NAFION-FREE HYDROCARBON-BASED POROUS MEMBRANE FOR VANADIUM REDOX FLOW BATTERY APPLICATION

IITM Technology Available for Licensing

Problem Statement

- **Vanadium Redox Flow Batteries (VRFBs)** are touted as a promising energy storage system for stationary applications such as **load leveling of the grids fed with the energy from renewable sources** like wind and solar.
- The **Ion exchange membrane (IEM) or separator is a critical component** that provides a pathway for **ion transport and isolates the two halves of the cell**, thereby preventing direct mixing and short circuits. Perfluoro sulfonic acid (PFSA) based membranes such as **Nafion are the most employed membrane** in VRFB.
- However, **Nafion®-117 suffers poor selectivity toward vanadium ion crossover** and amounts **to 35-45% of the overall cost** of the battery.
- **Non-ionic porous separators** have gained attention due to their excellent mechanical and chemical stability and **low cost compared to Nafion®** membrane. However, porous separators **suffer from a higher rate of crossover** due to the absence of suitable barriers for ion movements, poor selectivity, and higher pore size.
- There is a **need for suitable alternatives to the state-of-the-art Nafion®** that delivers **better electrochemical** properties and **cost-effective VRFB performances.**

Intellectual Property

- IITM IDF Ref 2727
- **IN 202341088792 Patent Application**

TRL (Technology Readiness Level)

TRL 4 Technology Validated in Lab

Technology Category/ Market

Category- Energy, Energy Storage & Renewable Energy

Industry Classification:

NIC (2008): 27202- Manufacture of electric accumulator including parts thereof (separators, containers, covers).

NAICS (2022)- 335910 Battery Manufacturing

Applications:

Manufacture of Ion Exchange Membranes for Vanadium Redox flow batteries used for storing energy harvested from solar, wind and tidal energies.

Market report:

The global vanadium redox flow battery (VRFB) market was valued at $188.7 million in 2023, and is projected to grow to $523.7 million by 2030 with a CAGR of 15.8%

Research Lab

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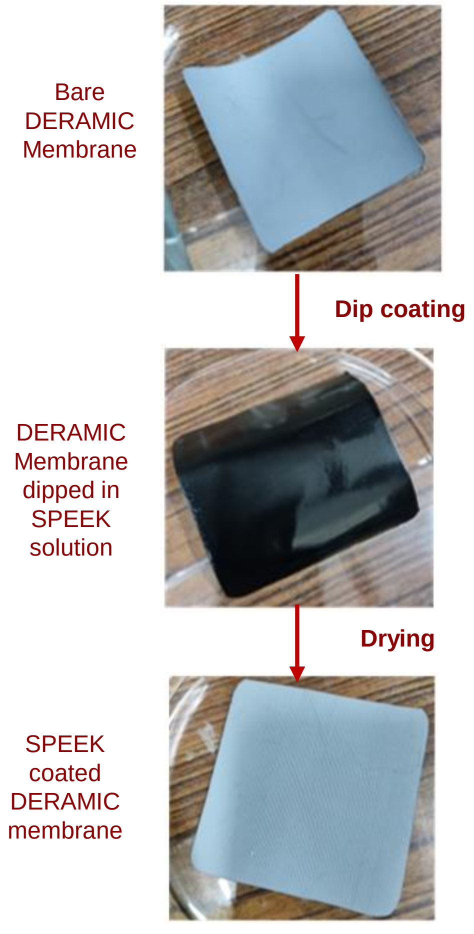

Figure: Preparation method of DARAMIC/SPEEK membrane

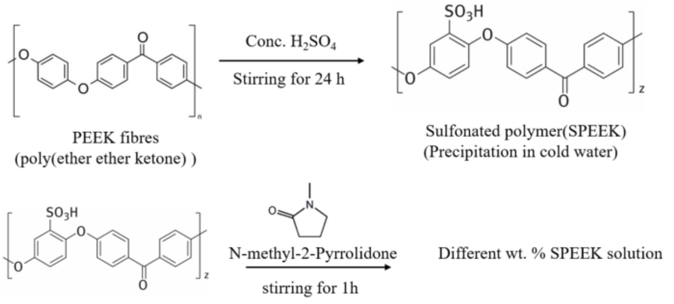

Figure: Reactions involved in the preparation of the DARAMIC/SPEEK membrane

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Membrane	SPEEK loading
M1	Bare membrane
M2	2 mg cm^{-2}
M3	3 mg cm^{-2}
M4	4 mg cm^{-2}
M5	5 mg cm^{-2}
M6	6 mg cm^{-2}
Nafion® 117	NIL

