LiON: Lithium Oxygen Batteries for NASA Electric Aircraft

John Lawson (PI, ARC), Vadim Lvovich (co-I, GRC)

National Aeronautics and Space Administration

Overview/Description

Li-Air batteries are a unique fit for electric aircraft due to their high theoretical energy densities and their potential to leverage on-board oxygen systems. Electrolytes are the limiting factor for advancing this technology. We will investigate novel "electrolyte engineering" concepts to enable Li-Air batteries with high practical energy densities, rechargeability and safety. New stable electrolytes will be designed and fabricated for Li-Air batteries and tested in an electric flight. An unprecedented "Dream Team" of experts from NASA, DOE, academia and industry will tackle this problem.

Feasibility Assessment / Benefit if Feasible

- Li-Air battery with energy density of 400+ Wh/kg
- Li-Air battery that cycles 100+ times
- Li-Air battery demonstrated in UAV flight
- High energy density, rechargeable, safe batteries are essential to enable electric and hybrid-electric aircraft
- **ARMD SIP: Thrust 4 Outcome Risk** - *ARMD needs targeted research in critical areas such as batteries to account for the significant differences in requirements for electric aircraft*

Partners – "Li-Air Dream Team"

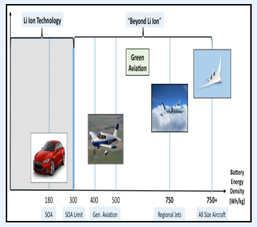
- ***NASA ARC***, Computational Materials
- ***NASA GRC***, Materials Science; Electrochemistry
- ***NASA AFRC***, Electric Flight Analysis
- ***UC Berkeley***, Li-Air Battery Characterization
- ***Carnegie-Mellon University***, Computational Screening
- ***IBM Almaden Research Center***, Synthetic Chemistry
- ***Lawrence-Berkeley National Lab***, Material Characterization

Accomplishments:

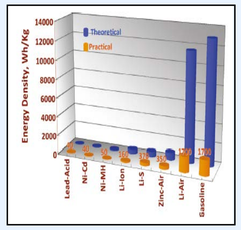
- High stability inorganic molten salt electrolytes designed and demonstrated to improve Li-Air cycle life
- Novel electrolyte additives designed, synthesized and demonstrated to improve cycle life
- Fundamental organic electrolyte decomposition chemistry discovered and detailed
- Li-Air battery pack built and demonstrated in the laboratory under electric flight conditions
- Multiscale modeling and simulations framework from fundamental chemistry to high throughput materials screening to battery multiphysics implemented and demonstrated to accelerate materials and cell development
- More than 20 peer reviewed journal articles and more than 40 conference presentations

Li-Air Batteries for Electric Aircraft

Big Question: Can we design and build a viable battery which satisfies the significant requirements of electric aircraft

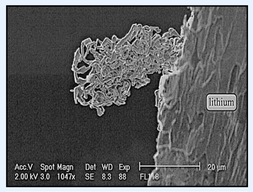


SOA Li-Ion plateaus at 300 Wh/kg. Advanced technologies required!



Li-Air has the highest theoretical battery energy density

Li-Air Battery Challenges

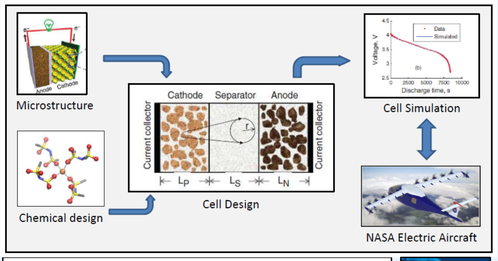


Electrolyte decomposition limits energy density and rechargeability

SOA electrolytes are flammable. Unacceptable for aircraft

Electrolytes are limiting factor for Li-Air batteries for:
- ***Practical energy densities***
- ***Rechargeability***
- ***Safety***

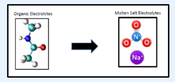
1. Multiscale Battery Modeling



Multiscale modeling and simulation tools for arbitrary application specific battery chemistry

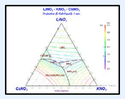
TTT Vision 2040 Report

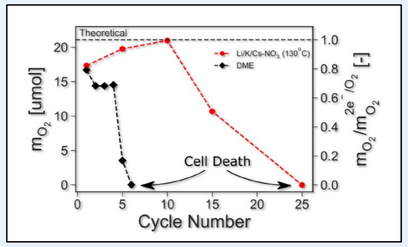
2. Material Design I: Molten Salt Electrolytes



Unconventional molten salt electrolytes

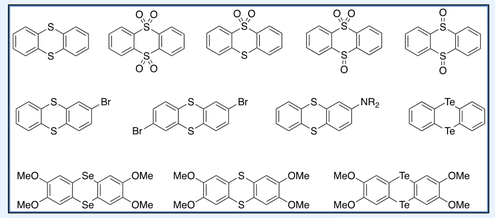
Calphad modeling to obtain optimal mixtures



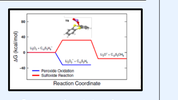


5X improvement in cycle life vs SOA organic electrolytes

3. Material Design II: Electrolyte Stabilizers

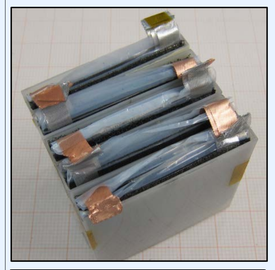


Tunable platform of electrolyte stabilizer materials. Vary properties by different substituents

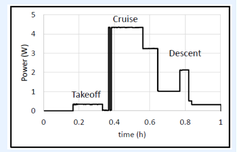


Computational chemistry confirms the correct behavior

4. Li-Air Battery Pack



5 cell 12-V Li-Air pack



Electric flight power profile test

CONVERGENT AERONAUTICS SOLUTIONS