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Hydrogel Electrolyte Application to Zn|MnO_2 Rechargeable Batteries

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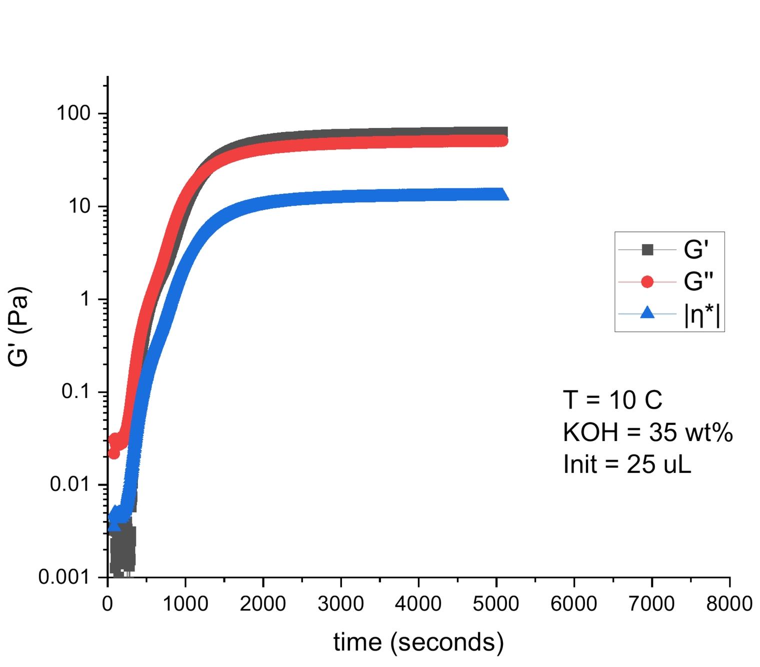
Motivation

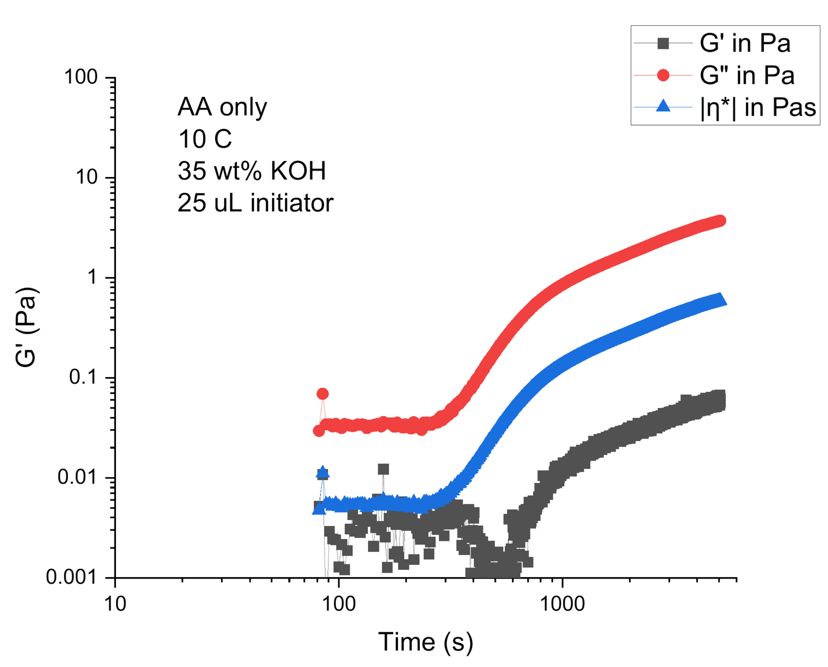
A gel electrolyte is essential for the development of a maintenance free and portable leakproof alkaline Zn-MnO_2 battery. Additionally, gel electrolyte can potentially solve problems such as capacity fade due to active materials being re-distributed by the electrolyte or protection from over-discharge. Challenges exist for incorporating the gel electrolyte into the alkaline Zn-MnO_2 batteries, mainly due to reduced ionic conductivity and electrode utilization. The goal is therefore to develop poly(acrylic acid)-potassium hydroxide (PAA-KOH) hydrogel gel electrolyte for rechargeable alkaline Zn-MnO_2 batteries that maintains good cycle life and acceptable overvoltages, all at practical current densities.

