Design of Ion-Conducting Materials for High-Temperature Energy Applications

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Introduction

- Acid-doped polybenzimidazole (PBI) membranes are promising for their reasonably high proton conductivities at high-temperature operations of proton exchange membrane fuel cells (PEMFCs) with little or no humidification[1].
- However, PBI-based membranes have issues due to the weak acid-base interaction and phosphoric acid (PA) leaching[2].
- Incorporation of quaternary ammonium group into the PBI matrix will improve PA retention due to strong ion pair interaction energy[3].

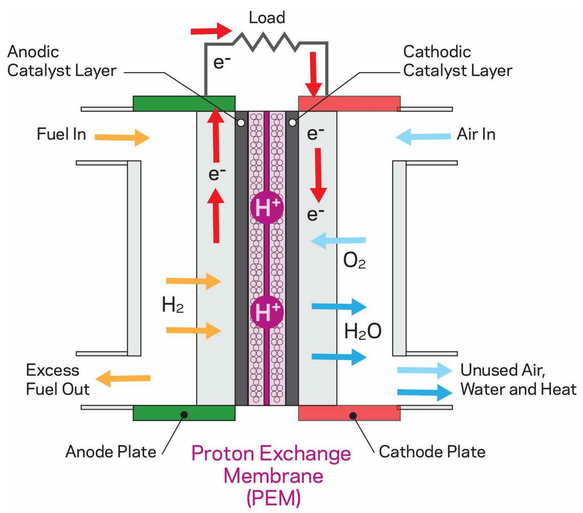
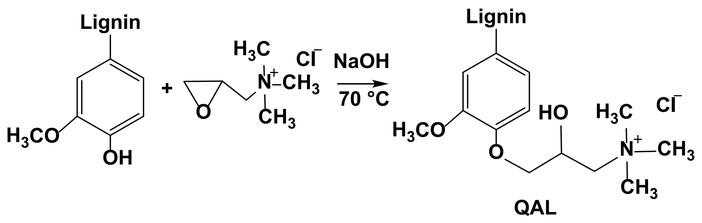


Figure 1. Working principle of PEMFC

Research Objective

- Utilize lignin (a 3D-structured and branched polymer[4]) as a storage site for PA.
- Convert lignin's -OH groups to quaternary ammonium functionalities.
- These cationic functionalities will be utilized to hold PA within the PBI-QAL matrix via ion-pair interactions.

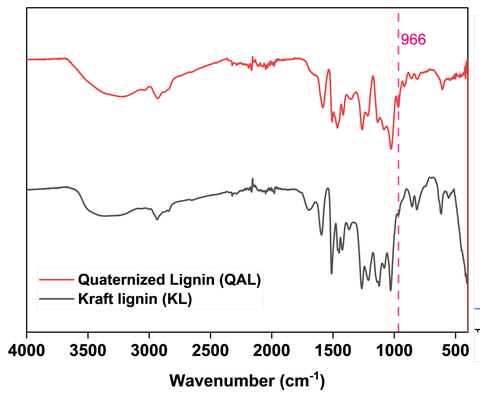
Modification of Lignin

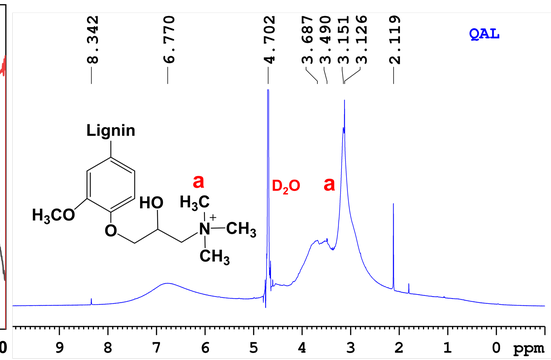


Scheme 1. Reaction scheme to render cationic functionalities to lignin and yield QAL[5].

Results

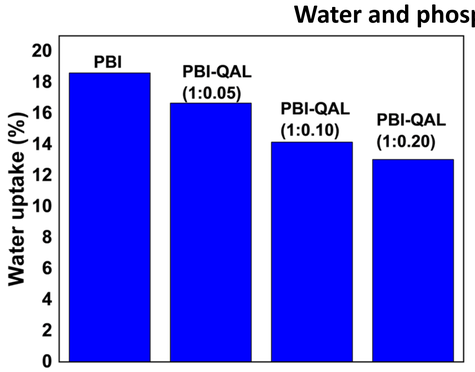
Spectroscopic analysis (FTIR and NMR)

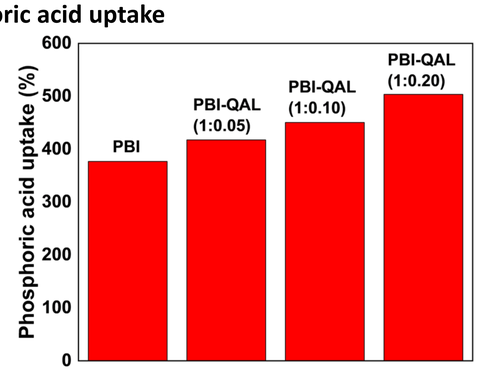




- The peak at 966 cm^{-1} in QAL corresponds to CH_2 and methyl peaks of GTMAC.
- The peak range from 2.49 to 3.36 ppm corresponds to quaternary amine protons

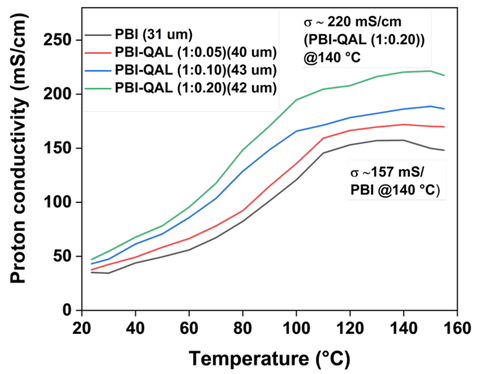
Water and phosphoric acid uptake

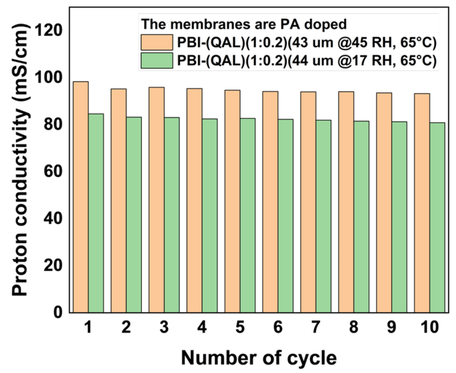




- Water uptake decreases as QAL content increases, due to the stiffness of QAL and its interaction with PBI.
- PA uptake of PBI-composite membranes was higher than that of pure PBI. The increase in acid uptake is a result of ion-pair interactions between PA and QAL.

Proton conductivity and cycling experiment





- PBI membrane conductivity increased with increasing QAL loading.
- The cycling experiment showed a negligible reduction in conductivity over 10 cycles.
- This shows the strong ion-pair interaction of PA with PBI-QAL

Conclusions and Future work

- Quaternary ammonium functionalities were successfully grafted on neutral kraft lignin.
- PA capture significantly improved with the increase in QAL loading in PBI membrane matrix.
- A significant improvement of proton conductivity at high temperature was achieved from PBI membranes upon QAL loading.

Future Work

- Exploring cationic group incorporation techniques into lignin and study proton conductivity and cycling performance.

References

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