EFFECTS OF METHYL PROPIONATE ON THE PERFORMANCE OF LITHIUM ION BATTERIES

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OBJECTIVE:

The goal of this experiment is to measure the impact of Methyl Propionate as an electrolyte additive on the performance of lithium Ion batteries, with regards to their charging rate and cyclability.

INTRODUCTION:

- Lithium ion batteries are a viable option for a high powered, renewable energy source, but there are many improvements that must be made to the current commercial lithium ion battery
- As time passes, lithium ions are consumed during the lithiation and de-lithiation processes, and the internal impedance increases, which decrease the discharge capacities of the cells
- Additives in the electrolyte have the potential to positively impact the molecular interactions which can help combat the decrease in discharge capability

BACKGROUND:

- Inside the battery, negative charges in electrolytes are transported through the separator from cathode to anode, and the opposite direction for positive charge; the movement of positive charges and electrons lead a current circuit
- High charge rates and cyclability are important for adopting lithium ion batteries as a renewable energy source, for use in everything from phones to electric vehicles
- A commonly used commercial electrolyte that was used as the control group is LP40
- Methyl propionate (MP) is an electrolyte additive used to improve the performance of lithium Ion batteries

SUMMARY OF METHODS

STEP 1: Cathode Fabrication

Measure for the composition ratio 8:1:1 (NMC111:PVDF:Super P)

↓

Mix ingredients

Combine NMP + PVDF	Mix until homogenous	Add Super P	Mix until homogenous	Adjust for consistency

↓

Spread on Al foil, adjust thickness to ~10μm

↓

Cut into 12mm-diameter disks

↓

Dry in vacuum for at least 8 hours

↓

Press the cathodes

↓

Weigh to find the mass of the active ingredients

STEP 2: Form Electrolyte Groups

- Make 500μL of each electrolyte, adding MP and LiPF6 (salt) to LP40 to create a 1M solution for each group

Control Group	20wt%	40wt%	60wt%

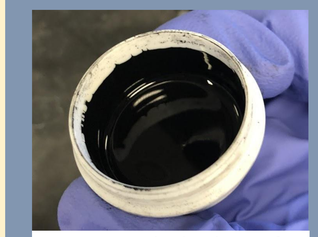

Figure 1: Cathode slurry after being mixed to a smooth consistency

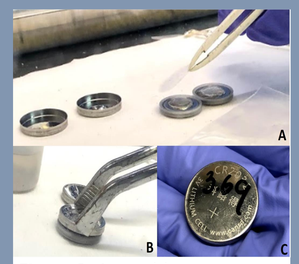

Figure 2: Assembly process, marked in chronological order

STEP 3: Half Cell Assembly

- Assemble two half cells per group, a total of eight half cells. See Figure 2 & 3 for assembly details

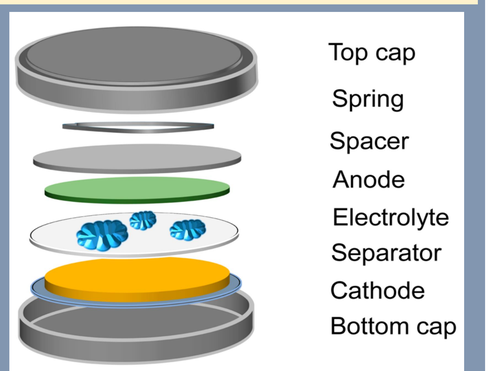

Figure 3: Schematic diagram of the structure of a half cell battery [3]

RESULTS:

Rate Performance

The control battery had the highest discharge capacity, contrary to prior research

The 40wt% demonstrates the most gradual slope. This indicates the least amount of variation in discharge capacity, but this is also the lowest discharge capacity of all

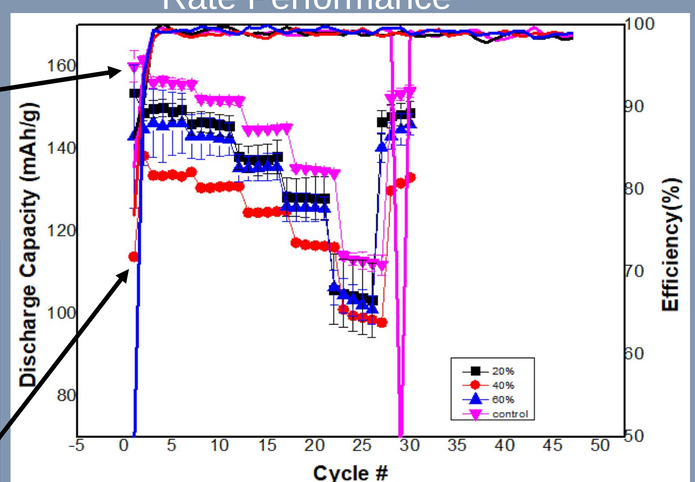

Figure 4: Discharge capacity (line with symbols) and Coulombic efficiency (solid line) for the rate test cells. The cells are activated at 0.1C for 2 cycles, then cycled at 0.3C, 0.5C, 1C, 2C, 5C and 0.3C for 5 cycles each

