National Aeronautics and Space Administration

FY24 Topic Areas Research and Technology Development (TRTD)

Expanding the Operation Temperature Window of Zinc Metal Anode Batteries for Applications under Extreme Conditions in Space Missions

Principal Investigator: Keith Billings (346)**; UCR Lead Investigator:** Juchen Guo (University of California Riverside);
Co-Investigators: Zeeshan Chaudry (346), Kimberly Jimenez (346), Miguel Rodriguez (346), Jasmina Pasalic (346), Jianjun Chen (University of California Riverside), Alan Larrea Caro (University of California Riverside), Yuqing Fu (University of California Riverside), Ruoqian Lin (346)

Strategic Focus Area: Energy storage

Objective:

Develop and demonstrate electrolyte formations that improve the temperature operating window of zinc metal batteries

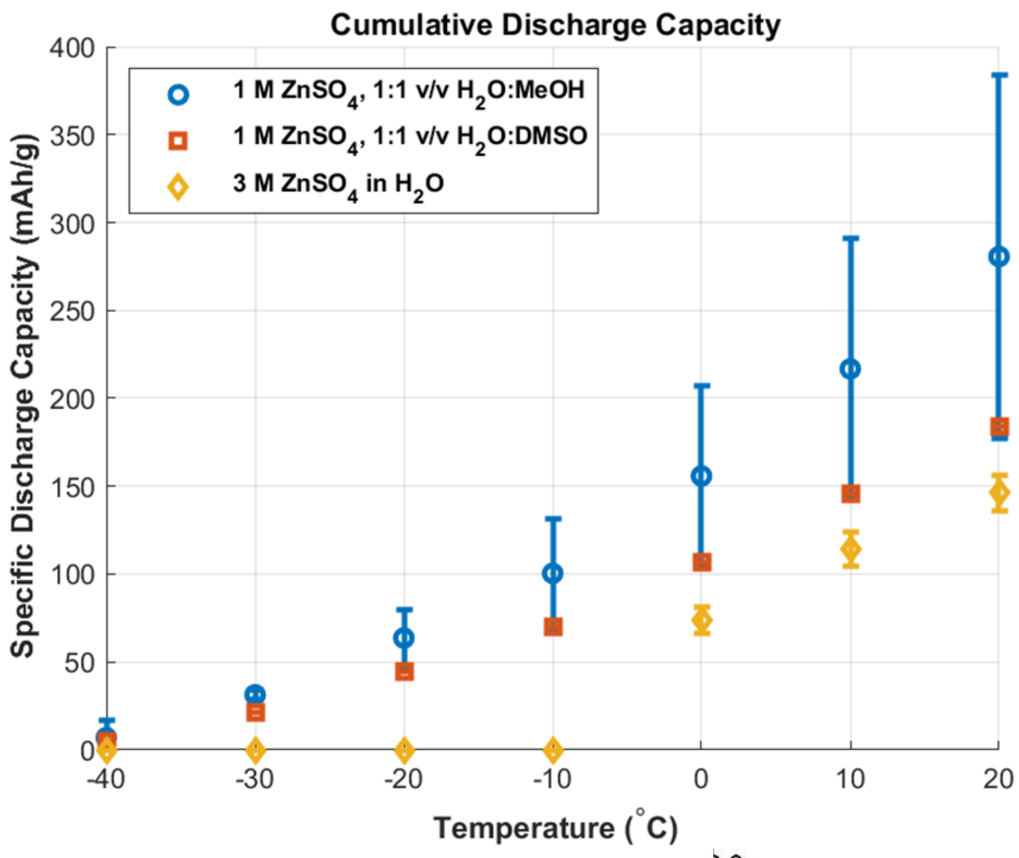
- Target temperatures of -40ºC and +90ºC
- Emphasis on safe, less flammable electrolytes
- Aqueous and non-aqueous blends

Approach:

