30 µm thin, highly conductive PBI-based anion exchange membrane (AEM) for VRFB applications

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Introduction

Limited publications of AEM's compared to PEM's

- Quaternized polysulfone (QAPSF) [1]
- Quaternized poly(fluoro ether) [2]
- Polybenzimidizole (PBI) [3]

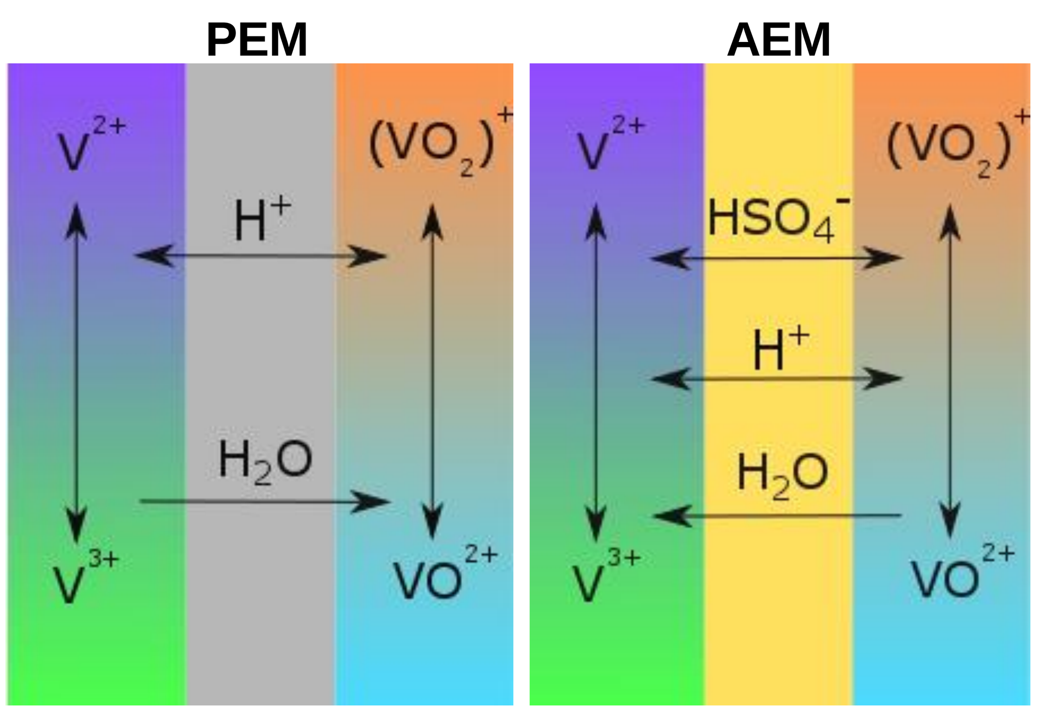

Figure 1: General schematic of PEM and AEM operation in a VRFB environment

VRFB Membrane Requirements

Low V crossover
Chemically Stable
Mechanically Stable
High conductivity

New Material Application

- Hexamethyl-p-terphenyl poly(benzimidazolium) [4]
- Reported previously for fuel cell and electrolyser applications → **This work: First application for redox flow batteries**
- Non fluorinated
- Chemically & mechanically stable in acidic media

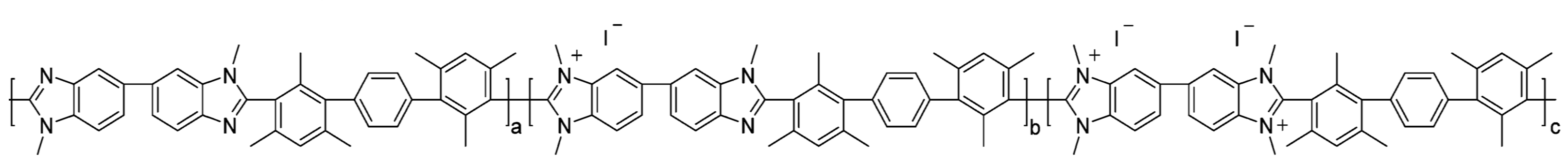

Figure 2: Structure of HMT-PMBI, as reported by Wright et al. [4]