Rheology of the Gel Electrolyte

During 2019, in-situ in-battery formation of poly(acrylic acid)-potassium hydroxide (PAA-KOH) hydrogel was developed and optimized as the electrolyte due to its high hydrophilicity and high ionic conductivity.

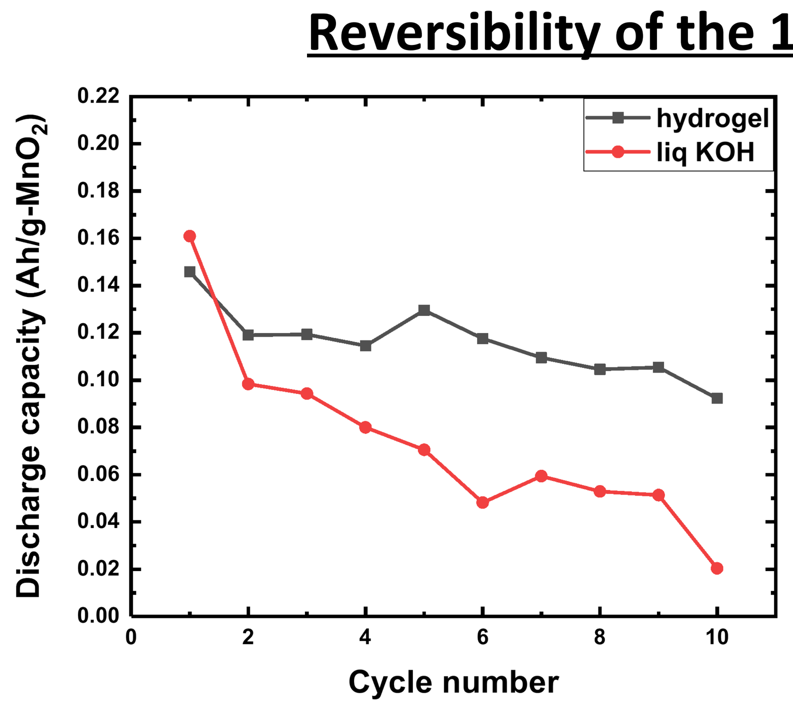
Rheology of this electrolyte was obtained during early 2021





