Synthesis of novel ion-conducting materials for fuel cell application

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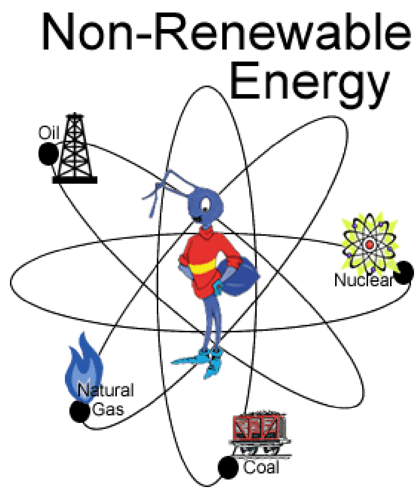
Introduction



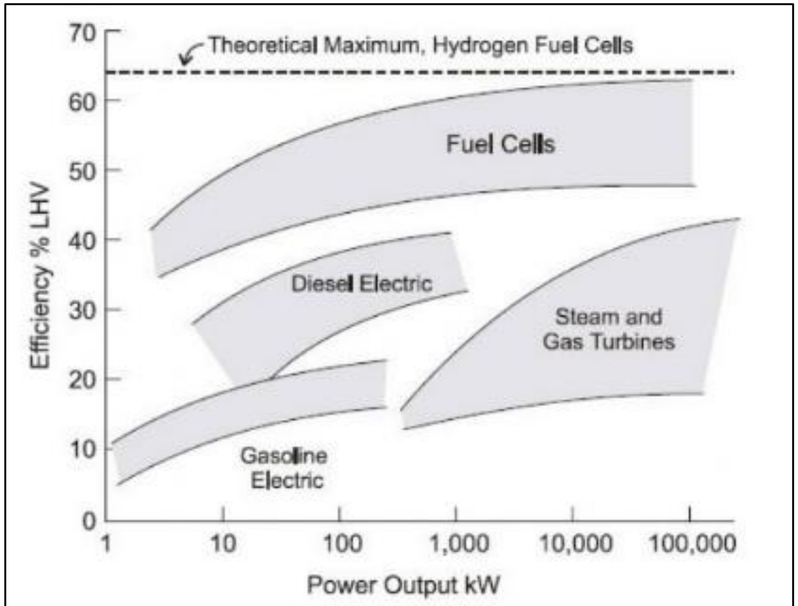
Introduction

Fuel cells

Introduction

Fuel cells

1. Higher energy efficiency;
2. Less CO_2 emissions.

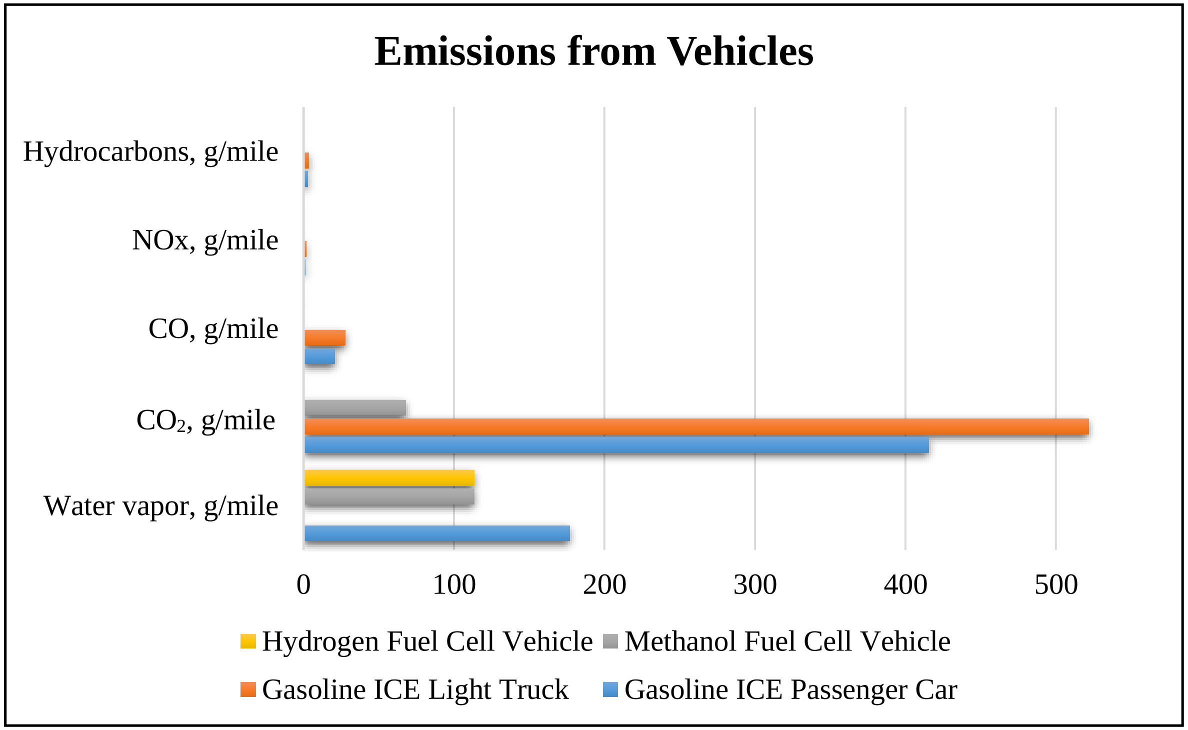


Efficiency Comparison

Introduction

Fuel cells

1. Higher energy efficiency;
2. Less CO_2 emissions.



Introduction

Fuel cells

1. Polymer electrolyte membrane/proton exchange membrane fuel cells (PEMFC);
2. Phosphoric acid fuel cells (PAFC);
3. Alkaline fuel cells (AFC);
4. Solid oxide fuel cells (SOFC);
5. Molten carbonate fuel cells (MCFC).

