PTFE reinforced electrolyte membrane for high performance and durability in Proton Exchange Membrane Fuel Cell (PEMFC)

Subash C. Bhandari

Advisor: Dr. Anima Bose

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UNIVERSITY of HOUSTON
DEPARTMENT OF PHYSICS

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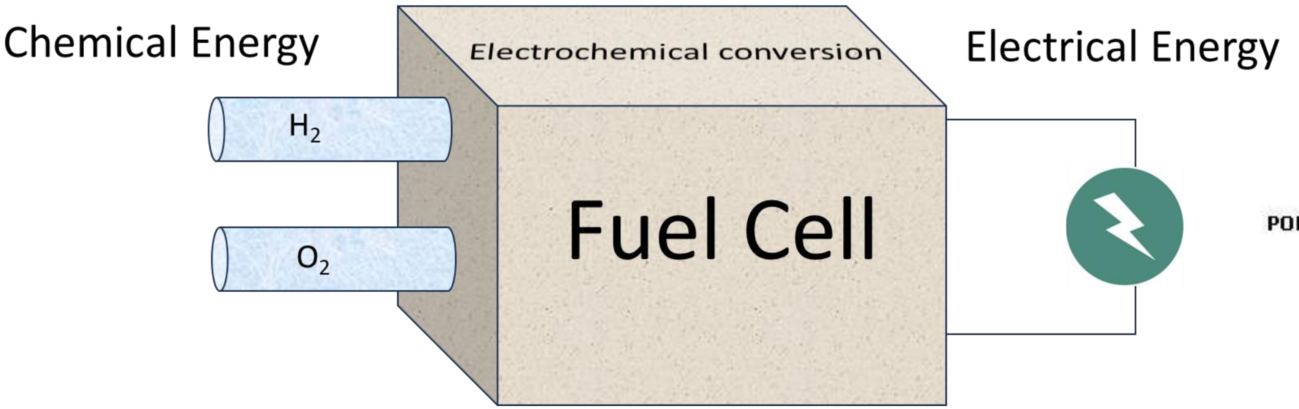
Outline

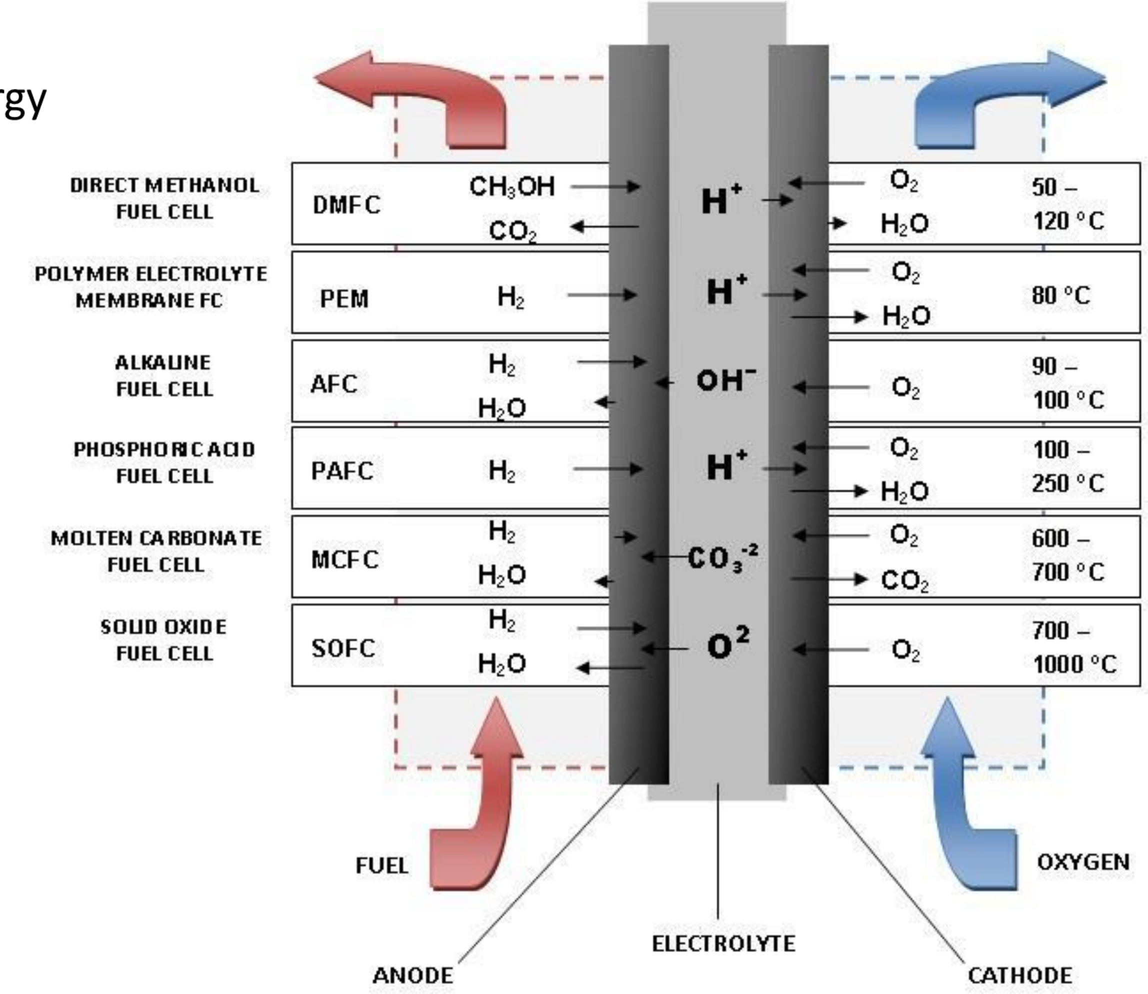
1. Introduction on Fuel Cell
2. Experiment
3. Results and Discussion
4. Conclusion

