Bench-scale advanced system design for hydrogen production using SO_2 depolarized electrolyser

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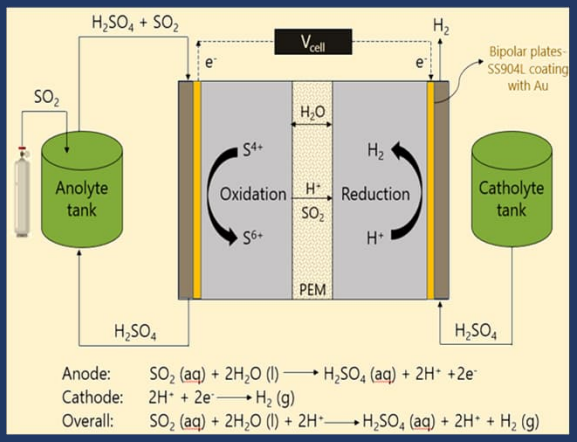
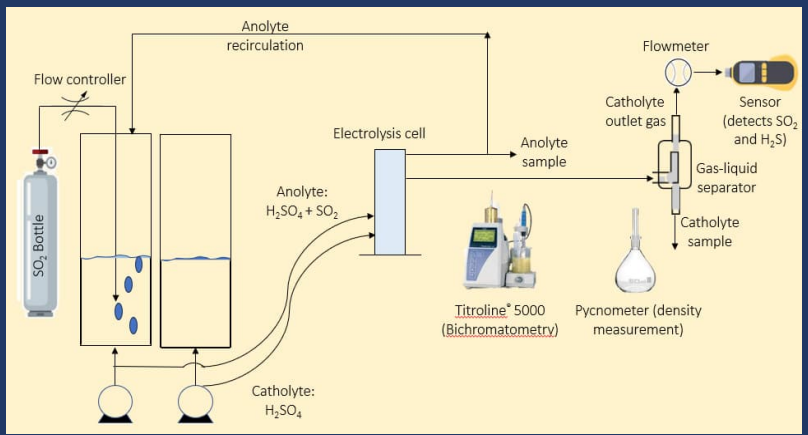
Introduction

The SO_2 Depolarized Electrolyser (SDE) is a breakthrough in the production of hydrogen on a large scale. SDE has the potential to produce hydrogen with lower energy requirements and less environmental impact. However, SDE can produce sulfur-based contaminants at the cathode, which can reduce the quality of the hydrogen produced. The goal is to improve system design to present gas flow analysis and impurities in the produced gas and to analyze the catholyte to understand the required purification steps before it is recirculated into the system.

Experimental Setup

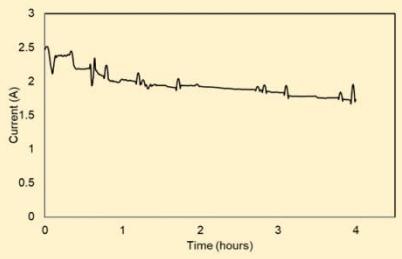
- Bench-scale electrolyser with Au electrocatalyst[2] (active area- 100cm^2) and commercial Nafion™ 117 membrane was used setup (as shown in the figure on the left)
- SO_2 was fed into the system using the flow controller where a flow rate of 0.144 l/min was maintained for a period of 10hrs until a concentration of 200mM was achieved.
- Electrolysis by chronoamperometric method was performed at 1.7V with a single cell for a period 4 hrs.
- The following parameters were measured:
  a) SO_2 concentration in anolyte and catholyte outlet streams using Bichromatometry titration [3]
  b) The total gas flow was measured using LOW-ΔP-FLOW F-101D flow meter
  c) The purity of H_2 was obtained by subtracting the quantities of SO_2 and H_2S measured using the G7 blackline analytics sensor.





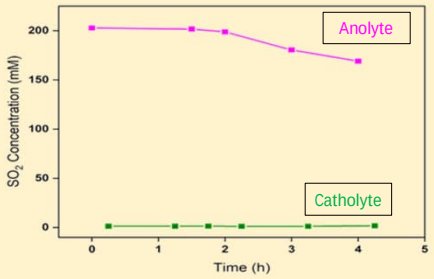
Results and Discussion

Electrolysis at 1.7V



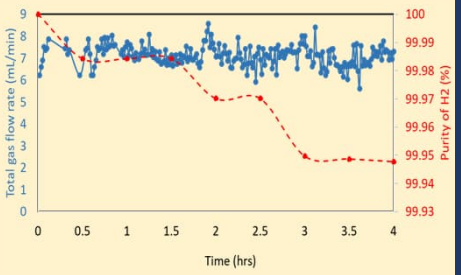
- Catholyte was not recirculated
- Hydrogen bubble growth at the cathode plate causes the peaks seen in the current curve

Gas analysis



- SO_2 concentration in anolyte decreases over time as the SO_2 molecules are consumed or cross-over during electrolysis
- SO_2 concentration in catholyte increases minimally, up to 1.7 mM

Gas analysis



- 430 mL of hydrogen produced per hour
- Hydrogen purity consistently above 99.9%
- Impurities include SO_2 and H_2S

Future work

The system incorporates analysis systems that gives an enhanced overall analysis of the electrolysis. Further work will be done to achieve a higher current density and lower SO_2 cross-over:

- A detailed analysis of a long SDE run (>50hrs) is required to comment strongly on the crossover rate and impurities in the gas and liquid catholyte streams.
- Since the catalyst is plated on SS904L, to increase the active area, a coating of the catalyst can be made on the membrane that would also act as a blocking layer for SO_2 crossover.
- Search for membranes with lower SO_2 cross-over rate to improve performance

References

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(2) Santasalo-Aarnio A, Lokkiluoto A, Virtanen J, Gasik MM. Performance of electrocatalytic gold coating on bipolar plates for SO2 depolarized electrolyser. Journal of Power Sources. 2016 Feb 29;306:1-7.
(3) A. Santasalo-Aarnio, I. Galfi, J. Virtanen, and M. M. Gasik, "New analytical methodology for analysing S (IV) species at low pH solutions by one stage titration method (bichromatometry) with a clear colour change. Could potentially replace the state-of-art-method iodometry at low pH analysis due higher accuracy," Plos one, vol. 12, no. 11, p. e0188227, 2017.

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