I would like to dedicate this thesis to my family who has supported and encouraged me throughout this endeavor: Thank you for your love and support throughout my entire life and helping me to realize who I am today

CERTIFICATE

It is certified that the work contained in the thesis titled "**Porous Polymeric Membrane for Fuel Cell and Radionuclide Waste Management**" by ***"Om Prakash"*** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the Comprehensive, Candidacy and SOTA requirements for the award of a PhD degree.

Pmaiti

Date: **07 July 2021** **Prof. Pralay Maiti**
Place: IIT (BHU), Varanasi **(Supervisor)**

DECLARATION BY THE CANDIDATE

I, **Om Prakash,** certify that the work embodied in this thesis is my own bonafide work and carried out by me under the supervision of **Prof. Pralay Maiti** from **January 2016 to June 2021** at the **School of Materials Science & Technology**, Indian Institute of Technology, Banaras Hindu University, Varanasi. The matter embodied in this thesis has not been submitted for any other degree/diploma award. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further say that I have not willfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports, dissertations, theses, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

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Supervisor

(Chandana Rath)
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Date: 07.07.2021

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LIST OF ABBREVIATIONS

PEM	Proton electrolyte membrane
AEMs	Anion Exchange membranes
CEMs	Cation exchange membranes
BPMs	Bipolar membranes
PFSA	Perfluorosulfonic acid
DMFCs	Direct methanol fuel cells
MEA	Membrane electrode assembly
PEMFCs	Polymer electrolytes Fuel cell membrane.
PVDF	Poly (vinylidene fluoride)
OCV	Open circuit voltage
PTFE	poly(tetrafluoro ethylene)
PVDF-HFP	poly(vinylidene fluoride–co– hexafluoro propylene)
PVDF-CTFE	poly(vinylidene fluoride–co– tetrafluoro ethylene)
SHI	Swift heavy ions
LET	Linear energy transfer
NH	Nanohybrid
PSSA	Polystyrene sulfonic acid
MeV	Mega electron volts
PS	Polystyrene
DS	Degree of sulfonation
IEC	Ion exchange capacity
WU	Water uptake
3-HT	3 –hexyl-thiophene

P3HT	poly(3 hexylthiophene)
DCM	Dichloromethane
GPSC	General Purpose scattering chamber
SRIM	Stopping range of ions in materials
DMF	Dimethyl formamide
PVDF-s	Direct sulphonation poly(vinylidene difluoride),
PVDF-NH-s	Direct sulphonation of the PVDF nanohybrid membrane
QAPPESK	Quaternizedpoly(phthalazinon ether sulfone ketone
QAPVA	Novel cross-linked quaternized poly (vinyl alcohol) (PVA)
FEP-g-PVBTMAOH	The radiation-grafting of vinyl benzyl chloride onto poly (hexafluoropropylene-co-tetrafluoroethylene)
QPPESN	Quaternized phenolphthalein based poly(arylene ether sulfone nitrile)
FPAES-Im-52	Fluorene-containing poly(arylene ether sulfone)s with imidazolium groups
SP	Selectivity parameter
Symbols	**Description**
α	Alpha
β	Beta
γ	Gamma
δ	Delta
T	Trans
G	Gauche
Ǻ	Angstrom
µm	Micro meter
nm	Nano meter

θ	Angle
ρ	Resistivity
σ	Conductivity
d	Interplanar spacing
V	Volt
A	Ampere
Mm	Mili meter
cm	Centi meter
g	Gram
^0C	Temperature
I_{max}	Current Density
P_{max}	Power Density
mW	Mili watt
mA	Mili ampere
Ea	Activation energy
P	Methanol permeability
S	Siemens

PREFACE

Membrane technologies have been the key component of research in the last few decades, with the latest improvement in both fabrication and design aspects. Porous / nanochannel polymeric membranes have gained much attention in this perspective for their utilization in a variety of fields such as adhesive, sensor, biotechnology, waste water treatment including separation techniques and ion exchange membranes for polymer electrolytes membrane fuel cell (PEMFCs), because of their excellent thermal, outstanding mechanical properties along with electrical properties when suitably functionalized with some functional group.

This thesis mainly focuses the research work being conducted on fabricating porous polymer membranes followed by the functionalization and subsequently their applications in fuel cell technology as electrolytes membrane and Functionalized membrane used for the waste water treatment mainly in the radionuclide tracing. In this context, swift heavy ions (SHI) bombardment on the polymeric membrane design the porous membranes having controlled channels dimension using ions of different size, nanoparticles and fluence variation. The effect of SHI on the polymeric membrane creates the reactive sites (free radicals), which are utilized to functionalize for relevant applications. However, this thesis aims to discuss the fabrication of latent track/ nanochannels in polymer membrane and subsequent functionalization for energy applications, especially in fuel cell technology.

The thesis consists of seven chapters; in the first chapter, we will discuss a brief introduction of the polymeric membrane, materials like PVDF and its copolymer and their conformations, Radiation-induced grafting (Swift heavy ions). A detailed literature survey has been carried on fuel cell technology and the effect of the SHI on the polymer. In the second chapter, detail of materials, experiments, characterizations technique and measurements are discussed. In third chapter functionalized (sulphonates) the PVDF-HFP polymer membrane using chlorosulphonic acids and measures the DMFCs efficiency. In the fourth chapter of the thesis, swift heavy ions, Sliver ions 120 MeV energy and 5×10^{7} ions /cm^{2} fluence irradiated PVDF and its nanohybrid film followed by the chemical etching subsequent grafting with the help of the conducting monomer 3-Hexyl thiophene and sulphonation carried out grafted spices make the nanochannel / latent track into conducting nanochannel for the ions transport. Furthermore, the functionalized membrane assembled Fuel cell stack and measure cell efficiency. In the fifth chapter, Silver ions with fluence 1×10^{7} ions/cm^{2} irradiated on the polymer film followed by the styrene monomer grafting sulphonation subsequently for the purpose of the fuel cell membrane and radionuclide tracing and in the sixth chapter, lithium ions irradiation with two fluences 1×10^{7} and 1×10^{6} ions/cm^{2} and grafting of the styrene monomer followed by ionic group tagging for low waste radionuclide sensing and finally in the last chapter (seventh) gives significant observations, conclusions and suggestions of the future work.