Study of the Properties of Iron/Iron Redox Flow Batteries

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Motivation

IFB's have several advantages, including low-cost active materials, a large supply of resources, and a high theoretical energy density [1]. The Hruska et al. battery was discovered in 1981 and uses a reactant pair composed of three different oxidation states of a single element to prevent irreversible reactant loss[1]. Additionally, the Fe(II)/Fe(III) redox couple has a high standard potential of 0.77 V. The Recombination cell was used in this system to prevent irreversible capacity loss caused by hydrogen generation [2]. An understanding of IFB's fundamental properties, performance characteristics are essential for practical energy storage applications. Therefore, in this study, It was aimed to investigate properties of IFB's using a recombination cell in the system.

Experimental Procedure

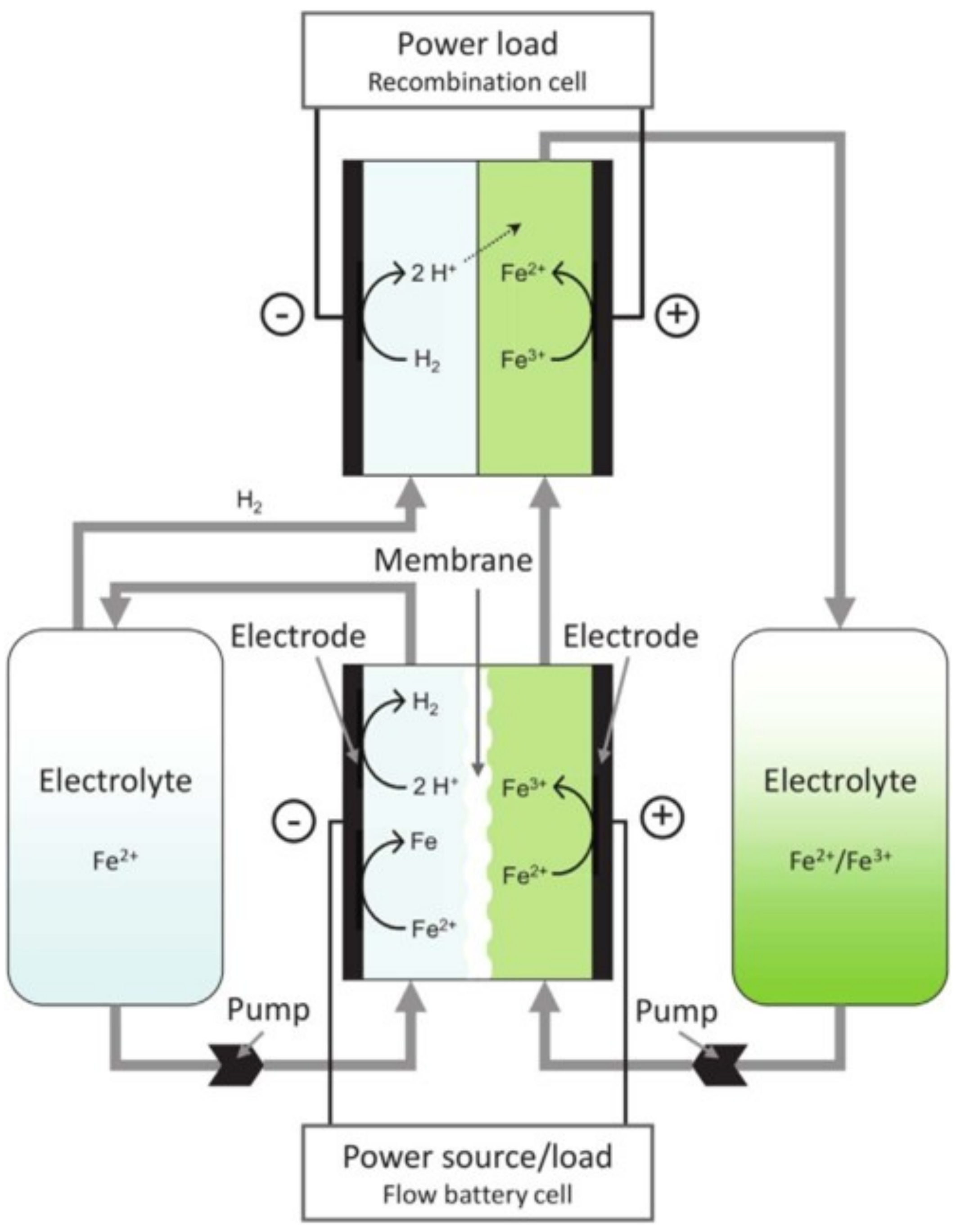

Figure 1: Schematic diagram of an iron/iron redox flow battery [2]. with recombination cell.

- For battery tests, a test stand was setup which is shown schematically in above figure.
- An Iron solution (1.5 M $FeCl_2$, 0.2 M HCl, 2M NH_4Cl) has been used.
- Battery cycling behaviour was studied in a 40 cm^2 Fe/Fe single cell with +/- 25 mA cm^{-2} by increasing the charge/ discharge time from 0.5 - 8 hours and the electrolyte volume from 70- 310 mL.

