Polysulfone Multi-block Cationomers: Properties and Vanadium Redox Flow Battery Performance

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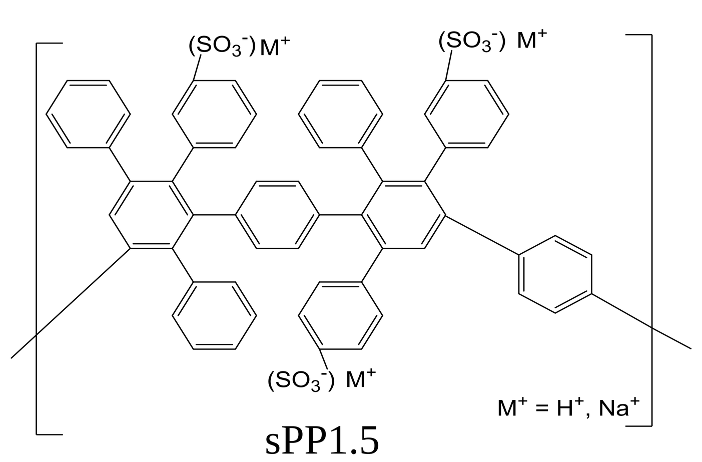
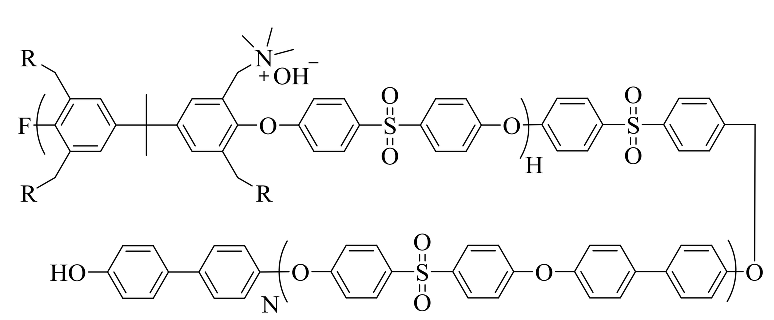
INTRODUCTION

Because the need for grid-connected energy storage systems is on the rise worldwide due to increasing demand and expansion of renewable energy sources, a larger amount of variable electricity will need to be managed.[1] Unlike other battery systems, redox flow batteries store electricity as chemical energy in flowing electrolytes and vanadium redox flow battery (VRB) is one of the most promising electricity storage systems due their localization flexibility, scalability and efficiency.[2,3] As one of the key components of VRB, ion exchange membrane is used to prevent cross mixing of the positive and negative electrolytes and allow the transport of ions to complete the circuit during the passage of current.[4,5] In recent years, our lab has been successful in employing sulfonated poly(phenylene) in VRBs which demonstrated energy efficiencies upto 67% versus 64.5% of Nafion 117. Anion exchange membranes (AEMs) block the transport of cations due to Donnan repulsion effects and are widely used in electrodialysis. These inspired us to explore the properties of polysulfone multiblock cationomers (QmPAES) based bipolar membranes in VRBs.