1. Introduction: Fuel Cell



	Power Plant		Automobiles	
	Thermal Power Generation	Fuel Cells		Internal Combustion Engine
Energy Conversion System	CO_2		H_2O	CO_2
Efficiency	Electricity 40%	Electricity & Heat >90%	>40%	20%
Noise	Significant	Negligible		Significant

http://www.fcgroup.yamanashi.ac.jp/en/fuel-cell/index.html



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1. Introduction: Proton Exchange Membrane Fuel Cell (PEMFC)

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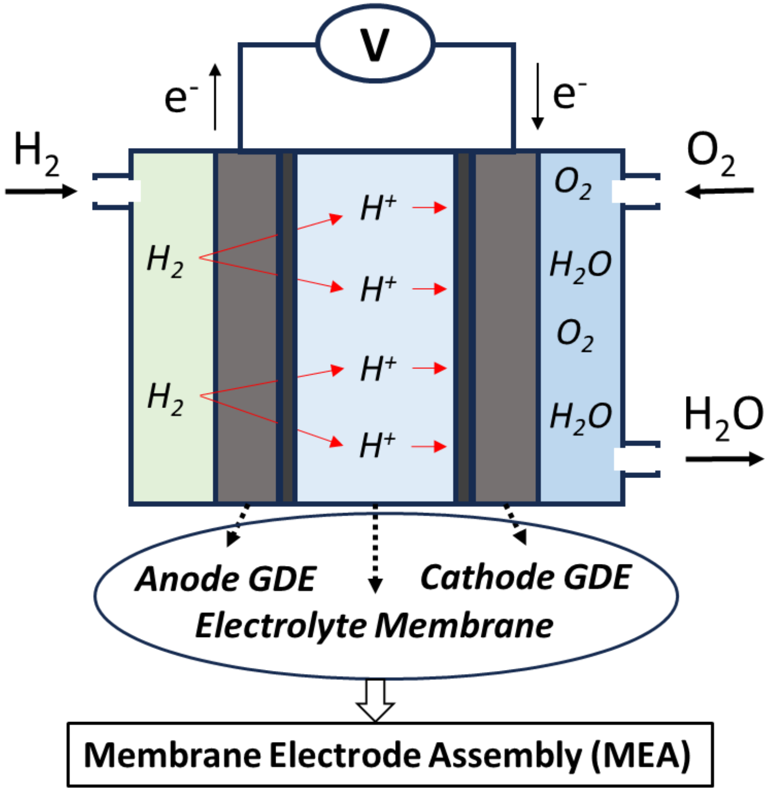

Proton Exchange Membrane Fuel Cell (PEMFC)

Anode reaction:	$2H_2 \rightarrow 4H^+ + 4e^-;$	ΔV_a = 0.00 V
Cathode reaction:	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O\ ;$	ΔV_C = 1.229 V
Overall reaction:	$2H_2 + O_2 \rightarrow 2H_2O\ ;$	ΔV_o = 1.229 V

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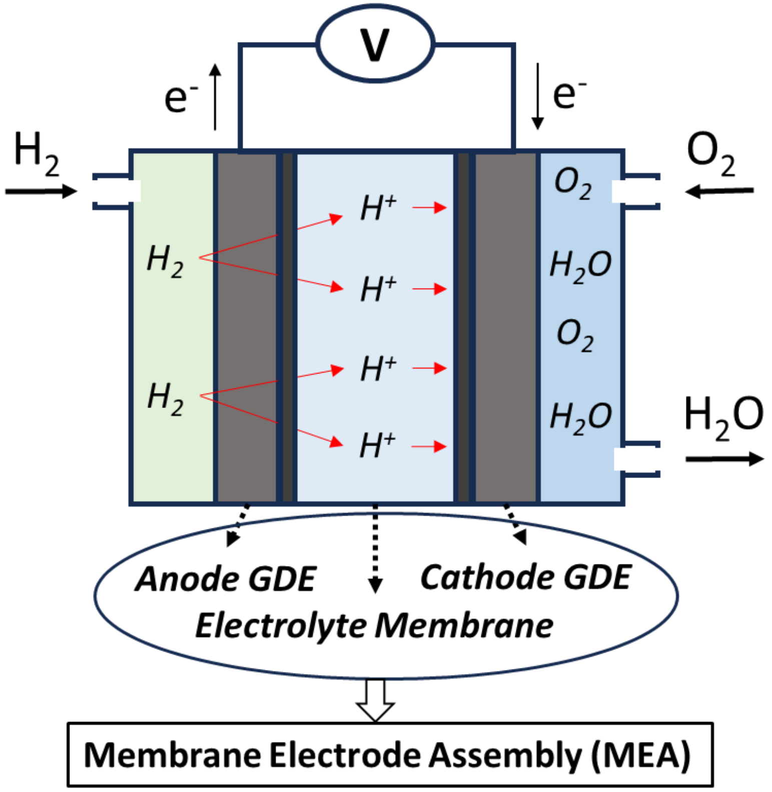