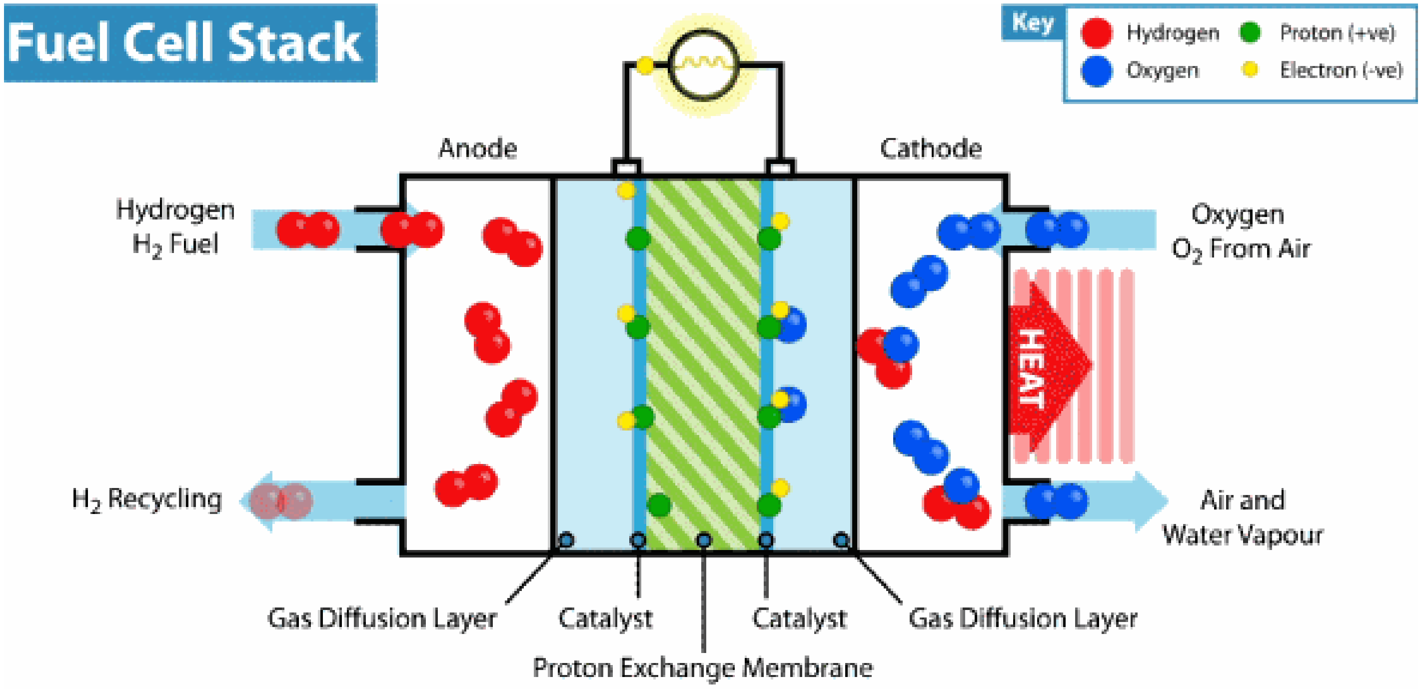
Introduction

Proton exchange membrane fuel cells (PEMFC)

Proton exchange membrane fuel cells (PEMFC)

- Low operation temperature;
- Higher energy density compared to batteries;
- Quiet operation;
- Fast startup;
- Zero local pollutant emission;
- High energy conversion efficiency.

Proton exchange membrane fuel cells (PEMFC)



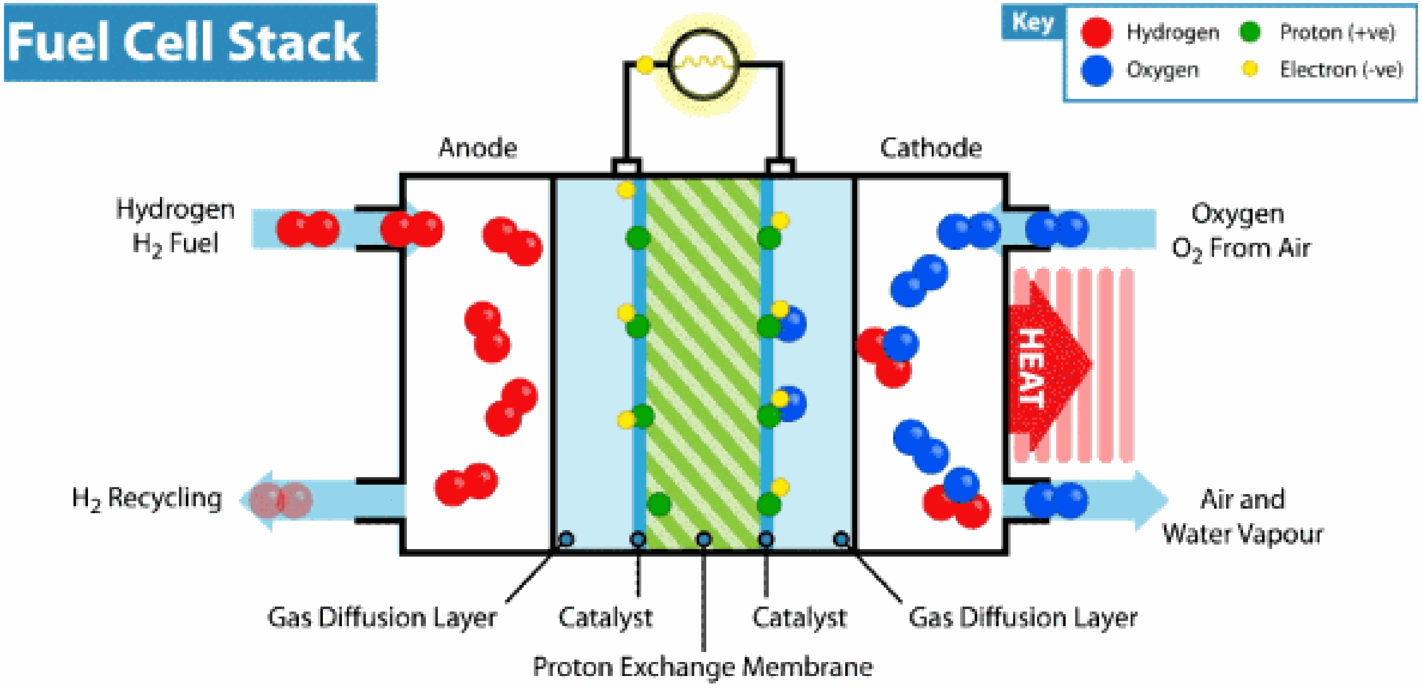
- **Anode:**

$$H_2 \longrightarrow 2H^+ + 2e^-$$

- **Cathode:**

$$1/2O_2 + 2H^+ + 2e^- \longrightarrow H_2O$$

Proton exchange membrane fuel cells (PEMFC)