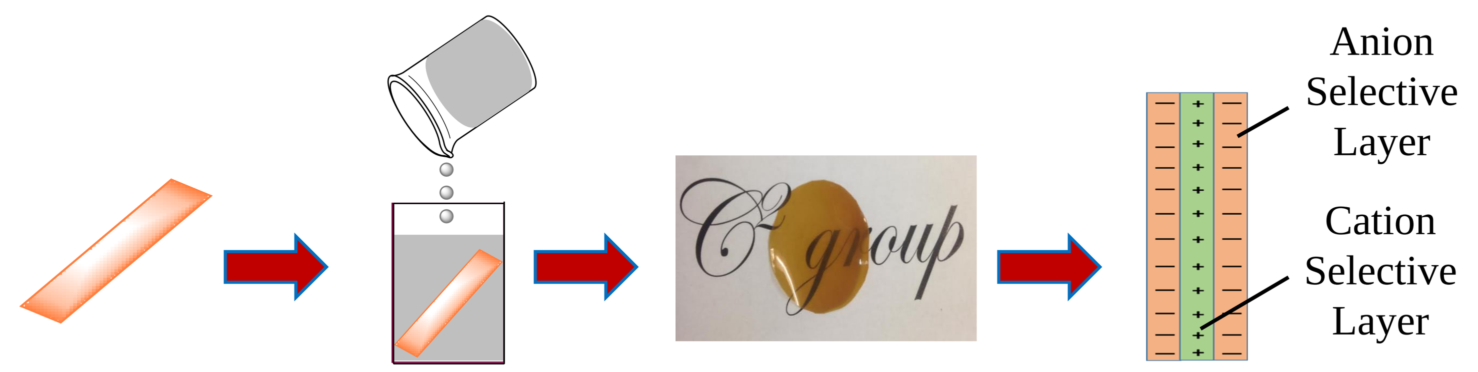
MEMBRANE PROCESSING



sPP1.5



QA-H:N [18k:8k]



sPP1.5 QA solution sPP1.5-QA membrane Bipolar membrane

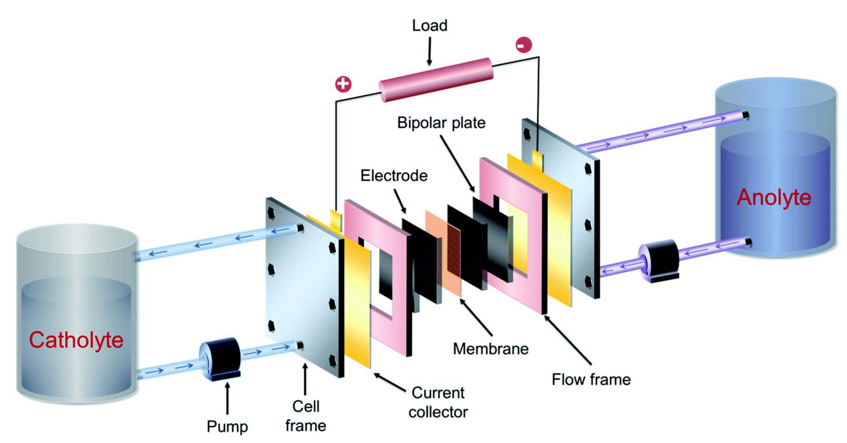
BATTERY ASSEMBLY

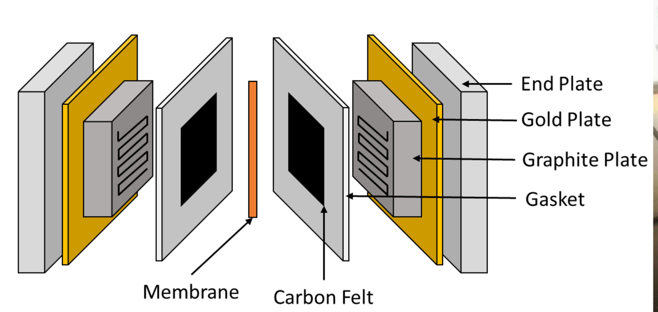
$$CE = \frac{t_d}{t_c} \times 100\%$$

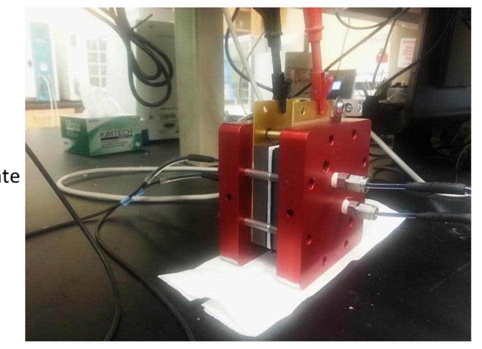
$$VE = \frac{V_d}{V_c} \times 100\%$$

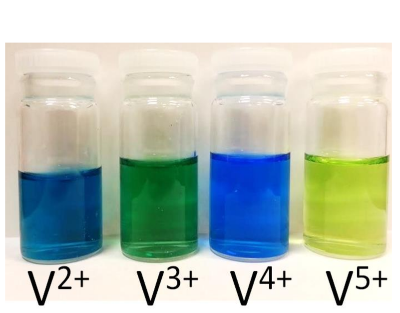
$$EE = CE \times VE$$

where
t_d is the discharging time,
t_c is the charging time,
V_d is the average discharging voltage,
V_c is the average charging voltage.