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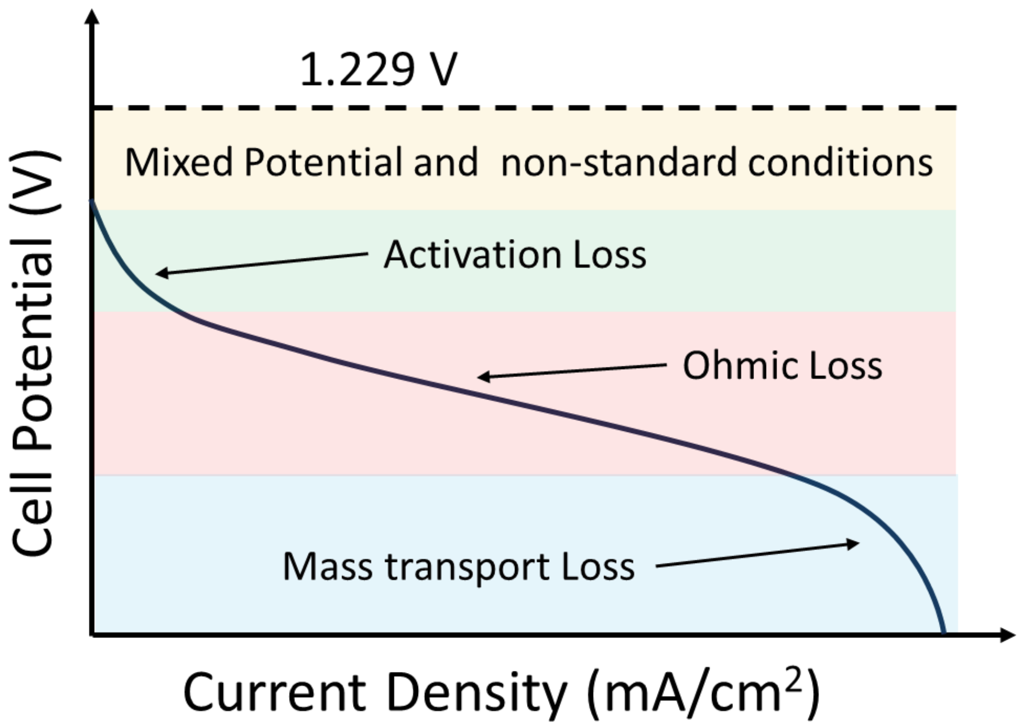

Over potential $(\eta) = \eta_{act} + \eta_{ohm} + \eta_{con}$

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$$\eta_{ohm} = iR_{internal}$$

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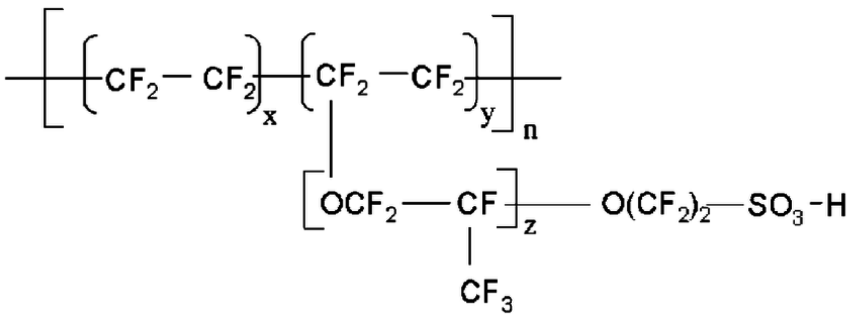

Chemical structure of state-of-the-art Nafion® monomer

General properties of PEM

- Excellent proton conductivity
- High electric resistivity
- Barrier to gas crossover
- Mechanically strong
- Higher chemical stability

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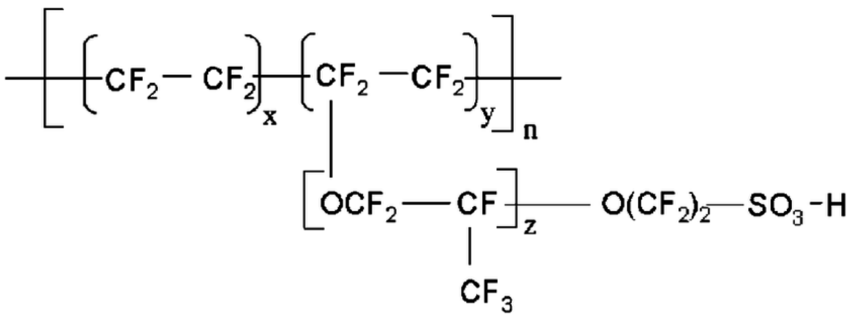

