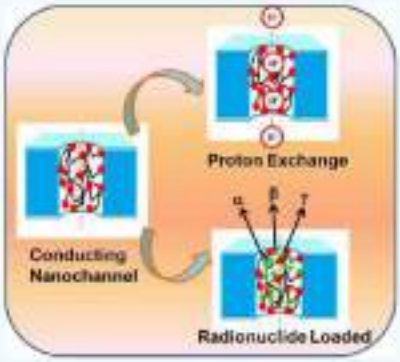
ABSTRACT: The conducting nanochannel is made up of poly(vinylidene fluoride) and its nanohybrid (NH) membrane through irradiation of high-energy (80 MeV) lithium ions followed by chemical etching. The NH is prepared through the solution route by dispersing 2-D-layered silicates in a polymer matrix. Morphological studies indicate that the dimension of the conducting nanochannel is in the range of 40−50 nm. The nanochannels are filled with the styrene monomer and are polymerized within the channels to use the free radicals available in the periphery of the walls, exposed after etching the irradiated films. Polystyrene chains are sulfonated and, thereby, converted the nanochannel ion conduction exclusively with a proton conduction of 30 mS·cm^{-1} in the NH membrane. The effect of fluence has been evaluated for the improvement of different useful parameters of the membrane. Structural alteration of the functionalized membrane is revealed through XRD, thermal measurements, and morphological studies. The functionalized membranes are used to capture radionuclide $^{241}Am^{3+}$, an alpha emitter. The studies on uptake kinetics show more than ~98% uptake within an hour. Alpha radiography is carried out to map the radionuclide distribution in the nanochannels. A comparison of Li^+- and Ag^+-ion-irradiated films indicates preferential grafting at the near-surface of the membrane in the case of Ag^+-ion-irradiated films, whereas comparatively more uniform distribution of radionuclides is observed in the Li^+-irradiated membrane across the depth. Measurement of scintillation pulse height spectra suggests relative response of the membrane depending on the nanochannel dimension. However, Li^+-ion-irradiated films are better suited for the possible application in uptake/transport of radionuclides, whereas Ag^+-ion-irradiated films are better suited for their applications in radionuclide sensing.



KEYWORDS: *PVDF, nanohybrid, swift heavy ions, radionuclide uptake, sensing of radionuclides*

INTRODUCTION

Membrane technology has continuously been developed into a prominent separation technology over the past few decades. There are many advantages of the membranes especially for the separation process which include light weight, tailor-made design, less energy consumptions, low cost, unchanged phase during its use, and its easy handling. Therefore, they find applications in various fields.[1−3] One of the most important applications is the management of radioactive waste which is generated during the operation of the nuclear facilities worldwide for nuclear energy production using various radioisotopes. Radioactive waste from nuclear fuel cycle in the reactor is a major concern globally as it cannot be disposed off directly into the environment.[4,5] Therefore, radioactive waste management is of prime importance[6−8] along with the detection of the radioactive element using a scintillation detector.[9] Radionuclides can be identified/quantified by measuring the various types of primary radiations emanating from the sources, for example, α-, β-, and γ-rays and neutrons, or subsequent effects arising from their interaction with matter.[4] Nuclear waste must be stored and processed to a reduced volume for their long-term storage for final disposal. This requires separation of long-lived radionuclides, particularly alpha emitters, from the bulk of the nuclear waste, thereby significantly compressing the volume of the nuclear waste for disposal. The membrane technology plays an important role for removing the different radionuclides such as Am^{3+}, U^{4+}, Pu^{4+}, and Np^{3+} and fission products such as $^{37}Cs^+$, $^{24}Na^+$, Ba^{2+}, and so forth.[10−14] The membrane should have specific functional groups so that they form either the complex with the radioactive species, mainly in the anionic form, or electron-rich species from aqueous solutions.[15,16] The grafted thin film is used for the ultrafiltration of the plutonium ions from their large-volume nuclear waste, succeeding to the quantification of the Pu^+ (preconcentrated) with the help of

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