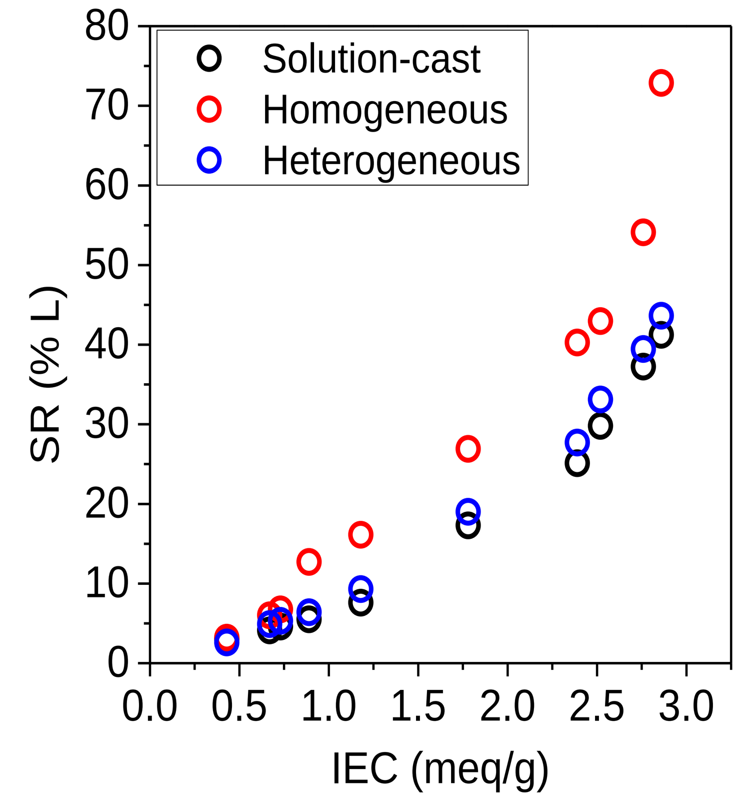








MEMBRANE SWELLING



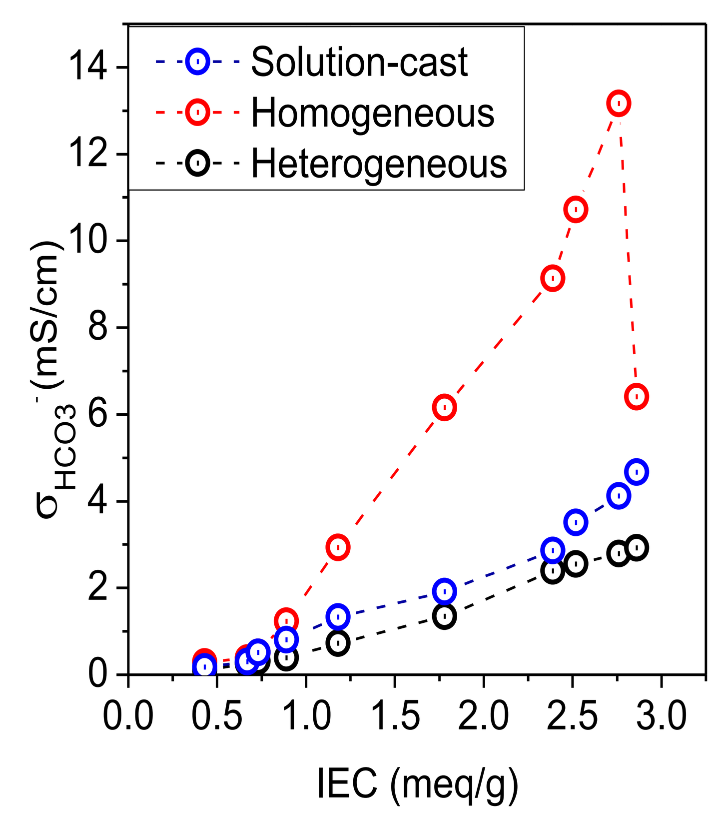
Solution-cast → Heterogeneous → Homogeneous — Increasing SR

- Genral trend: increasing IEC→ increasing SR
- For the same IEC: Solution-cast < Homogeneous
- Solution-cast at 80 °C ≃ Heterogeneous RT