Results

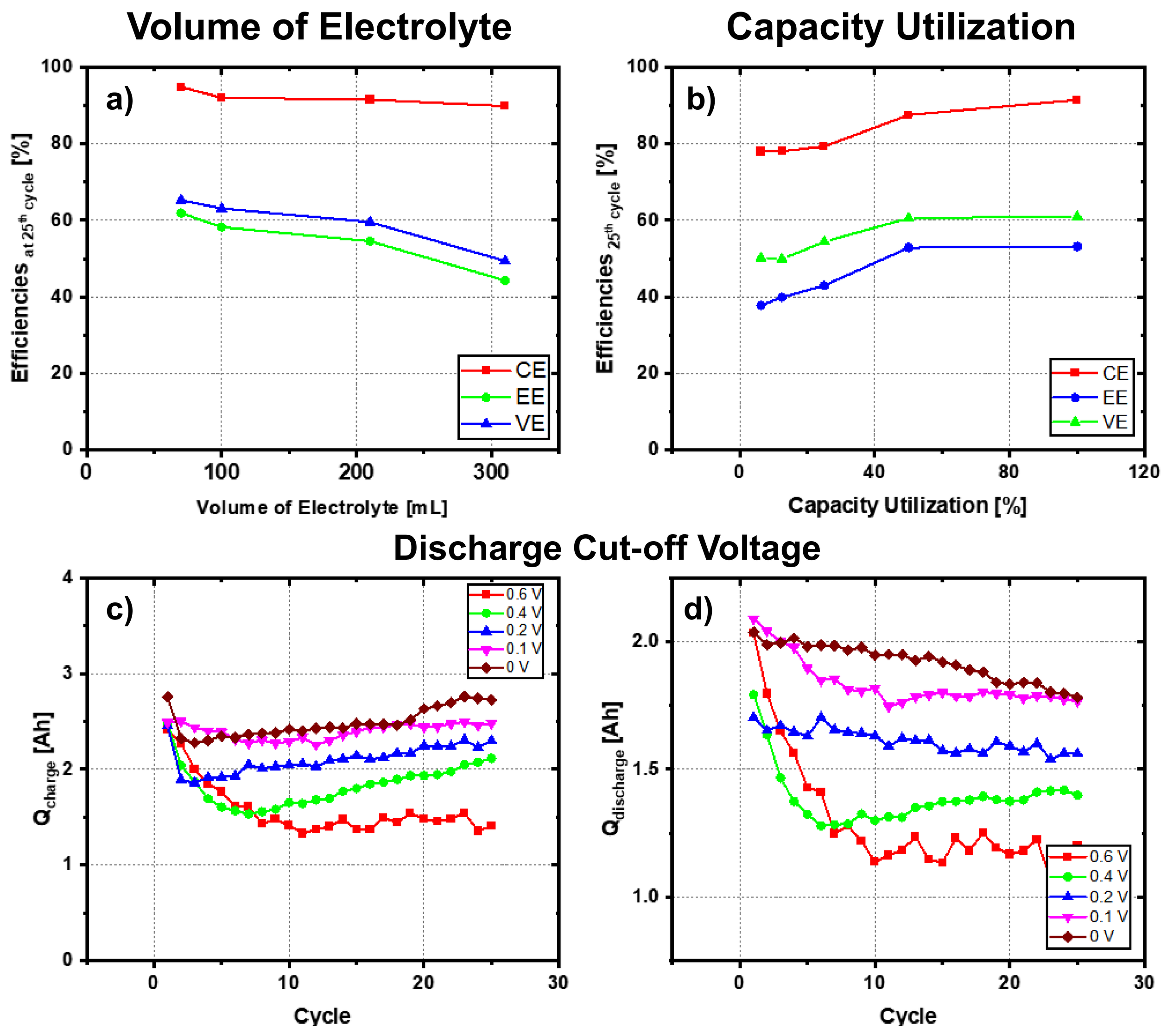

Figure 2: a) Volume of electrolyte vs efficiencies at 25th cycle ($T_{charge/discharge,\ max}$ = 1 hr, $U_{charge,\ max}$ = 1.9 V, b) Capacity utilization vs efficiencies at 25th cycle [$V_{electrolyte}$ = 210 mL], c) & d) charge and discharge capacity of varied discharge cut-off voltages vs cycles ($U_{charge,\ max}$ = 1.9 V, 1.5 M $FeCl_2$, 2M NH_4Cl, 0.2 M HCl).