Gel Electrolyte for 1st e- of MnO_2

Reversibility of the 1st e- MnO_2 reaction

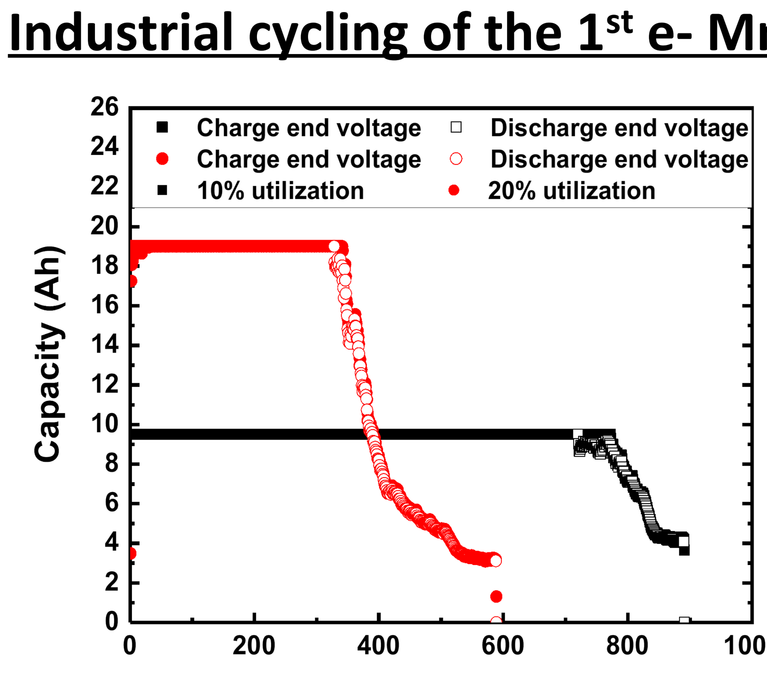


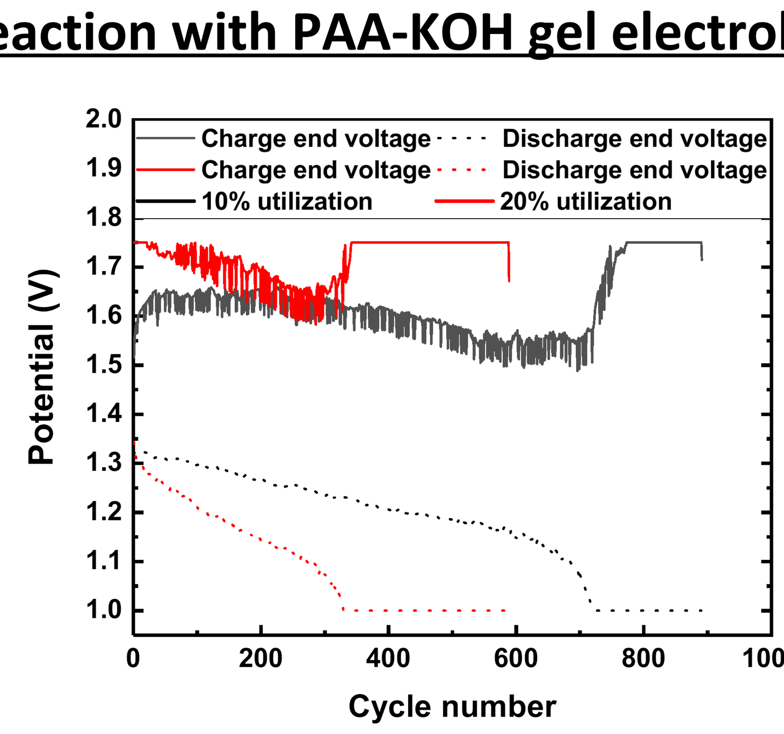
Discharge capacity during cyclic voltage scans across the 1st electron reaction window is improved by used of PAA-KOH hydrogel electrolyte

Experimental cell specifications:

- Zinc paste anode, MnO_2 cathode
- 2" x 3" electrodes
- Prismatic cell box
- Some with PAA-KOH electrolyte
- Some with traditional KOH electrolyte