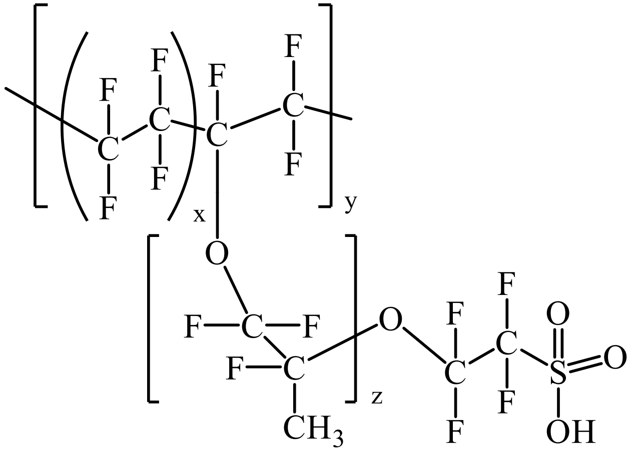


Overall reaction:

$$H_2 + 1/2O_2 \longrightarrow H_2O - \Delta H$$

Proton exchange membrane fuel cells (PEMFC)

Chemical structure of Nafion®



Advantages:

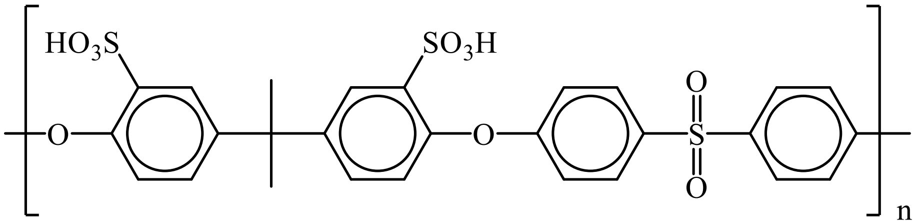
- Good mechanical properties (< 90 °C);
- Chemical stability;
- High proton conductivity.

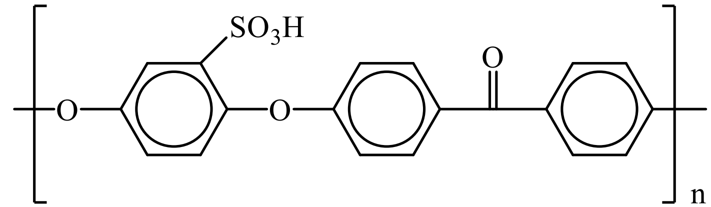
Disadvantages:

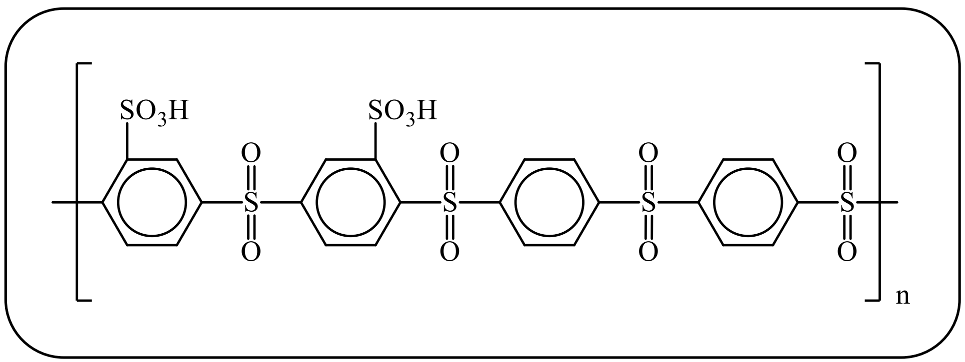
- Low operation temperature (< 90 °C);
- Environmental incompatibility;
- High gas permeability;
- High electroosmotic drag of water from the anode to the cathode;
- Deterioration of mechanical properties at high temperature and low humidity.

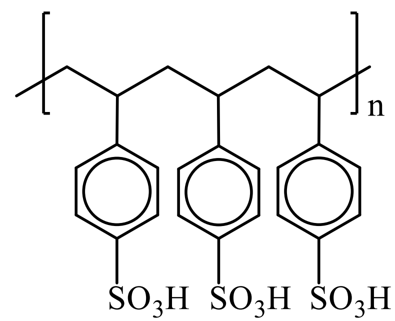
Proton exchange membrane fuel cells (PEMFC)

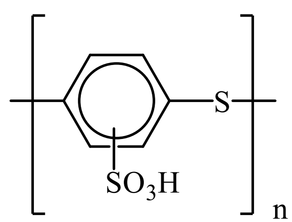
Chemical structures of sulfonated aromatic polymers





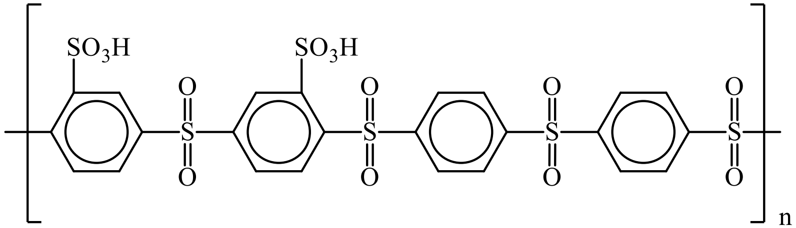


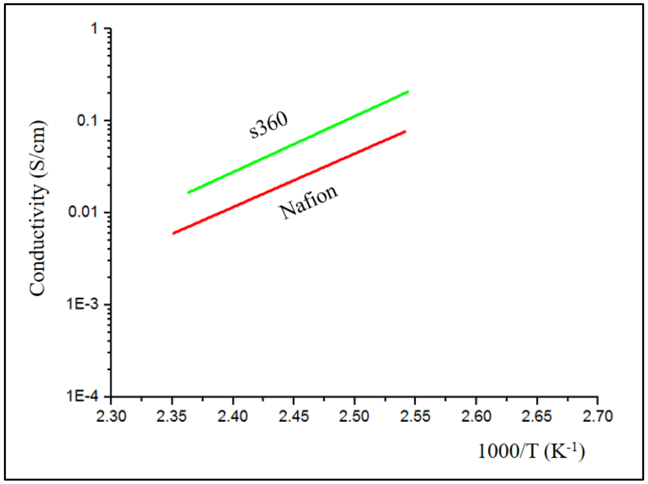




Proton exchange membrane fuel cells (PEMFC)

Chemical structure of $sPSO_2$-360





Advantages:

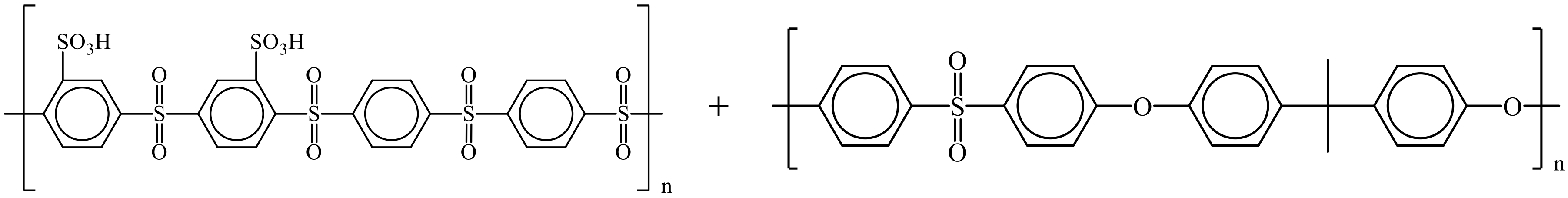
- High IECs and proton conductivities compared to fluorinated ionomers (PFSAs);
- Oxidative stability;
- Thermal stability;
- Low electroosmotic drag of water from the anode to the cathode;
- Good mechanical properties at moderate humidity.