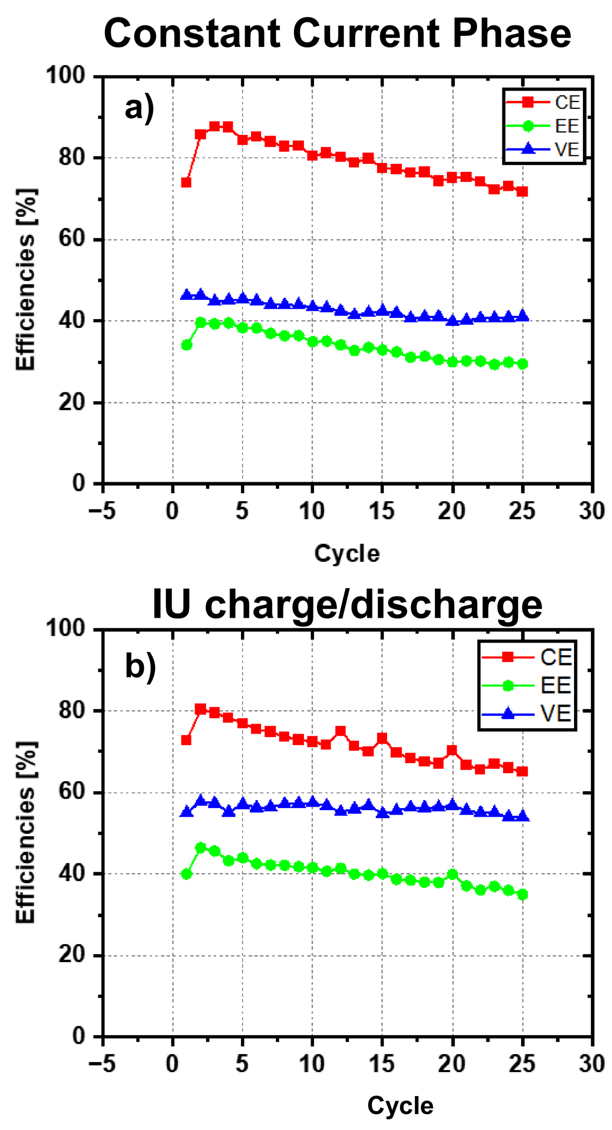

Figure 3: This graph indicates the comparision of efficiencies of a) Constant current phase, b) IU charge/ discharge phase ($U_{charge,\ max}$ = 1.9 V, $U_{discharge}$ = 0 V, 1.5 M $FeCl_2$, 2M NH_4Cl, 0.2 M HCl).

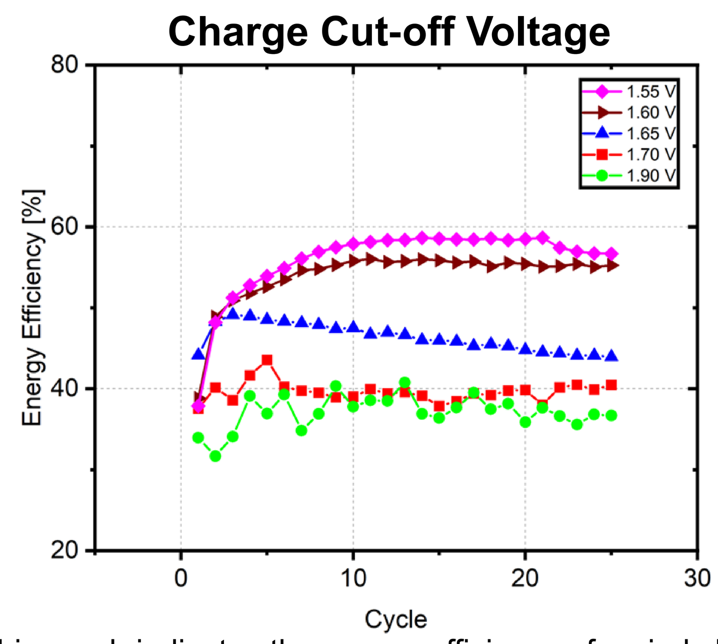

Figure 4: This graph indicates the energy efficiency of varied charge cut-off voltages over 25 cycles ($U_{discharge}$ = 0 V, 1.5 M $FeCl_2$, 2M NH_4Cl, 0.2 M HCl).

- The volume of electrolyte increased with constant charge time of one hour, the efficiencies decreased as did the possibility of precipitation due to hydrogen evolution at lower electrolyte volumes.
- when the capacity utilization of the battery reached 100%, the efficiencies at the 25th cycle increased.
- To prevent battery over-discharge, this study suggests limiting the discharge cut-off voltage to 0.1 V.
- The drop in energy efficiency of charge cut-off voltage curves was caused by an increase in charge carrier loss as charging time increased.
- Over 25 cycles, the energy and voltage efficiency of the IU charge/ discharge test shown better results than the constant current test.

Conclusion:

- The battery tested had a 54% energy efficiency over 25 cycles, charging up to 8 hours.
- Battery performs better with 1.9 V charge and 0.1 V discharge cut-off voltages.
- It was anticipated that including the IU charge/discharge phase will result in improved numbers by ignoring the cell resistance losses.

Acknowledgements:

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References

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[2] Jens Noack, Mike Wernado, Nataliya Roznyatovskaya, Jens Ortner and Karsten Pinkwart, Study of Fe/Fe redox flow battery with recombination cell, Journal of The Electrochemical Society, Volume 167, Number 16, 2020.

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