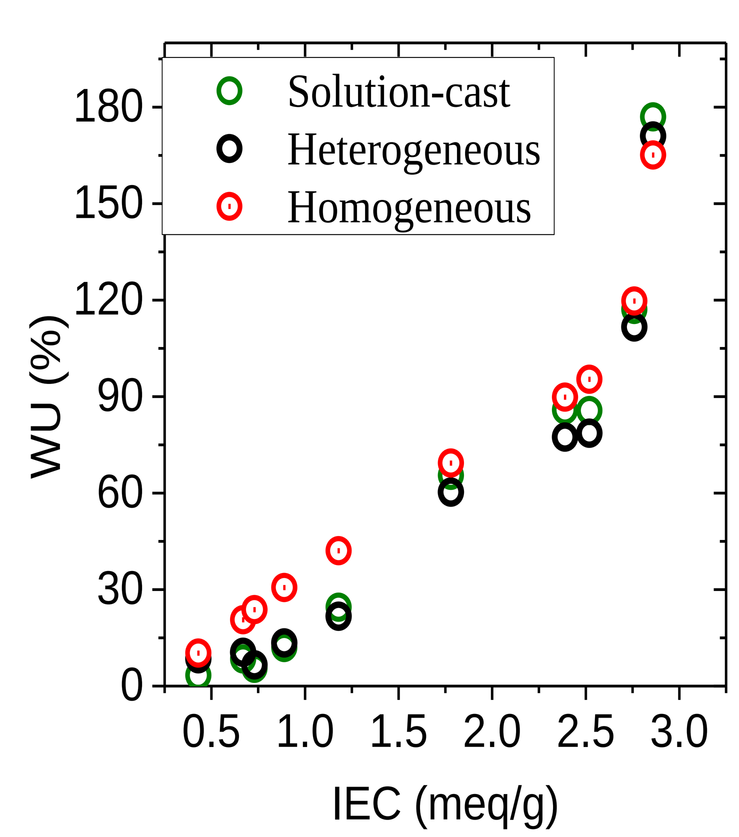
MEMBRANE CONDUCTIVITY

Homogeneous cationomer conductivity drops at high IEC → Dilution Effect

- General trend: increasing IEC→ increasing σ
- Heterogeneous ≃ Solution-cast →similar to WU
- Homogeneous > Heterogeneous ≃ Solution-cast