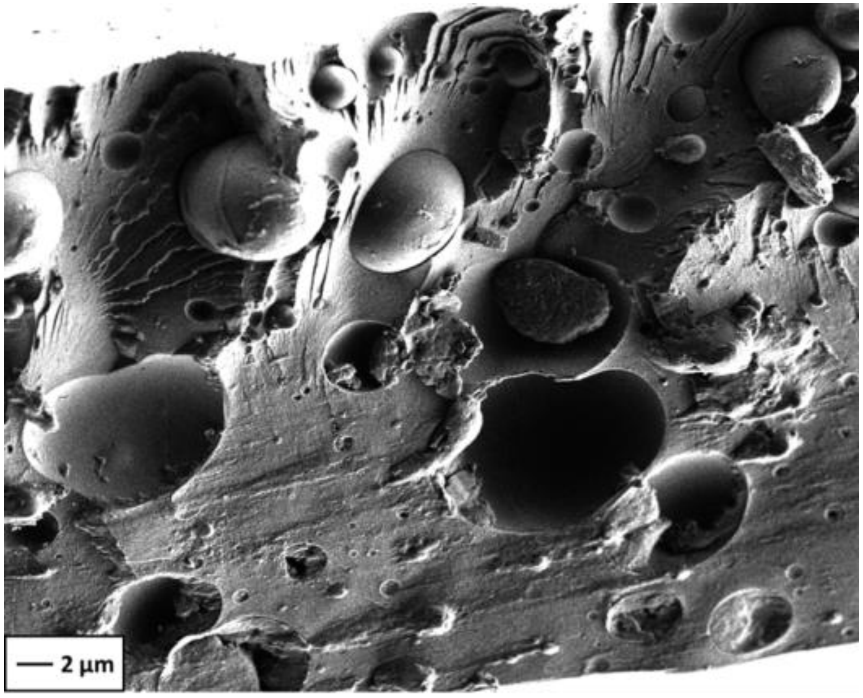
Disadvantages:

- Brittleness in the dry state;
- Unsatisfactory mechanical properties at high humidity.

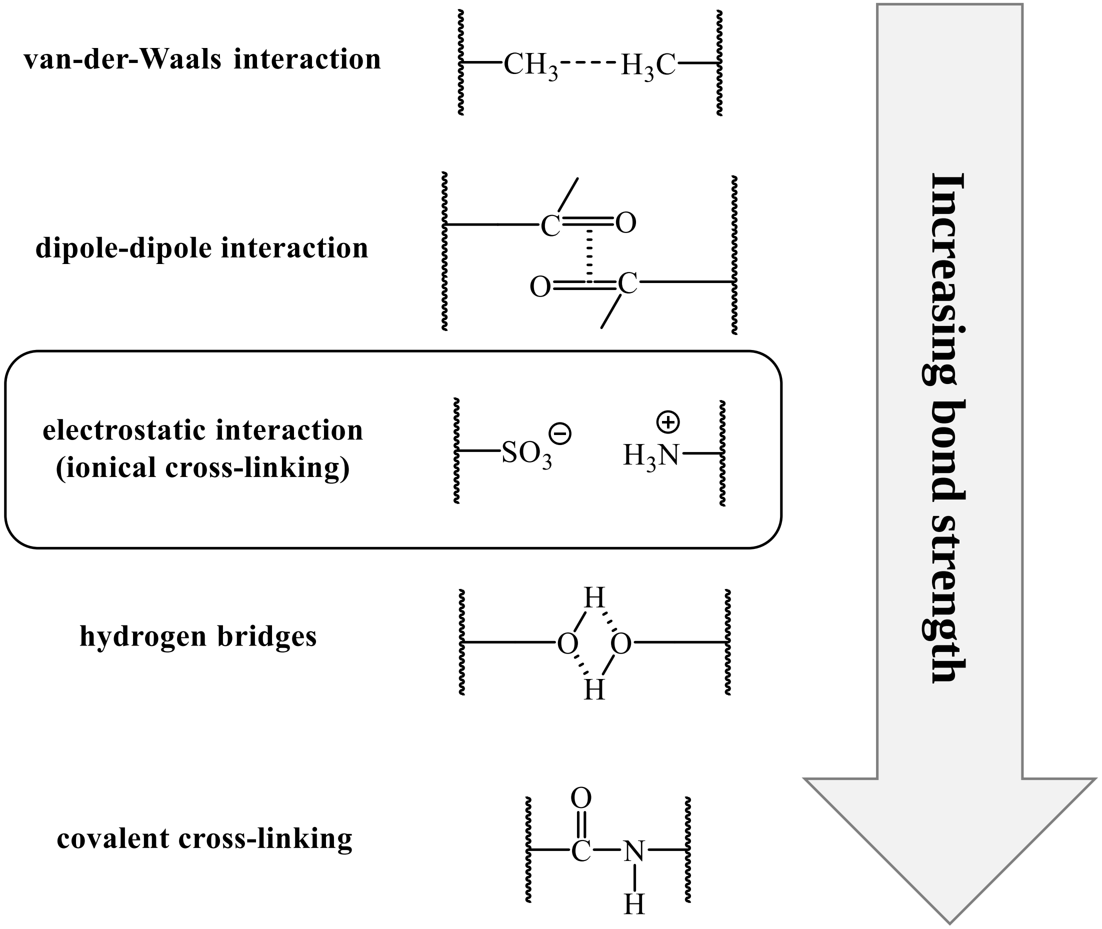
Proton exchange membrane fuel cells (PEMFC)