Figure: SPEEK loading of various samples prepared for testing

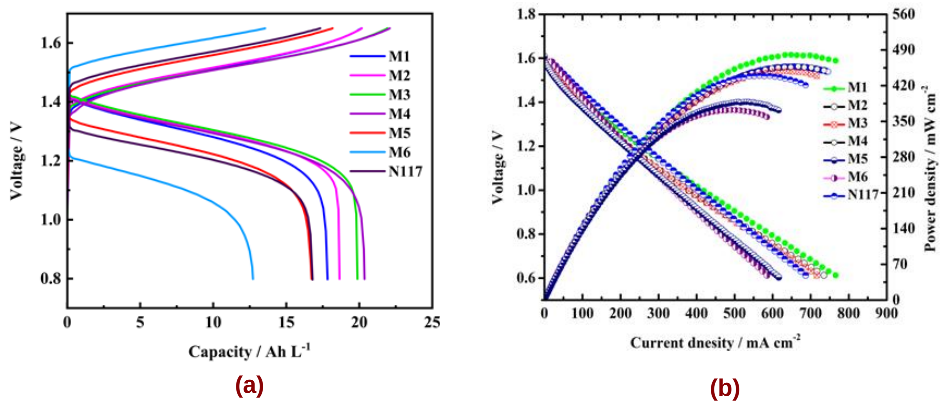

Figure: (a) Galvanostatic charge-discharge GCD comparison plot of different prepared membranes @ 100 mA cm^{-2} current density and **(b)** polarization and power density comparison plots of VRFB cells having different membranes using 1 M vanadium electrolyte. Considering the capacity offered by the cell and the power density it is elucidated that the M4 membrane has the highest discharge capacity and comparable peak power density with commercial Nafion® 117.

Technology

- The invention uses an affordable commercial hydrocarbon-based porous DARAMIC membrane as a base framework decorated with cation exchange polymer, i.e., sulfonated poly ether ether ketone (SPEEK), to reduce the cost of VRFB and improve ion selectivity respectively.
- The combination of Daramic and SPEEK polymer aims to create a hybrid membrane that retains the desirable properties of both materials. The Daramic matrix provides structural support and stability, reducing the swelling and improving the overall mechanical strength of the membrane. On the other hand, the SPEEK polymer component contributes to the membrane's proton conductivity and selective transport of ions.
- The cost-effective Nafion-free hydrocarbon-based porous membrane is prepared by the typical dip coating method. Five different membranes were prepared with a varying weight loading of SPEEK.
- **Vanadium electrolyte was prepared from $VOSO_4$. $VOSO_4$ was adopted as a starting material due to its higher solubility in an H_2SO_4 solution. D-fructose is used as an additive to suppress the hydrogen evolution reaction (HER) during the charging of the VRFB.**

Key Features / Value Proposition

- The cost of the invented membrane was only around 9% of Nafion®117, suggesting that it could significantly improve the economic viability of VRFB for large-scale energy storage applications
- The materials can be used in different flow battery applications. When compare to Nafion, The hydrocarbon-based membrane provides cost-effectiveness, which is essential for grid-level energy storage.
- The prepared composite membrane exhibits good stability in vanadium solutions under strong acid conditions, allowing it to sustain cell performance and its efficiency.
- GCD and polarization studies indicated that the prepared membrane significantly reduced the cost and exhibited similar performance to Nafion®117.
- The cycling stability tests showed the membranes were stable in vanadium and acid solution.

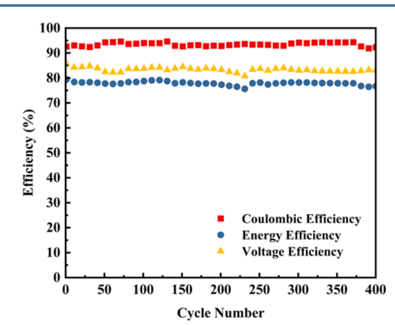

Figure: Efficiencies plot of M4 membrane @ 100 mA cm^{-2} current density using 1 M vanadium electrolyte in 3 M H_2SO_4. M4 membrane shows nearly 95% average CE and around 80% average EE over 400 cycles. This suggests that the prepared composite membrane exhibits good stability in vanadium solutions under strong acid conditions, allowing it to sustain cell performance and its efficiency.

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