Electrochemical Analysis

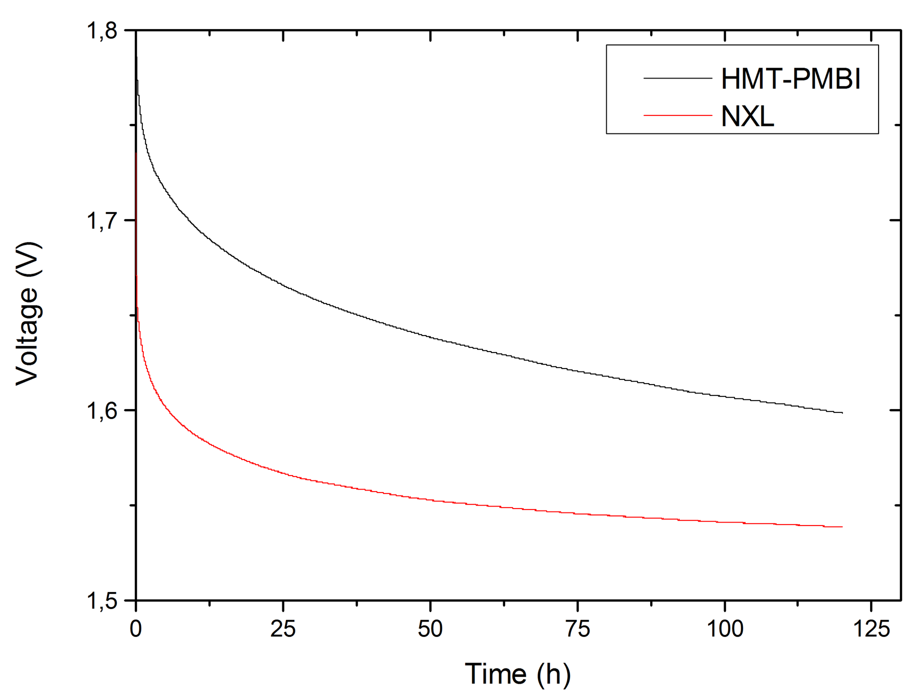

Figure 3: Self -discharge comparison of HMT-PMBI and Nafion XL

Lower self discharge rate compared to Nafion XL

- Lower V crossover due to charge repulsion (Gibbs – Donnan effect)

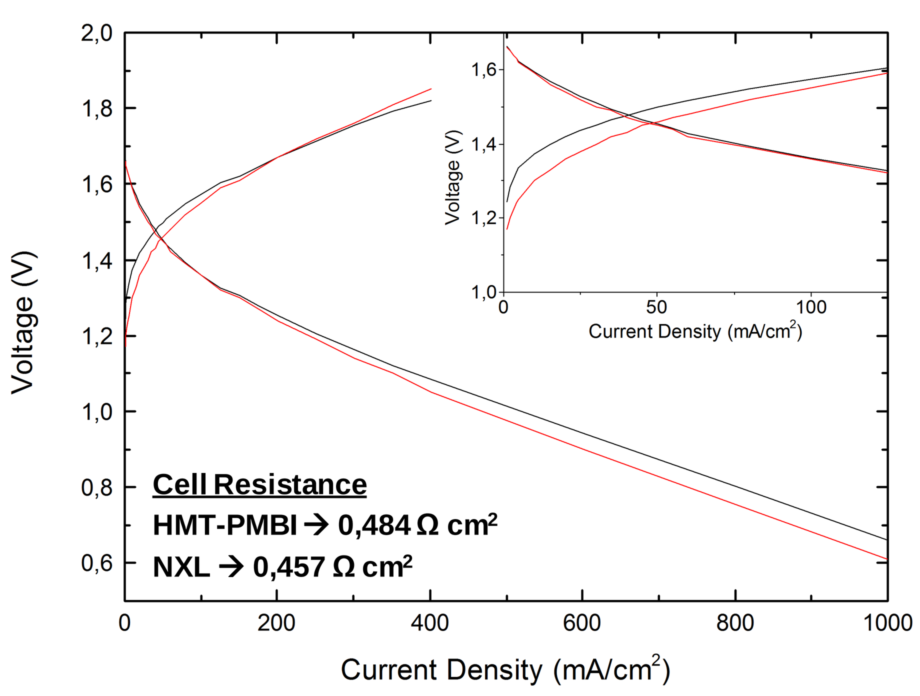

Figure 4: Polarization data comparison of HMT-PMBI (black line) and Nafion XL (red line). Inset image showing 0 – 125 mA/cm² range