Blend of $sPSO_2$-360 with PSU



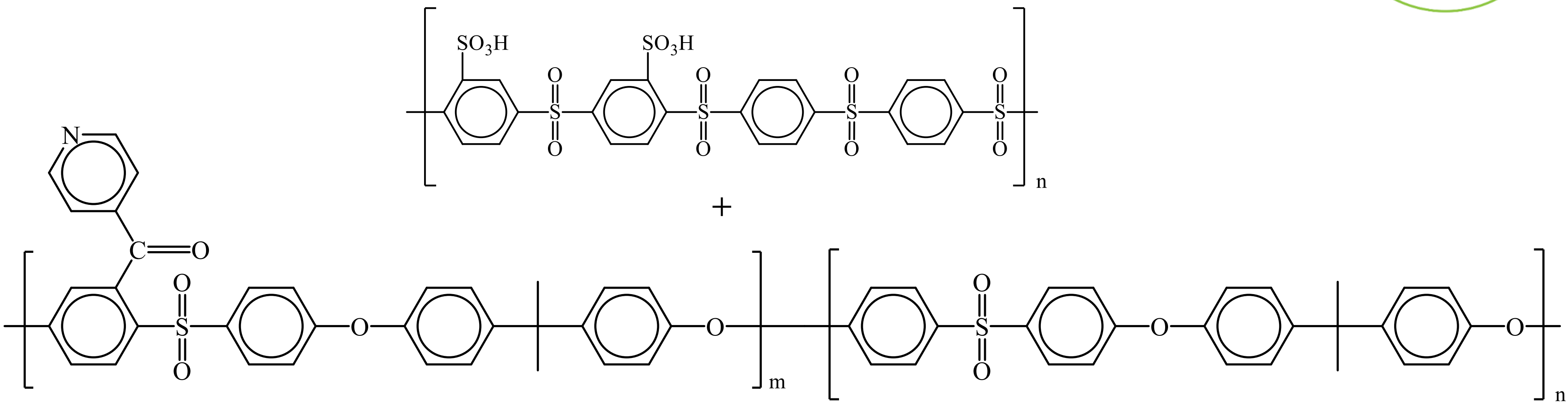


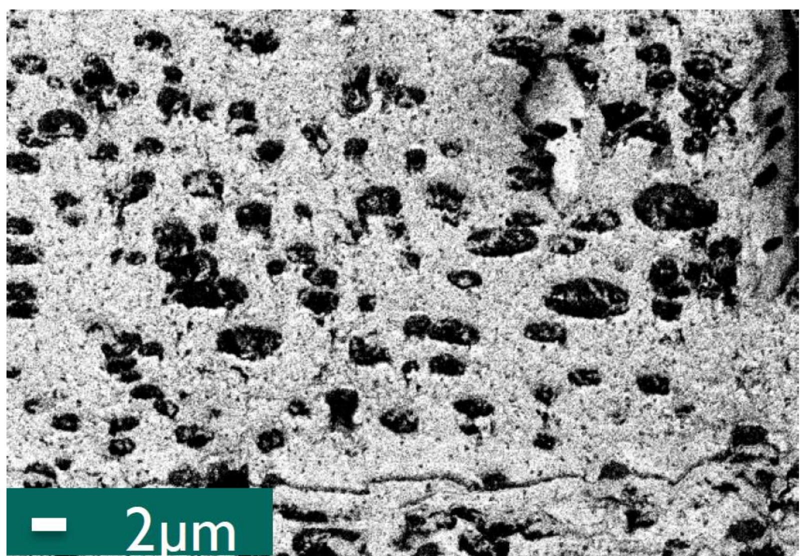
Specific interactions between macromolecules



Proton exchange membrane fuel cells (PEMFC)

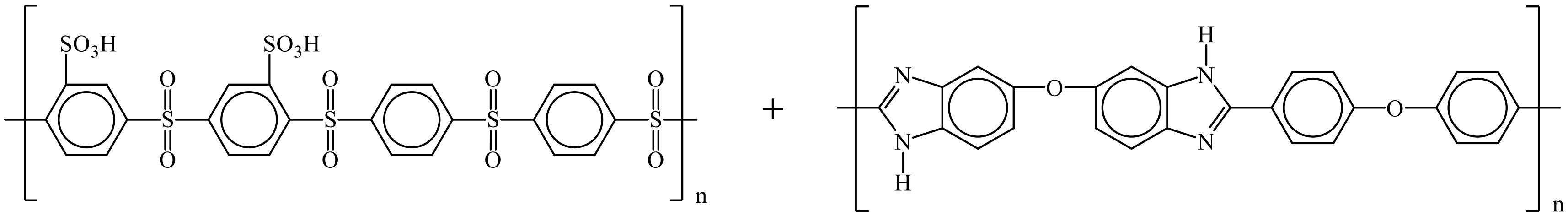
Blend of $sPSO_2$-360 with PSU-py

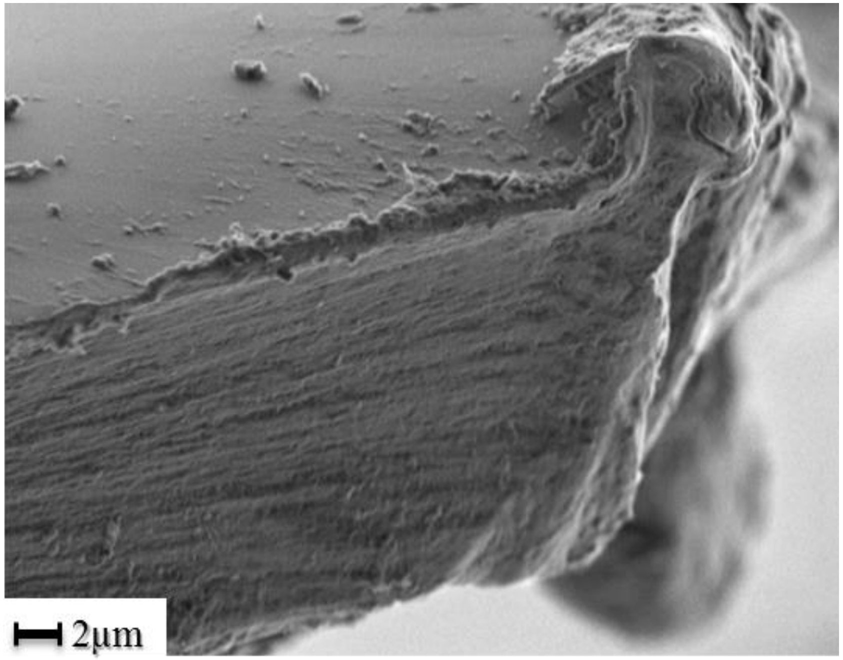




Proton exchange membrane fuel cells (PEMFC)

