National Aeronautics and Space Administration

Advanced, Wide Operating Temperature Batteries for Venus Aerobot Missions

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Program: FY22 R&TD Strategic Initiative

Strategic Focus Area: Technologies for Venus Cloud Environments /Venus In-Situ Aerosol Measurement Technologies - Strategic Initiative Leader: James A Cutts

Objectives:

Develop a wide operating temperature Li-ion battery cell to enable a Venus aerobot mission by way of:

1) Identifying Generation-1 wide temperature electrolytes to be provided to a commercial battery vendor
2) Procuring flight-like battery cells that incorporate these electrolytes
3) Demonstrating performance improvements over state-of-art cells operating from 85^{o}C to 100^{o}C

Background:

JPL seeks to develop technologies to enable a mission with a Venus-deployed aerobot with a temperature range from -30^{o}C to 100^{o}C. While space-rated Li-ion cells can be tailored to meet the lower temperature limit, operating or storage temperatures higher than about 60^{o}C can rapidly degrade cell performance. As such, a new mission-enabling battery cell technology must be developed that can tolerate the temperature extremes of the Venus atmospheric mission.

Approach:

- Carry out a sequential set of experiments working towards understanding the two primary failure mechanisms in Li-ion batteries associated with high temperature cycling: 1) Decrease in current-carrying capability and 2) loss of capacity.
- Focus on high temperature resilience since low discharge rates are anticipated at the low temperatures during the mission.
- Based on these studies, downselect and test promising electrolyte variants three-electrode cells to facilitate detailed electrochemistry studies.
- Provide four early-stage Generation-1 electrolyte formulations to the cell vendor (Saft Portiers) for incorporation into high TRL, flight-like cells.

Results:

- Screening studies carried out using coin cell experiments identified several promising electrolyte variants.
- 3-electrode cells isolate impedance growth at each electrode as a function of high temperature exposure.
- Anode impedance growth at high temperatures is negligible (Fig. 1).
- Cell impedance growth is dominated by cathode impedance (Fig. 2).
- Li inventory loss is conclusively demonstrated to be a key failure mechanism (Fig. 3).
- Flight-like cells with JPL electrolytes outperform state-of-art commercial cells in terms of capacity fade at high temperature (Fig. 4.)

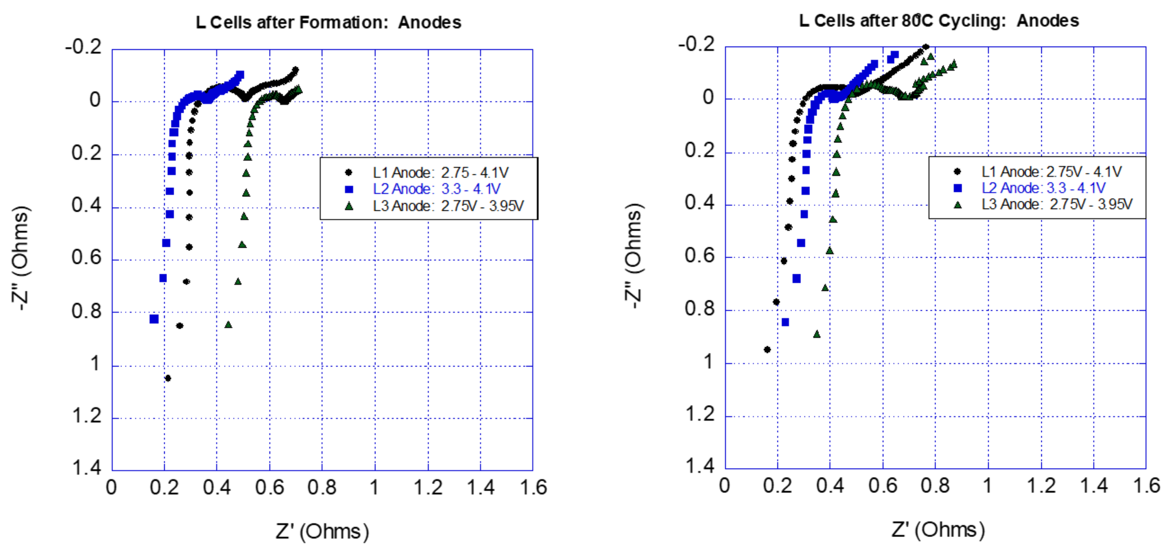

Fig. 1. Anode impedance before (left) and after (right) cycling at 80^{o}C (1.0 M LiTFSI + 0.50 M LiDFOB in EC+EMC+TPP (50:40:10 vol %) + 2% VC). Anode impedance is unchanged for high temperature cycling.