Industrial cycling of the 1st e- MnO_2 reaction with PAA-KOH gel electrolyte



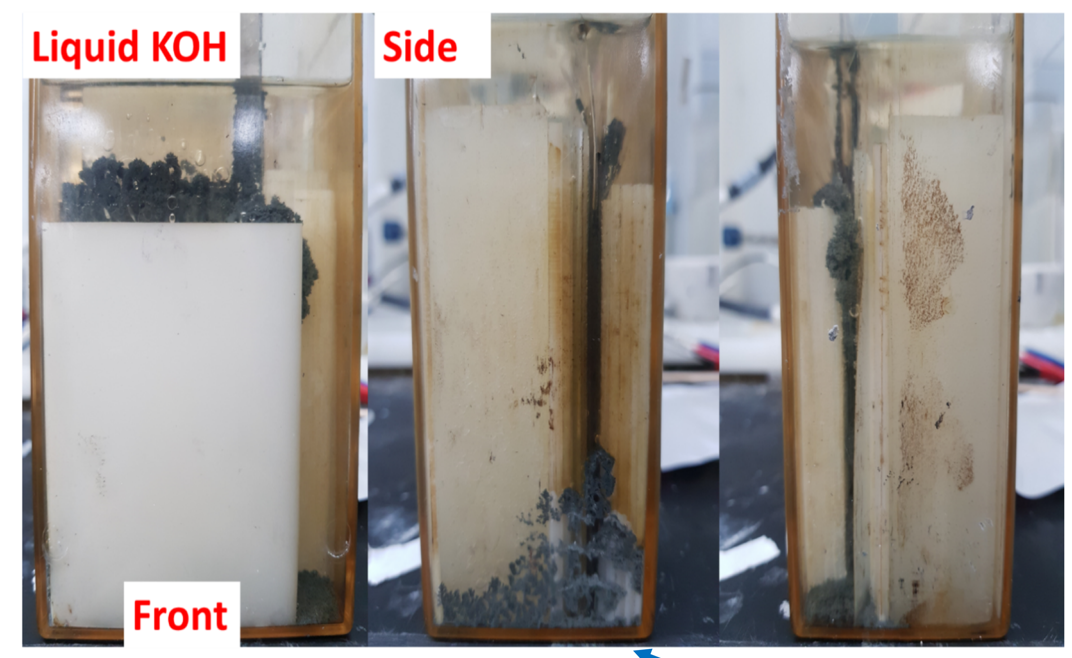


Industrial prismatic cells of were fabricated with PAA-KOH gel and other cells with traditional liquid KOH electrolyte. PAA-KOH gel electrolyte cells survive greatly more cycles than cells made with the liquid KOH electrolyte.

Experimental cell specifications:

- 9 zinc paste anodes, with 8 MnO_2 cathode electrodes, each of 3" x 6" size
- 95Ah (full 100% of 1st e- of MnO_2) in an industrial prismatic cell box
- Some with PAA-KOH electrolyte, some with traditional KOH electrolyte

Shape Change and Migration of Zinc

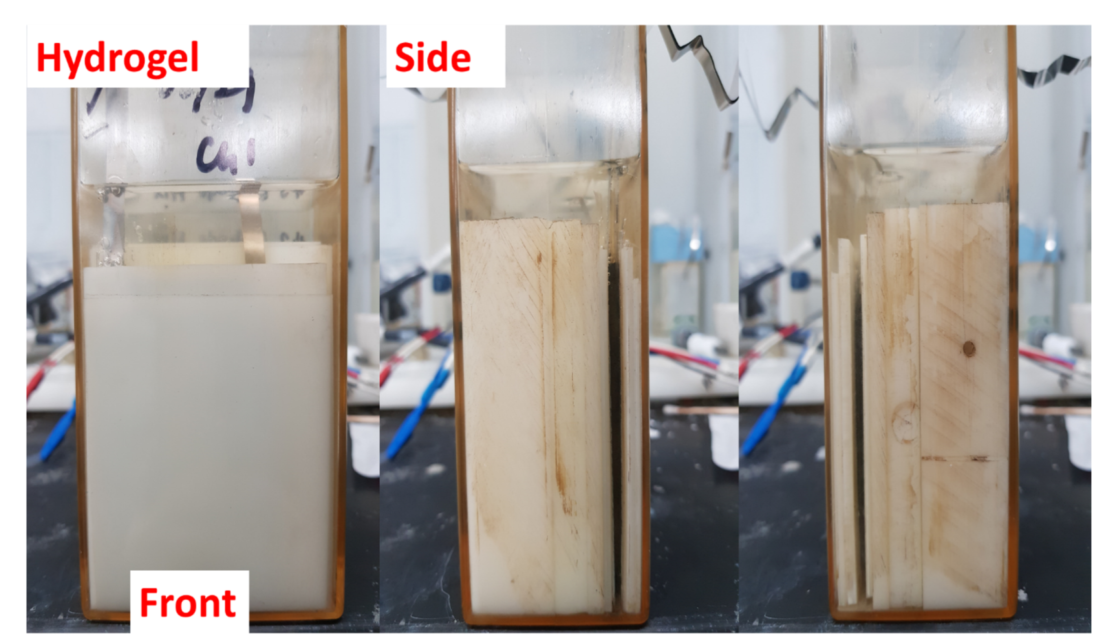


Stray zinc, loss from anodes

Traditional liquid KOH electrolyte
Allows rapid shape change and migration of the zinc away from the electrodes, ultimately causing failure

Experimental cell specifications:

- Zinc paste anode
- MnO_2 cathode
- 2" x 3" electrodes
- Prismatic cell box

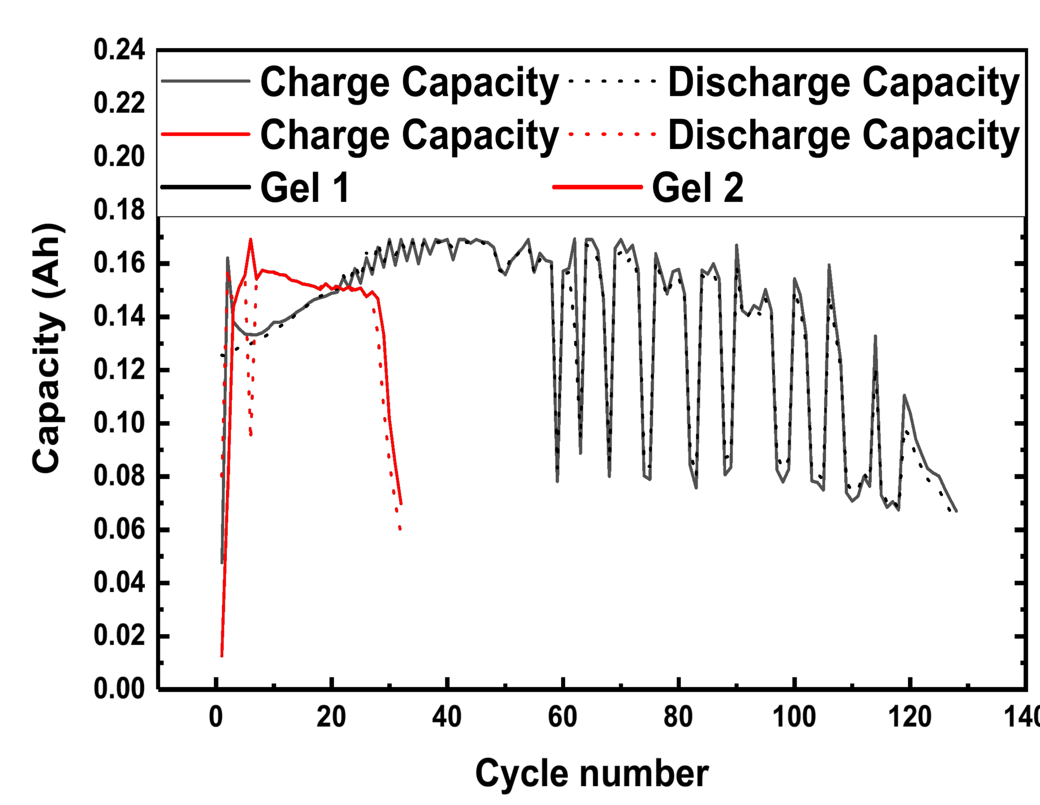


Hydrogel electrolyte
Mitigates Zn migration and shape change, leads to improved cycle life.

Experimental cell specifications:

- Zinc paste anode
- MnO_2 cathode
- 2" x 3" electrodes
- Prismatic cell box

Gel Electrolyte for 2nd e- MnO_2



Industrial prismatic cells were fabricated with PAA-KOH gel for the 2nd electron technology. This application is under development to perform longer cycle life

Experimental cell specifications:

- Zinc paste anode
- MnO_2 cathode
- 1" x 1" electrodes
- Prismatic cell box
- Gel 1 has a higher concentration than Gel 2

Conclusions

- A poly(acrylic acid)-potassium hydroxide (PAA-KOH) hydrogel electrolyte was developed and incorporated into the rechargeable alkaline Zn-MnO_2 batteries.
- The gel electrolyte was optimized to balance the ionic conductivity, chemical/mechanical stability, polymerization kinetics and electrochemical properties.
- Using hydrogel electrolyte showed better reversibility of the 1st electron MnO_2 reaction
- Cycling tests of gel electrolyte cells at different utilization and charging-discharging protocols suggested that the gel electrolyte provided more reliable performance vs. liquid electrolyte
- Hydrogel electrolyte was able to mitigate Zn migration and shape change, and this enhances cycle life

Acknowledgements

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