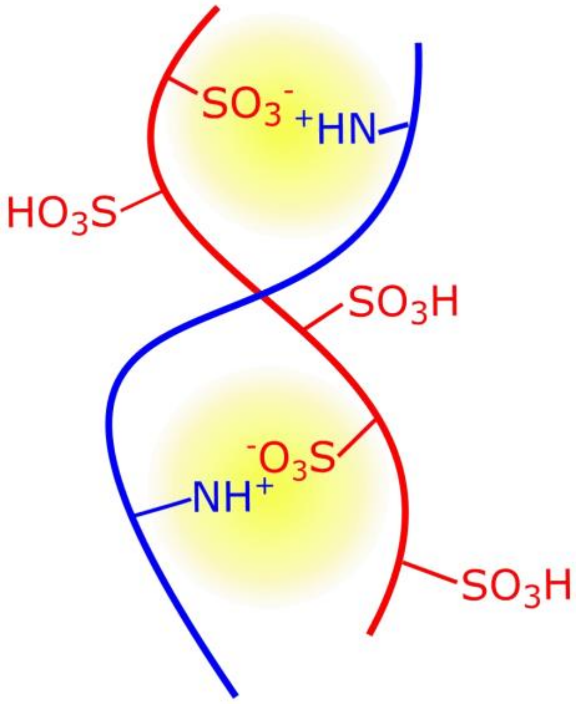
Blend of $sPSO_2$-360 with PBI-OO





Proton exchange membrane fuel cells (PEMFC)

Scheme of ionic crosslinking of a $sPSO_2$-360 (red) with a PBI-OO (blue)



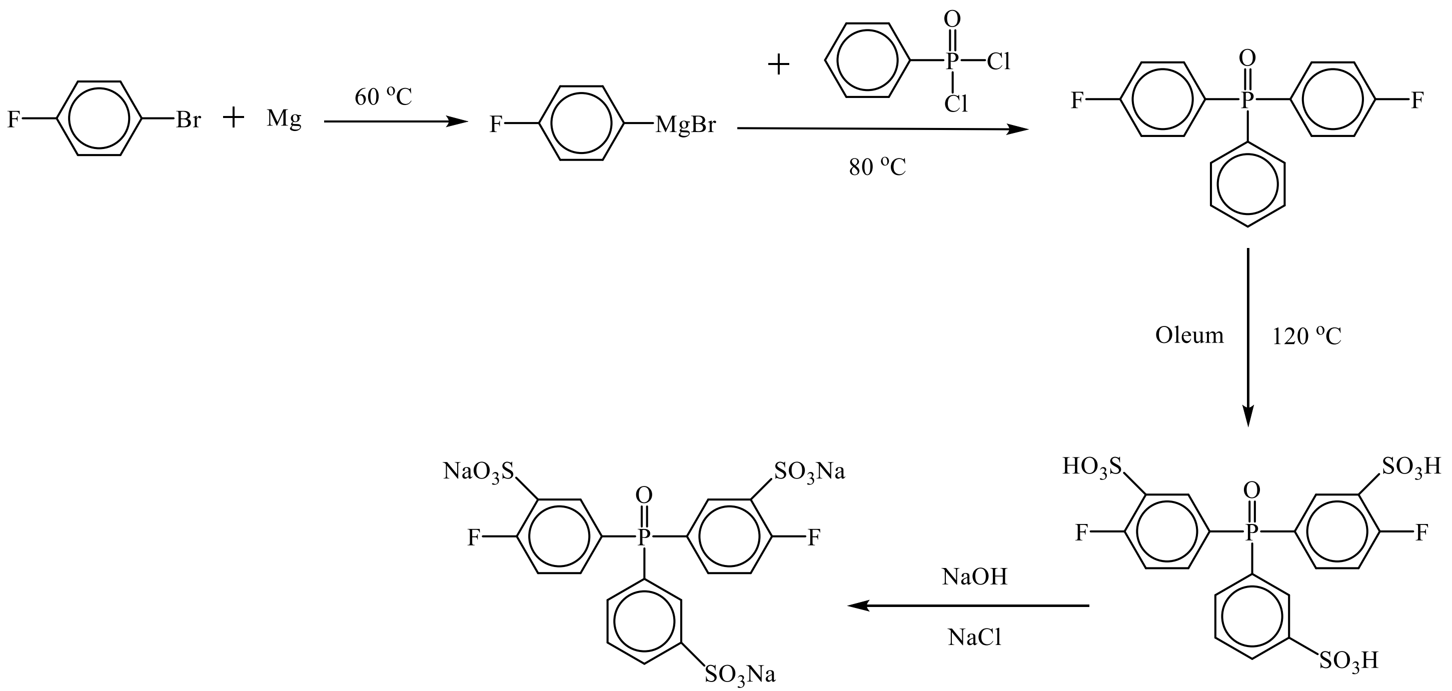
- Increase of mechanical strength;
- Decrease of proton conductivity;
- Decrease of ion exchange capacity.

Research objective:

Synthesis of monomer and polyelectrolyte with high sulfonation degree

Proton exchange membrane fuel cells (PEMFC)

Synthesis scheme of sodium 5,5'-((3-sulfonatophenyl)phosphoryl)bis(2-fluorobenzenesulfonate)[1,2]