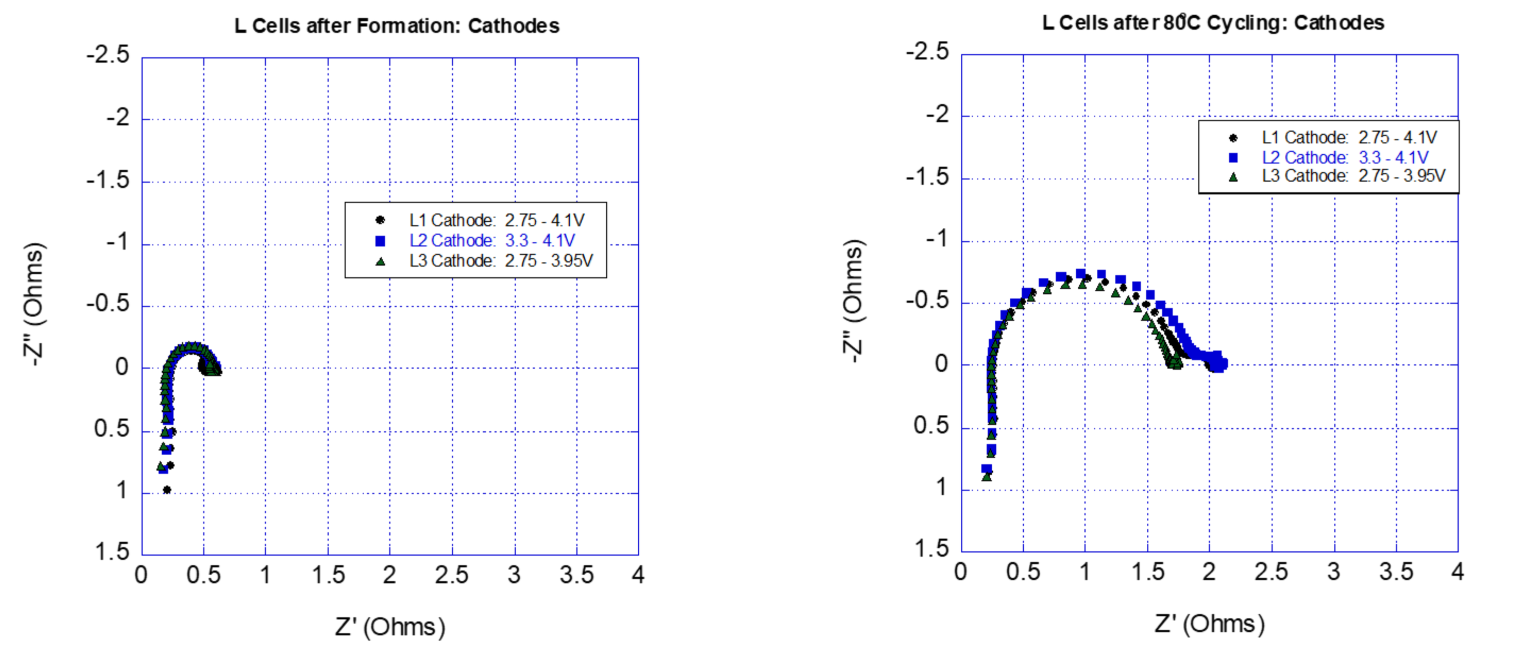

Fig. 2. Cathode impedance before (left) and after (right) cycling at 80^{o}C (1.0 M LiTFSI + 0.50 M LiDFOB in EC+EMC+TPP (50:40:10 vol %) + 2% VC). Cathode impedance grows significantly for high temperature cycling.