Comparable performance to Nafion XL

Similar cell resistance

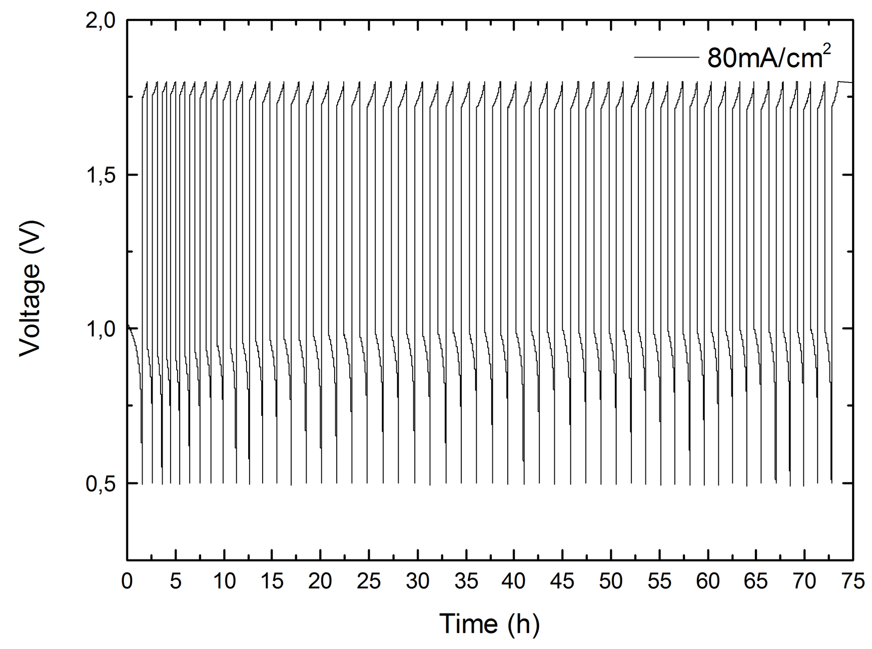

Figure 5: Cycling of HMT-PMBI at 80 mA/cm²

After 50th cycle:

- CE – 99.58%
- EE – 51.22%
- VE – 50.49%

•CE >99% is comparable to other reported results

•Low EE due to non-optimized electrodes

Chemical Stability Testing

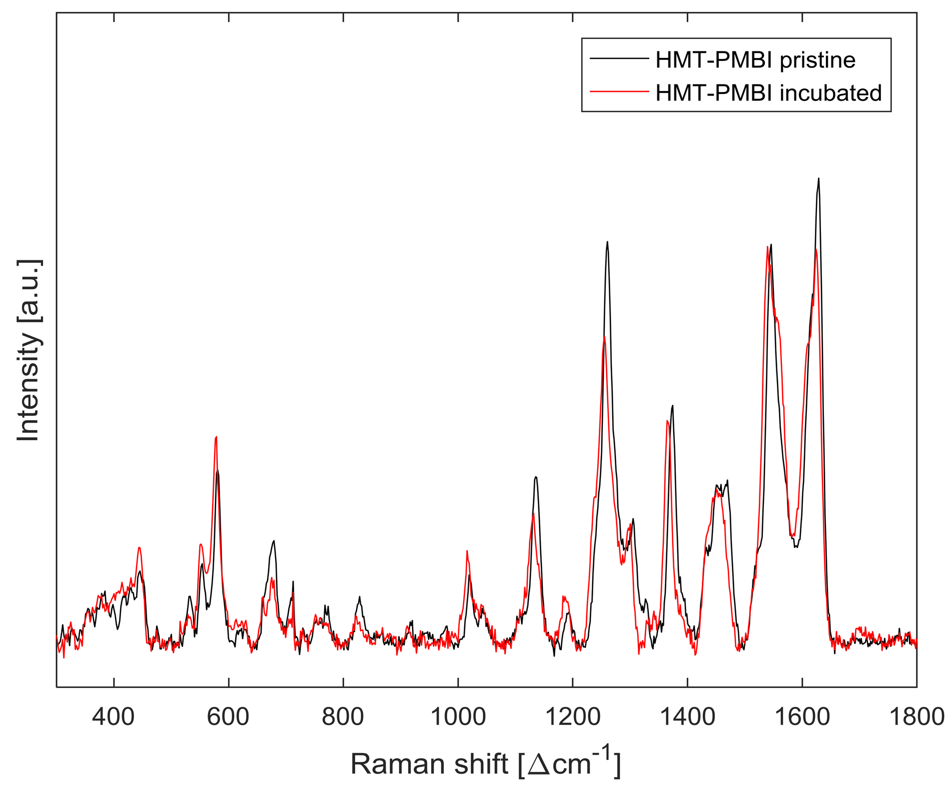

Figure 6 : Raman analysis of HMT-PMBI before and after chemical stability testing – 19 days, RT, 1M V^{5+} in 4M H_2SO_4 electrolyte

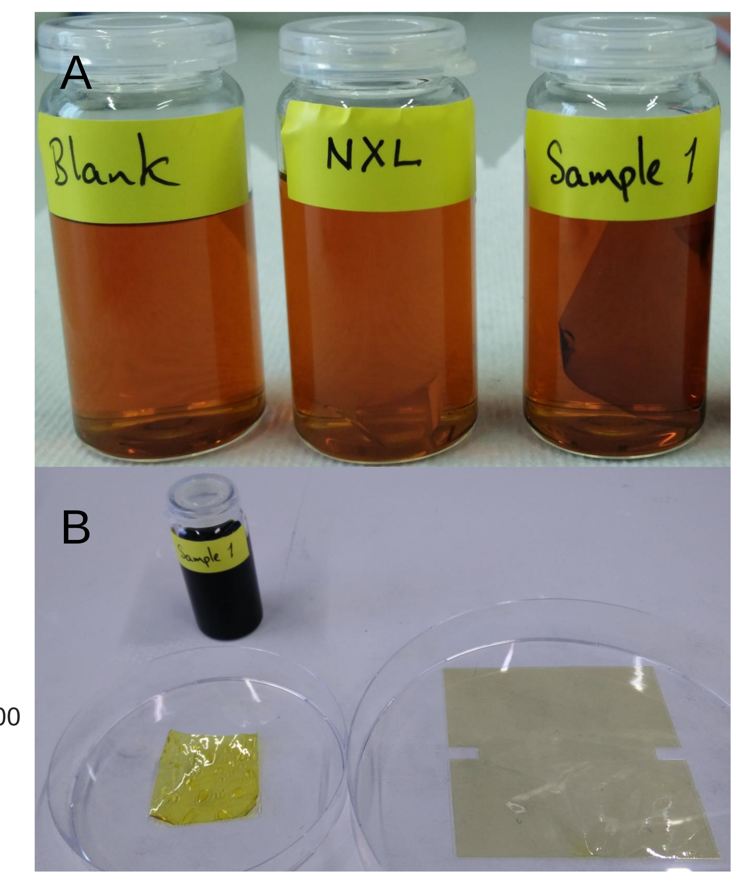

Figure 7: (A) Samples on Day 0. **(B)** HMT-PMBI on Day 19 (left), compared to untreated HMT-PMBI (right).

- Raman analysis indicates no surface chemical change after incubation.
- Coloration of membrane most likely due to V^{5+} absorption.

Conclusions

Initial testing has successfully demonstrated the application of HMT-PMBI, a 30 µm thin and non-fluorinated AEM, as suitable for use in VRFB systems. Comparable performance has been demonstrated against Nafion XL.

Outlook

Further testing and optimization required for a complete and comprehensive assessment :

- Longer cycling
- Longer term degradation study
- Cell optimization
- Vanadium crossover testing

Acknowledgements

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References

[1] J. Ren, Y. Dong, J. Dai, H. Hu, Y. Zhu, X. Teng, *Journal of Membrane Science* 544 (2017) 186–194.
[2] M.S. Cha, H.Y. Jeong, H.Y. Shin, S.H. Hong, T.-H. Kim, S.-G. Oh, J.Y. Lee, Y.T. Hong, *Journal of Power Sources* 363 (2017) 78–86
[3] C. Noh, M. Jung, D. Henkensmeier, S.W. Nam, Y. Kwon, *ACS applied materials & interfaces 9* (2017) 36799–36809
[4] A.G. Wright, J. Fan, B. Britton, T. Weissbach, H.-F. Lee, E.A. Kitching, T.J. Peckham, S. Holdcroft, *Energy Environ. Sci. 9* (2016) 2130–2142.

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