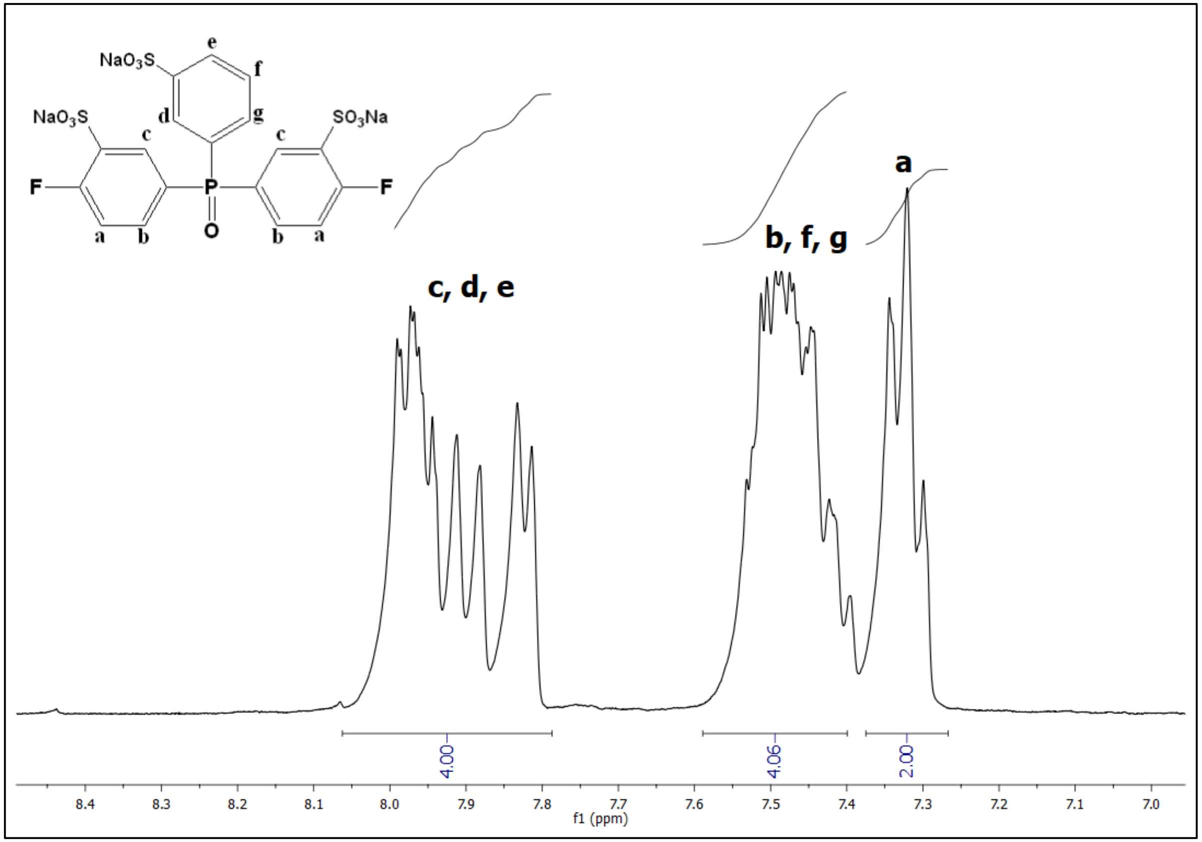


1. X. Ma, C. Zhang, G. Xiao, D. Yan, G. Sun, Synthesis and characterization of sulfonated poly(phthalazinone ether phosphine oxide)s by direct polycondensation for proton exchange membranes, J. Polym. Sci. Part A Pol. Chem. 46 (2008) 1758-1769;

2. Liao, H.; Zhang, K.; Tong, G.; Xiao, G.; Yan, D. Sulfonated Poly(arylene Ether Phosphine Oxide)s with Various Distributions and Contents of Pendant Sulfonic Acid Groups Synthesized by Direct Polycondensation. Polym. Chem. 2014, 5, 412–422.

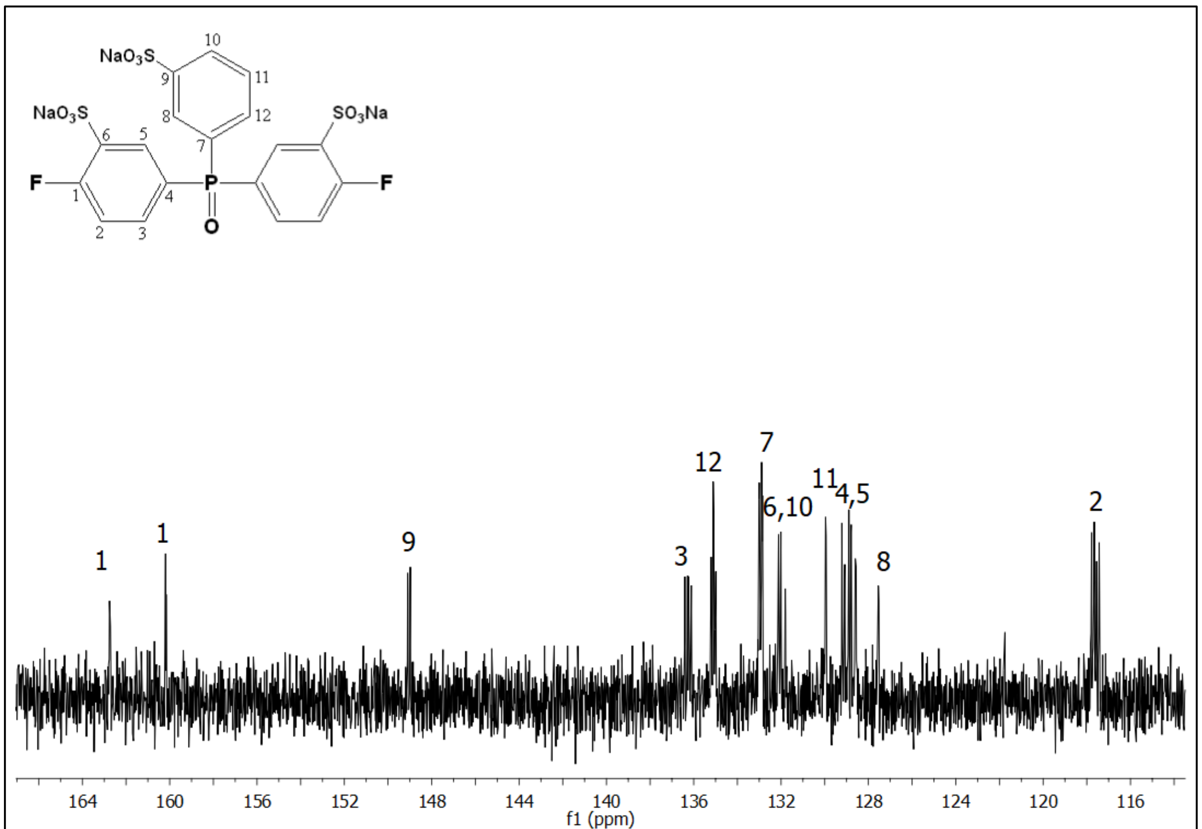
Proton exchange membrane fuel cells (PEMFC)

[1]H NMR Spectra of sodium 5,5'-((3-sulfonatophenyl)phosphoryl)bis(2-fluorobenzenesulfonate)



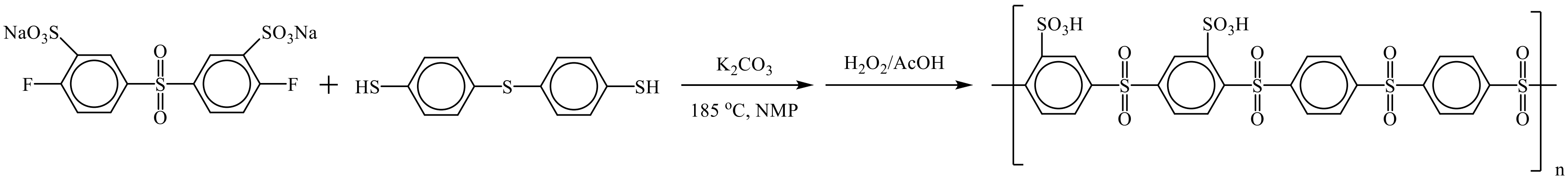
Proton exchange membrane fuel cells (PEMFC)

^{13}C NMR Spectra of sodium 5,5'-((3-sulfonatophenyl)phosphoryl)bis(2-fluorobenzenesulfonate)