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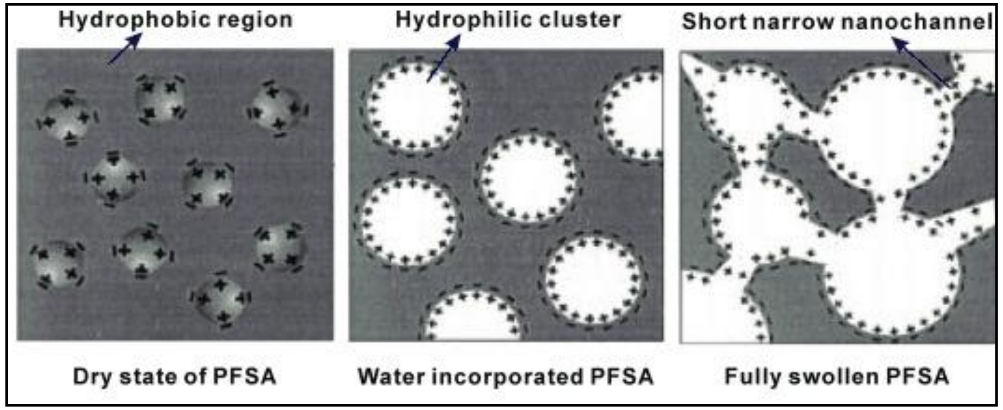
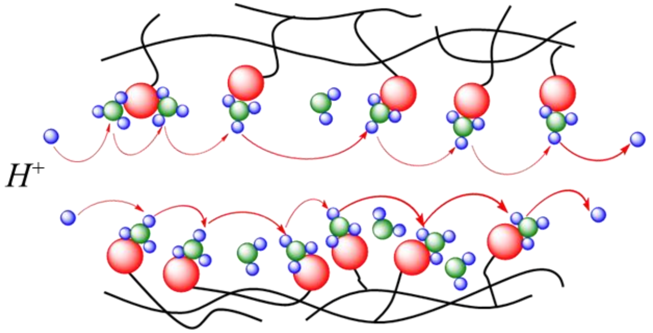
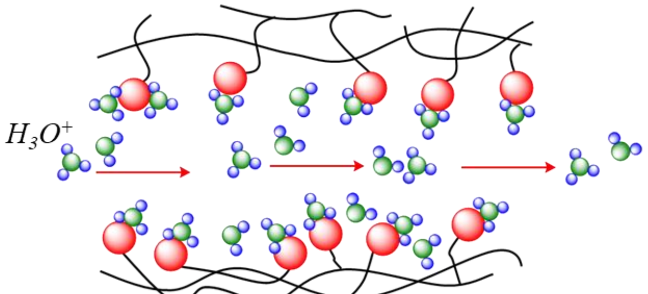
❖ Proton Transport Mechanisms



EnergyTechnol.2015,3,675–691



Grotthus Mechanism



Vehicular Mechanism

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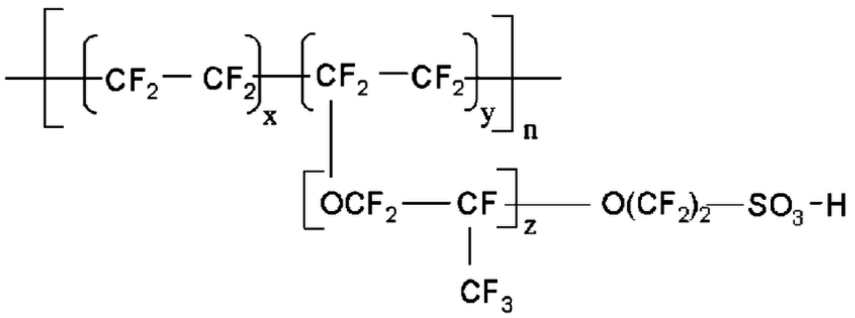

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Nafion® Membrane

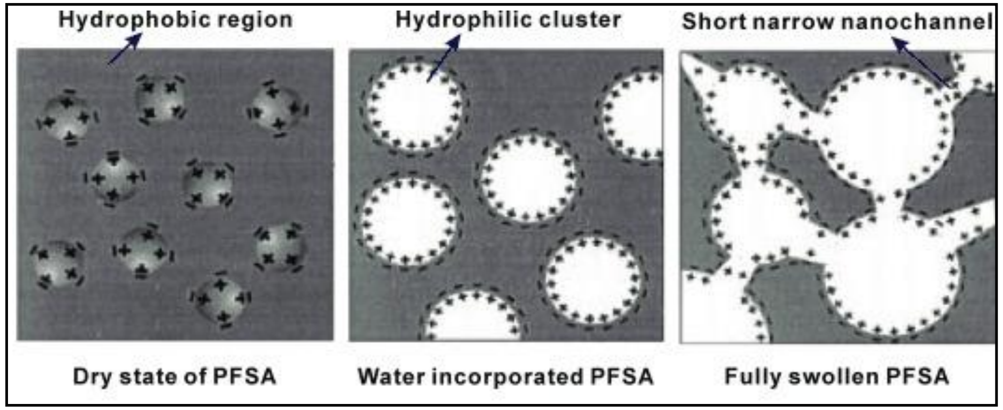
Pros:

- Excellent proton conductivity
- Good chemical stability
- Thermally stable up to 160 °C

Cons:

- Excessive swelling
- Gas permeability
- Low mechanical strength
- Expensive (~ 1000 $/m^2)

❖ Proton Transport Mechanisms



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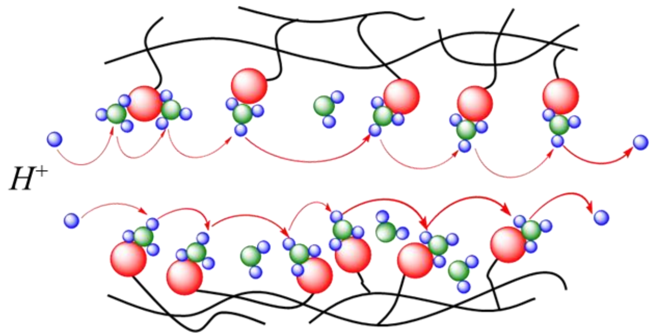