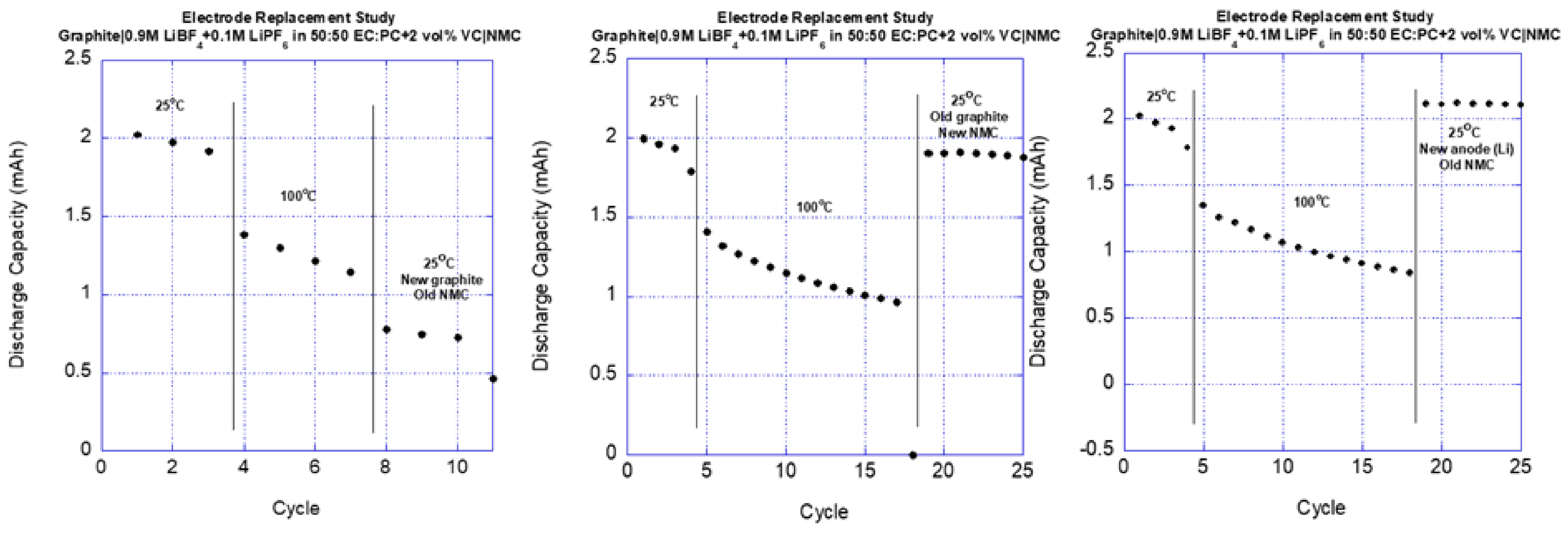

Fig. 3. Swagelok cell data replacing cell electrodes demonstrates failure mechanism is associated with loss of Li inventory.

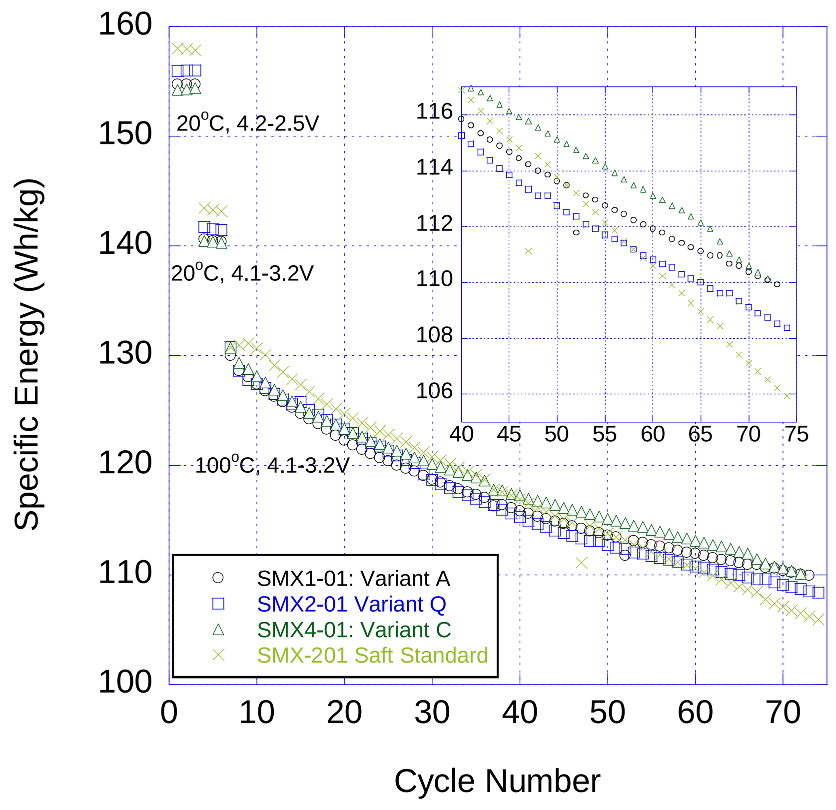

Fig. 4. Cell-level specific energy vs. cycle for cells with standard Saft and JPL electrolytes. Three JPL electrolytes outperform standard Saft electrolytes.

Significance/Benefits to JPL and NASA:

- This work has resulted in significant advancements in the understanding of two key failure mechanisms of Li-ion cells when operated at high temperatures.
- We have successfully identified and in partnership with Saft infused new wide operating temperature electrolytes into flight-like battery cells.
- Three of the four electrolytes specified by JPL have demonstrated improved high temperature cycle life relative to baseline Saft cells.
- These accomplishments will facilitate the rapid TRL elevation and future adoption of these cells into not only Venus aerial missions, but to other missions where the spacecraft is exposed to large variations in temperatures such as lunar surface missions.

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Publications:

- “Development of Specialized Li-ion Batteries for a Venus Aerobot Mission”, Will West, Marshall Smart, John-Paul Jones, Ruoqian Lin, Brendan Hawkins, Chengsong Ma, Benjamin Leguern, and Romain Cayzac, *Proc. 2022 Advanced Power Systems for Deep Space Exploration (August 2022).*

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