Chapter 7

Conclusions and Scope of the work

7.1 Conclusions:

In this thesis, the functionalized (ionic) polymer membrane is explored in energy as well as radionuclide waste management in nuclear power plants. In the present scenario the energy is prime need of hour, because of conventional fuels like, fossil fuel, petroleum and coal are exhausting very rapidly. The Fuel cell technology is energy generating technology and is an alternative to the conventional sources. Fuel cell devices mostly used in stationary and portable power sources and they supply power various range such as few mW to MW for multiple applications. In fuel cell technology the porous polymeric membrane is key component; they are used as electrolytes for ions conduction through the membrane and separate the electrons by external circuits followed by load application. Polymer electrolytes Fuel cells (PEMFCs) are light weight and compact and design with high electrical efficiency, due to their lightweight, the PEMFCs are used in space research. Nafion is a commercial PEMFCs electrolyte because of high ionic conductivity, thermal and mechanical properties**.** However, they have few drawbacks, such as high cost, ionic conductivity decrease at high temperature and high fuel permeability through the membrane. Now, more efforts are needed to develop new hybrid membrane which sort out the problems of the Nafion.

Hence, fluoropolymer like poly(vinylidene fluoride) based backbone is used for polymer electrolyte membrane for PEMFCs. PVDF is chemically inert and mechanically stable polymer but for PEMFCs the polymer membrane should have ionic group. Furthermore, the generation of the reactive sites followed by grafting and sulphonation leads to formation of ionomer on the backbone of polymer membrane fulfilling the prime requirement for PEMFCs. Several techniques are used for introducing ionic group in

polymeric membrane like; radiation induced grafting, chemical treatment followed by ionomer tagging and blending / composites of ion conducting moieties. The addition of the nanoclay and ionic group in polymer moieties leads to phase transformation; β-phase of PVDF is electroactive and piezoelectric in nature. The structural alternation, morphology, mechanical, thermal, ionic membrane characteristics, fuel cell performance and radionuclide management have been discussed for functionalized membrane. The major outcomes of the thesis are explained below chapter wise.

In **chapter 3,** mechanically stable sulphonated P(VDF-HFP) is prepared for the proton exchange membrane with high ions exchange capacity (IEC), moderated water uptake (WU), lower activation energy (E_a), lower fuel permeability (P) and good proton conductivity (k^m) clearly suggest that the functionalized membranes are suitable for fuel cell membrane. The functionalized P(VDF-HFP) membrane used to fabricate single cell fuel cell stack for direct methanol fuel cell and measure the electrical performance of membrane.

In **chapter 4,** nanohybrid proton exchange membrane has been developed through radiation induced grafting (swift heavy ion used). The swift heavy ions create the latent track in polymer membrane followed by selective chemical etching latent track convert into nanochannels after that latent track filled with 3-hexy thiophene monomer chemically subsequent sulphonation of 3-hexyl thiophene chain the nanochannel make them conducting. The functionalized membrane (NH-g-s) has improved electrical conductivity and due to dispersion of the organically modified nano clay the electro-active meta stable β-phase from ~25% to 72%, the enhancement of the electroactive conclude that the functionalize membrane better candidates for electronic applications. The 3-hexyl

thiophene grafted subsequent sulphonted membrane to fabricate the membrane electrode assembly (MEA) and measure the direct ethanol fuel cell efficiency and found that power density 92.0 mW/cm^2 correspond to current density 252.6 mA/cm^2 against the commercial Nafion (63.6 mW/cm^2) in similar condition. Indicate the new hybrid membrane for Fuel cell application.

In **chapter 5,** the PVDF and its nanohybrid functionalized membrane have been developed for cation exchanger membrane. The generation of the reactive sites through the swift heavy ions (silver ions), after the SHI bombardment subsequent chemical etching construct nanochannel in membrane and reactive free radical inside the nanochannel, the nanochannel grafted with styrene monomer followed by the sulphonation make them ion exchanger membrane. The cation exchange membrane used for the radionuclide (Am^{+3}) waste absorption ~80 % in nuclear power plant and from electrochemical analysis the functionalized polymer has the ability to resist corrosion with an inhibition efficiency determine ~92%. Furthermore the cation exchange membrane used to make fuel cell stack and measure the direct methanol fuel cell performance and the power density of 45 mW/cm^2 and the corresponding current density of 298 mA/cm^2 is achieved.

In **chapter 6,** development of the conducting nanochannel in pristine PVDF and its nanohybrid membrane using lithium ion swift heavy ions after that grafted it using styrene monomer consequent sulphonation making the nanochannel into conducting nanochannel and the functionalized membrane is cation exchange membrane. Furthermore, cation exchange membrane used for radionuclide absorption and within an hour equilibration time ~99 % radionuclide absorbed in radio nuclide aqueous solution. Moreover, the uniformity of radionuclide in surface and depth analysis was analyzed using radiography techniques

and alpha spectrometry method respectively. From the chapter 5 and chapter 6 result we conclude that in case of the silver ion radiated membrane the radionuclide disperse on the surface and in case of lithium ion radionuclide more dispersion in bulk hence the sliver ion radiated membrane use for sensing application and lithium ions membrane used for ion transporter.

7.2 Scope for future work:

The present thesis work reported synthesis, characterization and applications of functionalized PVDF and its copolymer porous polymeric membrane for fuel cell as well as radionuclide waste management in nuclear power plant. The swift heavy ions used for radiation induced grafting; the effect of ions, fluence, nanoclay studies for generation of the nanochannel in polymer membrane and also discussed the piezoelectric phase variations when above changes persist. Some other application such as corrosion inhibition efficiency also discussed. However, there are many scopes for further studies; some of these are given below:

- To see the effect of channel dimension variations, different *SHI ions* can be used.
- Nanohybrid fuel cell membrane efficiency can be improved by adding different fillers.
- Preparation of Proton Exchange Membrane having specific functional groups (phosphonation and per chlorination) in thermoplastic polymer.
- Instead of methanol some other fuel variation like hydrogen, alkaline solution etc.