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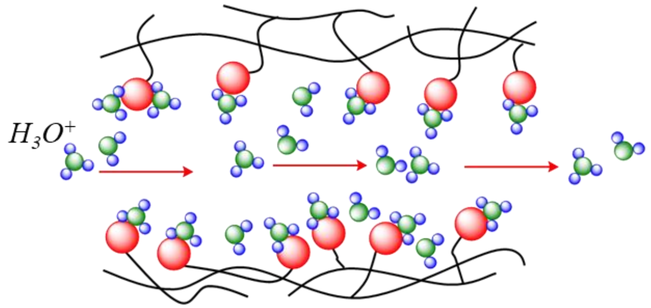
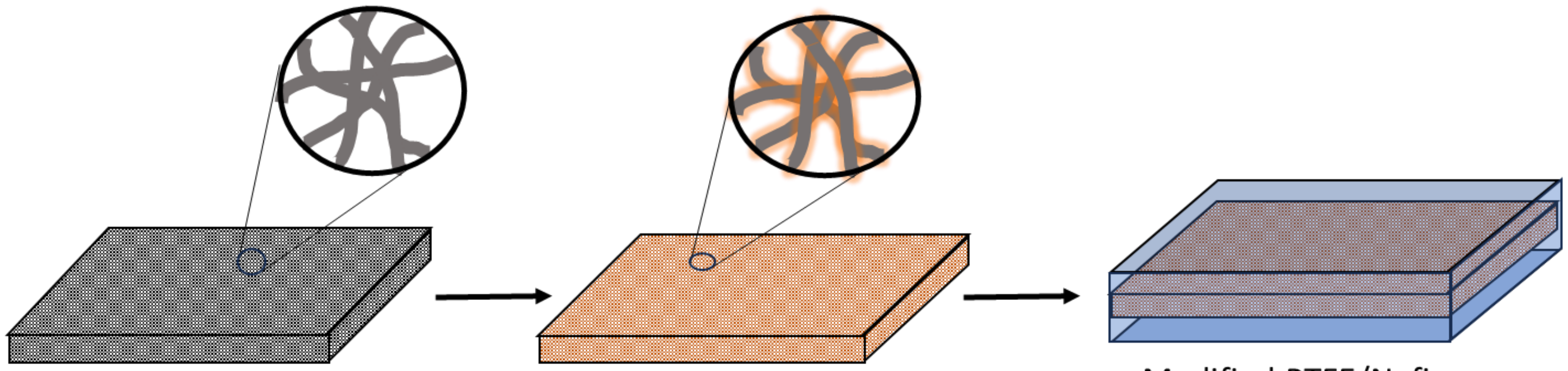
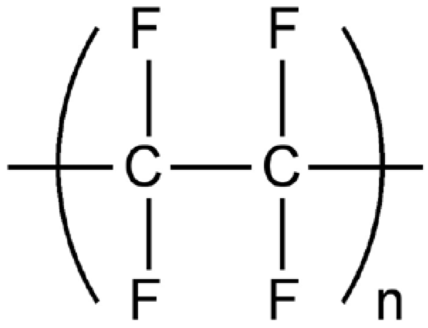


Vehicular Mechanism

2. Experiment

PTFE reinforced Nafion composite membrane:





Polytetrafluoroethylene (PTFE) chemical structure

1. Casting Nafion solution directly on porous PTFE Substrate (**PTFE/Nafion**)

2. Casting Nafion solution on modified-PTFE substrate (**modified-PTFE/Nafion**)

3. Result and Discussion: General Properties

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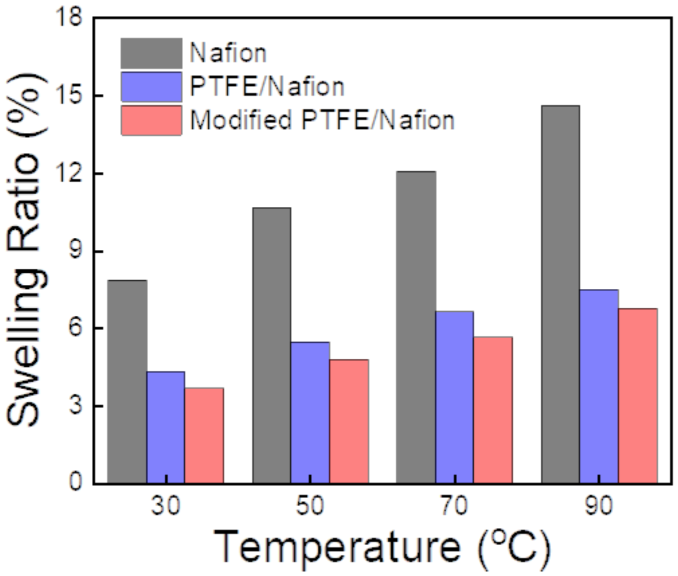
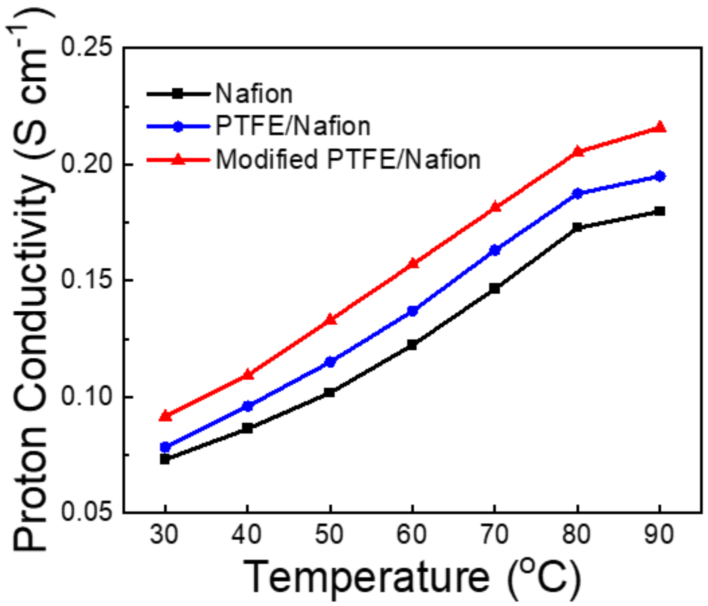
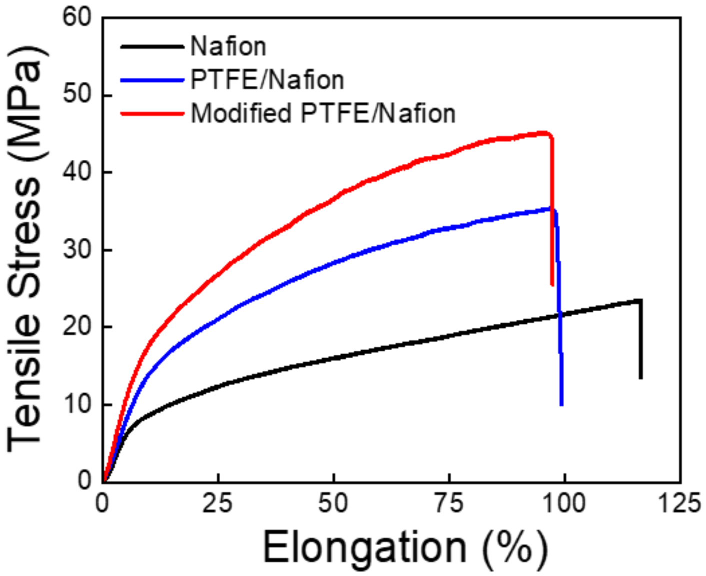
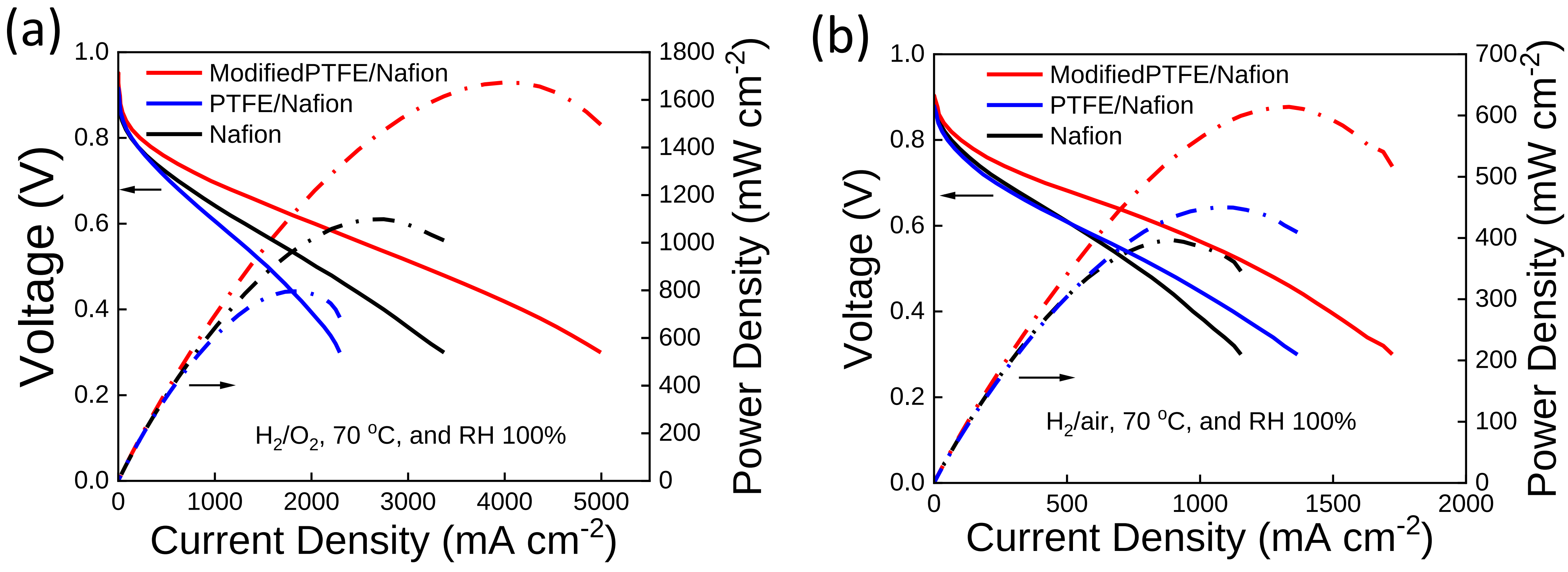