Cycling Performance

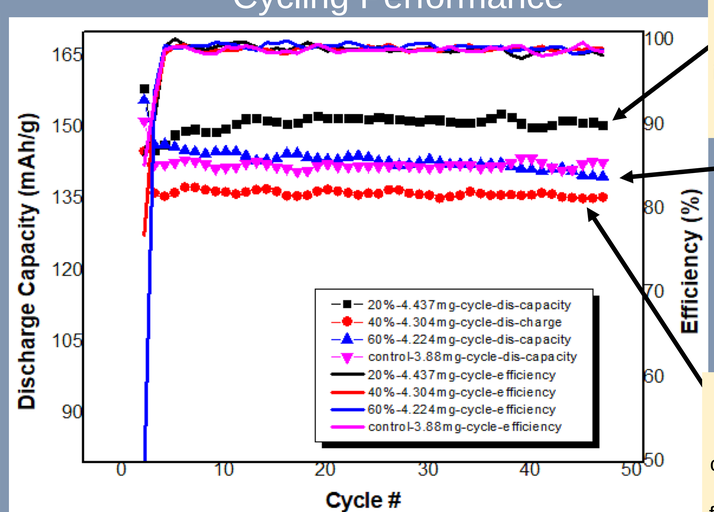

Figure 5: Discharge capacity (line with symbols) and Coulombic efficiency (solid line) for the cycling test cells. The cells were activated at 0.1C for 2 cycles, then cycled at 0.5C

20wt% (black) had the highest discharge capacity. Note that this is inconsistent with the graph displayed in Figure 4

60wt% (blue) demonstrates a gradual declining slope, as its discharge capacity fell below the control cell (pink)

40wt% demonstrates the lowest discharge capacity overall, but there is little fluctuation as cycles increase, demonstrated by the level slope

DISCUSSION

- A study conducted by NASA JPL demonstrated that MP additives generally increase the performance of lithium ion batteries when considering temperature power capabilities and battery life [1]
- The results of testing battery life in this experiment did not show enough degradation, which is something to investigate for future studies
- Another study suggests MP outperforms other ester co-solvents in improving battery performance because of the low freezing points, high ionic conductivity, and low viscosity [2]
- In the experiment, the 40wt% MP was able to charge more rapidly without unwanted lithium plating, and up to 20wt% MP was compatible with the electrodes used
- This experiment presented several inconsistencies and does not point to a linear relationship between using MP as an electrolyte additive to LiPF6
- Possible explanation for the lack of a direct relation between the two are chemical reactions within the half cells, lithium plating, or compatibility with the electrodes
- Going forward, the goal is to find what variables affected our results, how to account for these variables, and further testing of other additives to find the most effective solution

CONCLUSION

- Battery performance is important for everyday life, especially with the rise of electric vehicles
- To test the performance and the effects that additives have, coin cell batteries were made with different weight percent of Methyl Propionate
- The control group of batteries only contained LP40 in the electrolyte solution
- The results of the experiment showed that all the MP weight percentages cannot help improve the rate capability or cycling stability significantly
- The 20wt% group seems to perform the best, achieving the highest capacity in the cycling test, while the 40wt% and 60wt% groups performed worse than the control group performance

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References:
[1] Smart, Marshall C., and Ratnakumar V. Bugga. 2011. "Use Of Additives To Improve Performance Of Methyl Butyrate-Based Lithium-Ion Electrolytes". NASA Tech Brief 32(4), 56. https://ntrs.nasa.gov/search.jsp?R=20120006528.
[2] Ma, X.; Arumugam, R. S.; Ma, L.; Logan, E.; Tonita, E.; Xia, J.; Petibon, R.; Kohn, S.; Dahn, J. R. A Study of Three Ester Co-Solvents in Lithium-Ion Cells. J. Electrochem. Soc. 2017, 164 (14), A3556–A3562. https://doi.org/10.1149/2.0411714jes.
[3] Elahe Talaie, Patrick Bonnick, Xiaoqi Sun, Quan Pang, Xiao Liang, and Linda F. Nazar. 2017. "Methods and Protocols for Electrochemical Energy Storage Materials Research". Chemistry of Materials 29 (1), 90-105. https://doi.org/10.1021/acs.chemmater.6b02726