Hydrogen production efficiency in SO_2 Depolarized Electrolyser - Impact of proton electrolyte membrane

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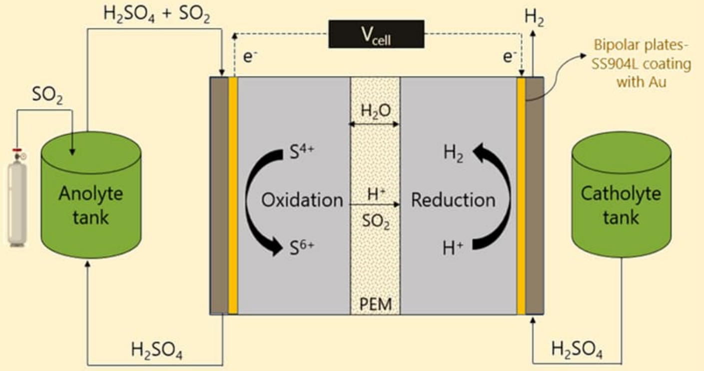
Introduction

The SO_2 Depolarized Electrolyser (SDE) is a breakthrough in the production of hydrogen on a large scale. The working of the SDE can be explained as:

- Oxidation of SO_2 from +4 to +6 oxidation state to produce Protons (H^+) and Sulfate ions (SO_4^{2-}) at the anode [1]
- The protons flow through a polymer electrolyte membrane (PEM) and reduce at the cathode to produce hydrogen.
- Along with protons, PEM also allows SO_2 to pass through leading to parasitic reactions at the cathode.
- SDE has lower standard reversible voltage, $E_{0,SDE} = 0.158V$, compared to PEM water electrolyser with $E_{0,PEM} = 1.23V$ [3].

The goal is to determine the effect of using different membranes in SDE to make it a viable technology for producing renewable hydrogen on a large scale by preventing parasitic reactions at the cathode.



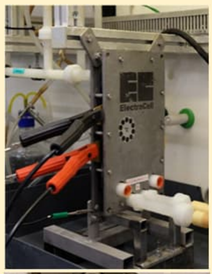
Anode: $SO_2\,(aq) + 2H_2O\,(l) \rightarrow H_2SO_4\,(aq) + 2H^+ + 2e^-$

Cathode: $2H^+ + 2e^- \rightarrow H_2\,(g)$

Overall: $SO_2\,(aq) + 2H_2O\,(l) + 2H^+ \rightarrow H_2SO_4\,(aq) + 2H^+ + H_2\,(g)$

Methodology

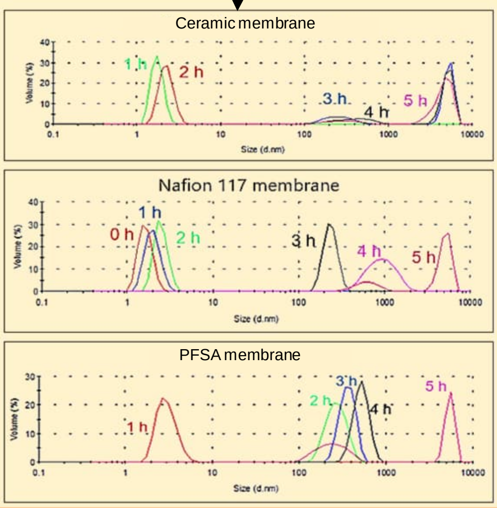
- Bench-scale electrolyser setup with Au electrocatalyst[2] was used
- Three membranes tested: Nafion 117, Ceramic, and PFSA – pre-commercial membrane
- Initial operation without SO_2; introduced after 500 s
- SO_2 feed halted after 1 hour, operation continued with 350 mM SO_2 for 5 hours
- Operating conditions: 15 wt% H_2SO_4 as electrolyte, 1.7 V operating potential
- Photon Correlation Spectroscopy[1] (PCS) used to analyze sulfur particle formation in the catholyte.

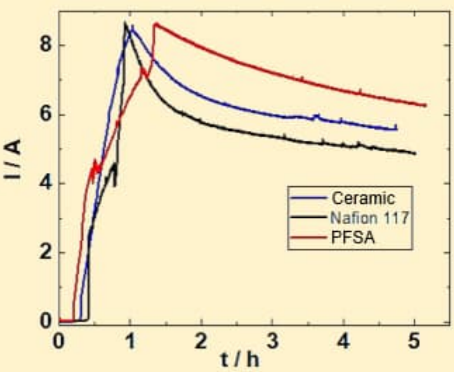


Results and Discussion

Sulphur particles observed in catholyte

- Small sulfur particles: 1-10 nm
- Large sulfur particles: 100-10000 nm
- Particle growth begins after 2 hours with PFSA, 3 hours with Nafion, and 5 hours with Ceramic.



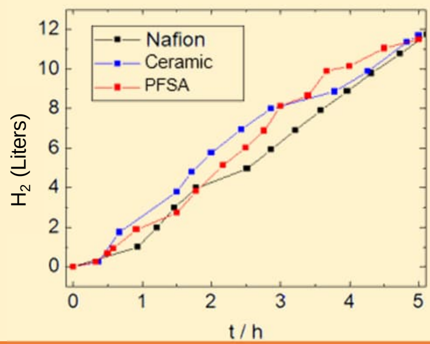


Performance of SDE based on current produced

- Similar maximum current density observed for all separators.
- Nafion 117 and ceramic membranes exhibit faster current decrease compared to PFSA; after 5 hours, the current is 5 A for ceramic, 6 A for Nafion, and 6.5 A for PFSA.

Hydrogen produced with time

Cumulative hydrogen production after 5 hours is similar for all three membranes



Conclusion

- The pre-commercial PFSA membrane shows steady performance in hydrogen production efficiency
- Additional testing needed to investigate SO_2 crossover using diffusion cell experiments, to understand the differences in different separator materials
- **Next steps:** Identify and validate different strategies to prevent SO_2 crossover, such as membrane coating or electrolyte solution modification.

References

(1) Santasalo-Aarnio, A.; Virtanen, J.; Gasik, M., SO_2 Carry-over and sulphur formation in a SO_2-depolarized electrolyser. Journal of Solid-State Electrochemistry 2016, 20, 1655-1663. https://doi.org/10.1007/s10008-016-3169-8
(2) Santasalo-Aarnio A, Lokkiluoto A, Virtanen J, Gasik MM. Performance of electrocatalytic gold coating on bipolar plates for SO_2 depolarized electrolyser. Journal of Power Sources. 2016 Feb 29;306:1-7.
(3) Gorensek, M.B., et al., A thermodynamic analysis of the SO_2/H_2SO_4 system in SO_2-depolarized electrolysis. international journal of hydrogen energy, 2009. 34(15): p. 6089-6095.

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Clean Hydrogen Partnership

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