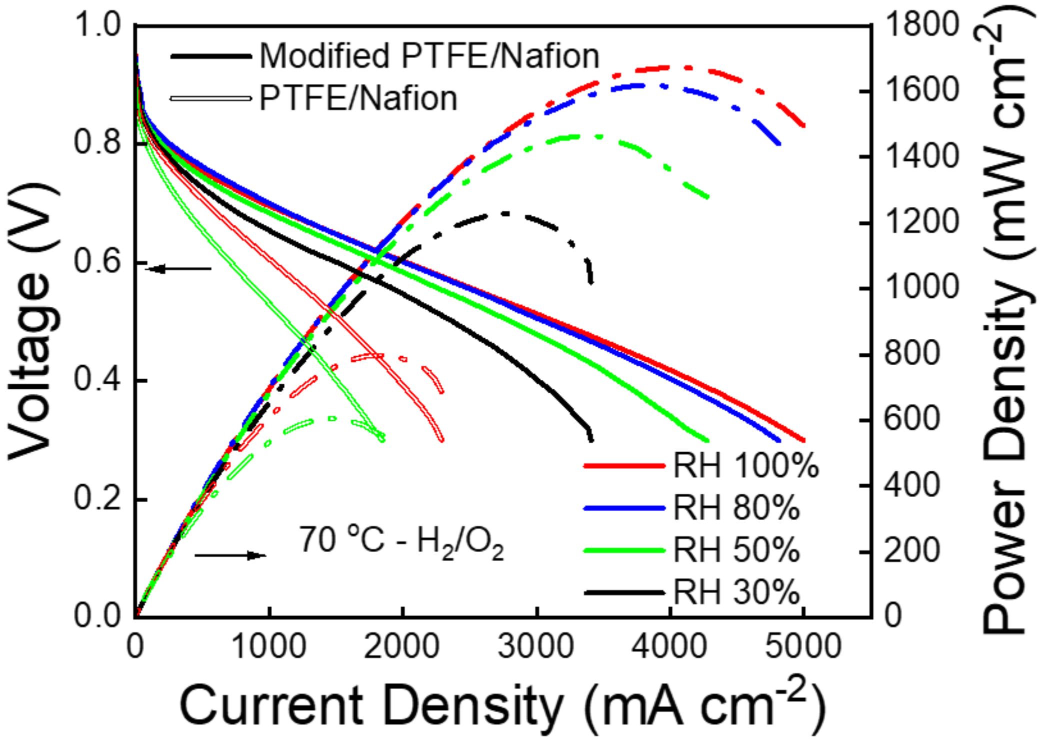


- Reduced swelling ratio
  - ➢ Constrained by PTFE network
- Increased proton conductivity
  - ➢ Packed-acid mechanism
- Enhanced mechanical strength
  - ➢ PTFE support

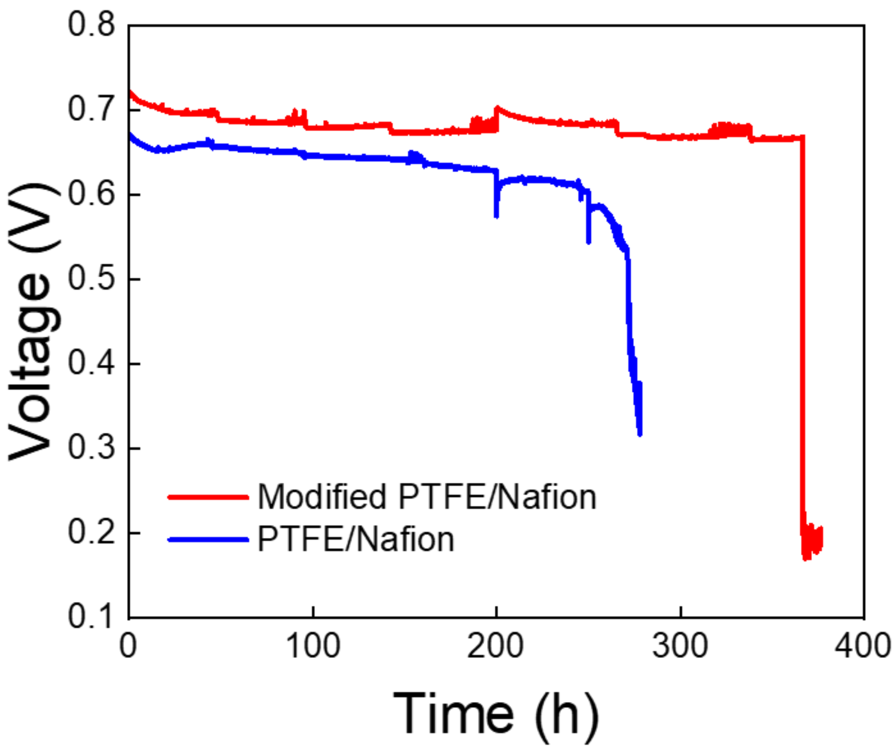
3. Result and Discussion: PEMFC performance



Single cell PEMFC performance in (a) H_2/O_2 and (b) H_2/air



Single cell PEMFC performance at various RH



Membrane durability test at constant current of 0.2 A with cell temperature of 90 ^{o}C and 30% RH

4. Conclusion

Compared to the state-of-the-art Nafion® membrane, modified PTFE/Nafion electrolyte membrane demonstrates;

- More than 57% lower swelling ratio
- Improved mechanical strength by 1.8-fold
- Improved PEMFC performance by 52% in O_2 and 35% in air
- Long term stability in harsh operating conditions of PEMFC