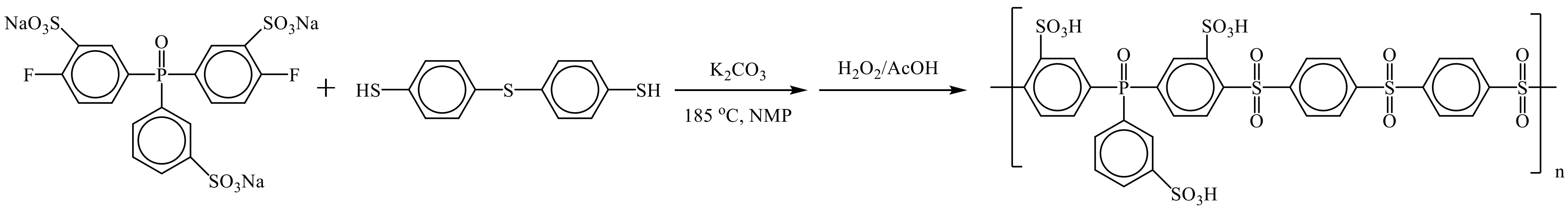


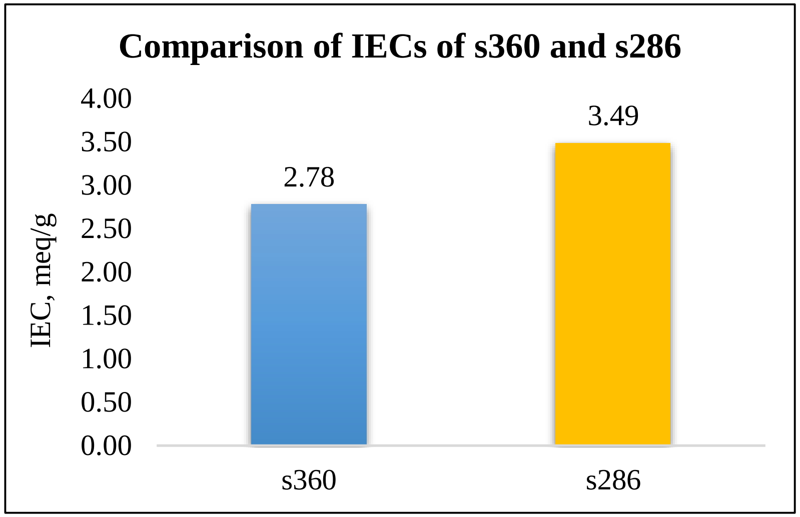
Proton exchange membrane fuel cells (PEMFC)

Synthesis scheme of $sPSO_2$-360



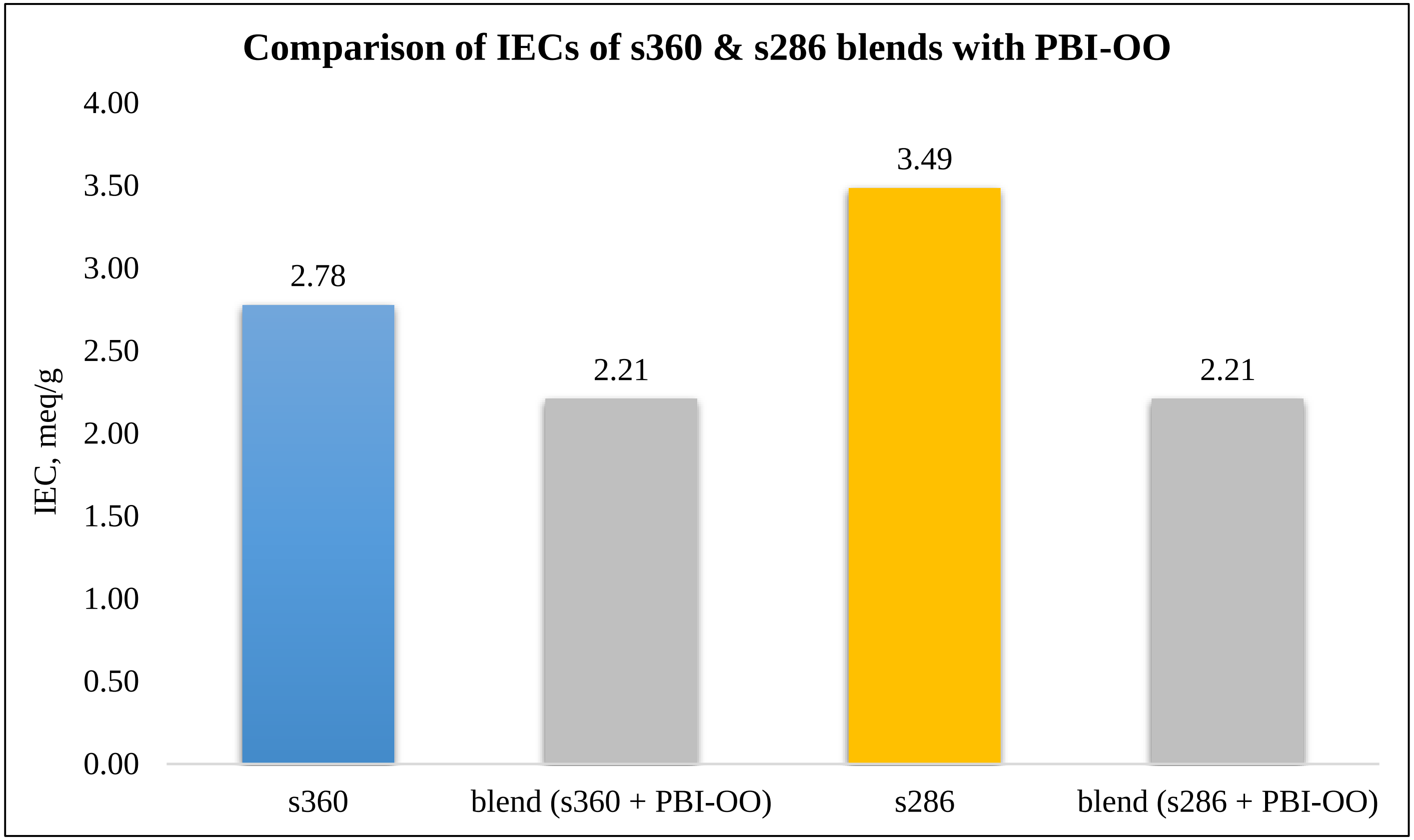
Synthesis scheme of $sPSO_2PO$-286





➢ **IEC increases by ≈ 25 %**

Proton exchange membrane fuel cells (PEMFC)



PBI-OO = 7.5 %

PBI-OO = 15.39 %

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Acknowledgments

Thank you for attention!