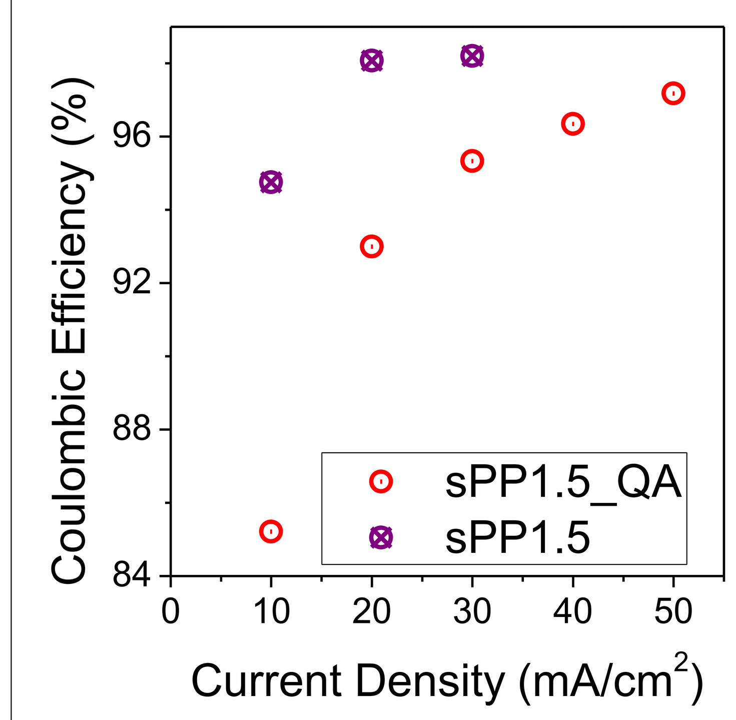
WATER UPTAKE

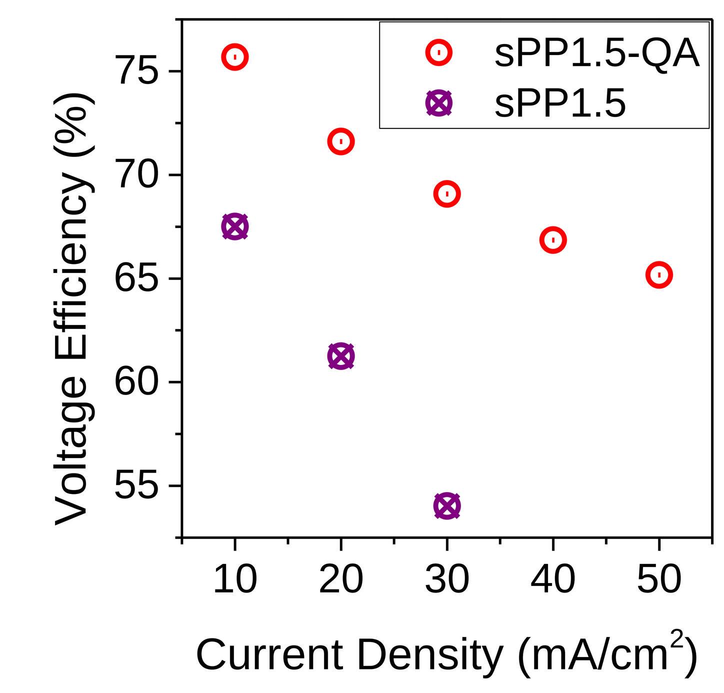


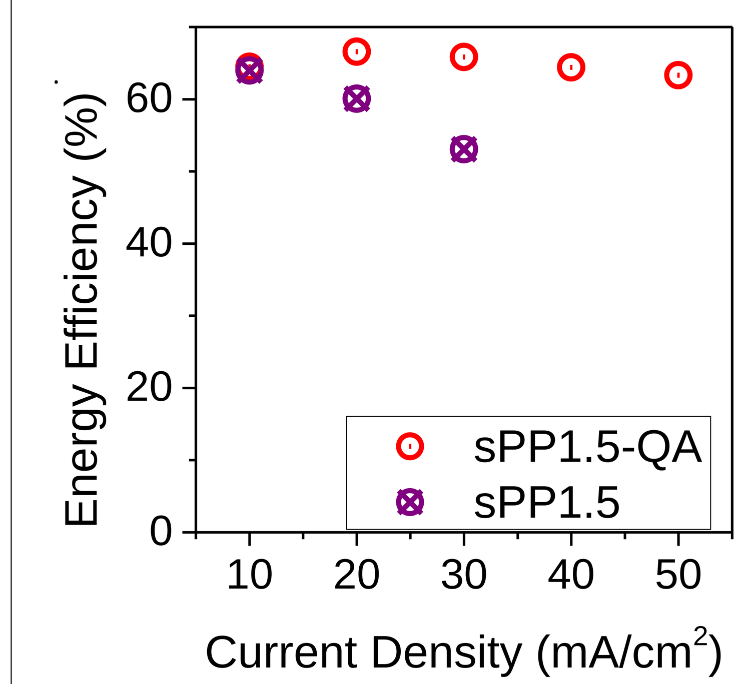
Solution-cast ↕ Heterogeneous ↕ Homogeneous — No apparent effect of processing

- General trend: increasing IEC → increasing WU
- For the same IEC: $H_M \simeq H_T \simeq S_C$
- H_M vs H_T vs S_C → no apparent change in WU

BATTERY PERFORMANCE







- sPP1.5 – QA VE > sPP1.5 VE
- sPP1.5 EE > sPP1.5-QA VE
- sPP1.5 CE > sPP1.5-QA CE

Bipolar membrane permits better efficiency than sPP1.5 and QA-based polysulfone

CONCLUSION

- Bipolar membrane fabrication facilitates better battery performance
- Membrane Processing plays an important role in battery performance
- Solution-cast multiblock cationomers have better dimensional stability
- Water uptake characteristic is mostly dominated by ion exchange capacity
- Homogeneous membrane undergo ion dilution resulting in lower conductivity
- Higher battery efficiency is believed to be due to improved V^{n+} ion diffusion resistance across the sPP1.5-QA bipolar membrane compared to sPP1.5

References

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