Acknowledgement

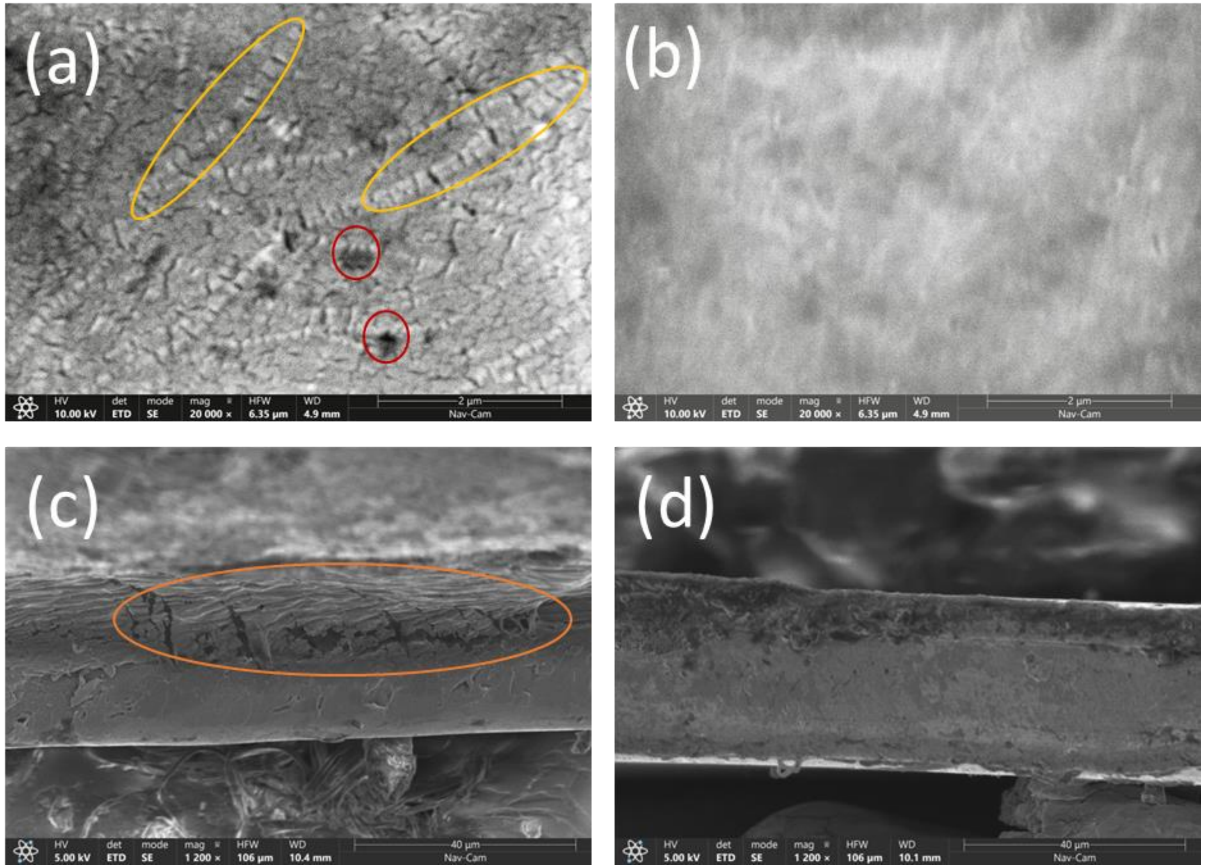
Current Lab Members

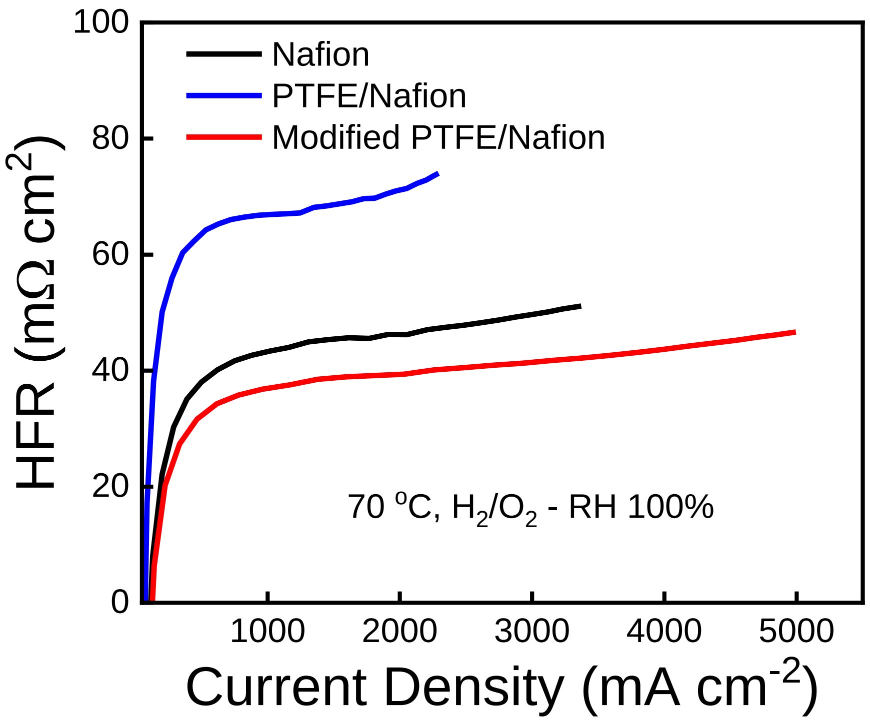
- **Dr. Anima Bose** : *Research Advisor*
- Dr. Dinh Cong Tinh Vo : *Postdoctoral Researcher*
- Subash Bhandari :*Graduate Student*
- Paul Byaruhanga : *Joint Graduate Student*

Thank you for your Attention !

PTFE/Nafion | Modified PTFE/Nafion

Surface SEM / Cross-section SEM





Thermodynamic potential:

$$V_{Nernst} = \Delta V_o + \frac{\Delta S}{nF}(T - T_o) + \frac{RT}{nF}\ln(\frac{P_{H_2}P_{O_2}^{1/2}}{P_{H_2O}})$$

Fuel Cell Potential $(V) = V_{Nernst} - \eta$

Over potential $(\eta) = \eta_{act} + \eta_{ohm} + \eta_{con}$

$$\eta_{ohm} = iR_{internal}$$

ΔS = Change in entropy
n = number of electrons involved in the reaction
F = Faraday's Constant
ΔV_o = Equilibrium cell potential
V_{Nernst} = Nernst Potential
R = Gas Constant
T = Operating Temperature
P = Partial pressure