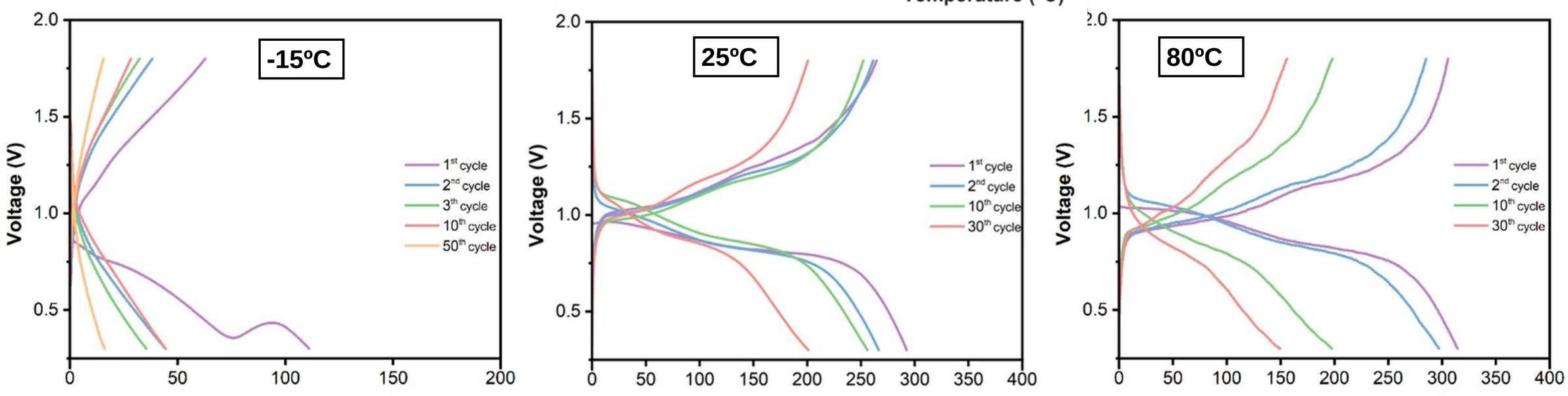
1. Choose a baseline coin cell format with which to screen and compare electrolyte formulations. **Zn foil anodes** were used with **V_2O_5 cathode material** and **glass fiber separators** in coin cells.
2. Screen co-solvents in 50/50 aqueous blends that can mitigate water interactions and depress the freezing point. 10 different co-solvents were tested in coin cells and down selected based on performance.
3. Screen non-aqueous electrolyte alternative blends. **Trimethyl phosphate (TMP)** was found to be a great solvent, which is also non-flammable. TMP blends are also good solvents for lithium salts, allowing an **efficient dual-ion approach**.

Background:

Zinc metal batteries offer the potential for significantly improved specific capacity and safety relative to state-of-the-art lithium ion, but also have significant challenges that must first be overcome. Zinc metal has a **theoretical specific capacity of 820 mAh/g**, about double that of graphite in lithium ion cells. Zinc cells can use water based electrolytes which are **safe and cheap**, but also produce undesirable **gas formation and dendrites**. Co-solvents and non-aqueous alternatives can potentially address these issues.



Methanol and dimethyl sulfoxide blends in water significantly improved capacity and enabled cycling down to -40ºC



Discharge curves of cells with 2M LiTFSI plus 0.5V $Zn(TFSI)_2$ in 1:1 TMP:MPN electrolyte

Results:

- Two aqueous co-solvents were found to **significantly improve low temperature performance**: methanol and dimethyl sulfoxide.
- Partners at UCR produced a non-aqueous TMP blend and dual ion system which has good capacity and can cycle at high temperatures
- Further development needed for long term performance in both systems

Benefits to NASA

Safer batteries with wider temperature operating windows will **decrease spacecraft power system complexity and improve efficiency**. Cells that are not vulnerable to thermal runaway like lithium-ion need less safety balance of plant, and wide operating windows mean less energy spent on heating and cooling systems.

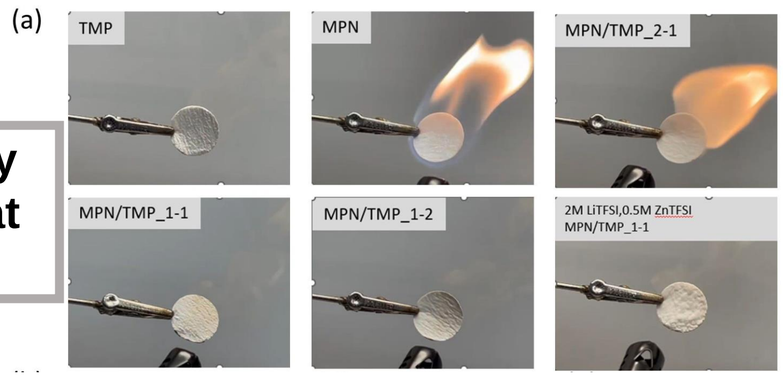
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

RPD-177 Clearance Number: CL#00-0000

Flammability tests done at UCR



PI/Task Mgr. Contact Information:
keith.j.billings@jpl.nasa.gov
818-393-4209