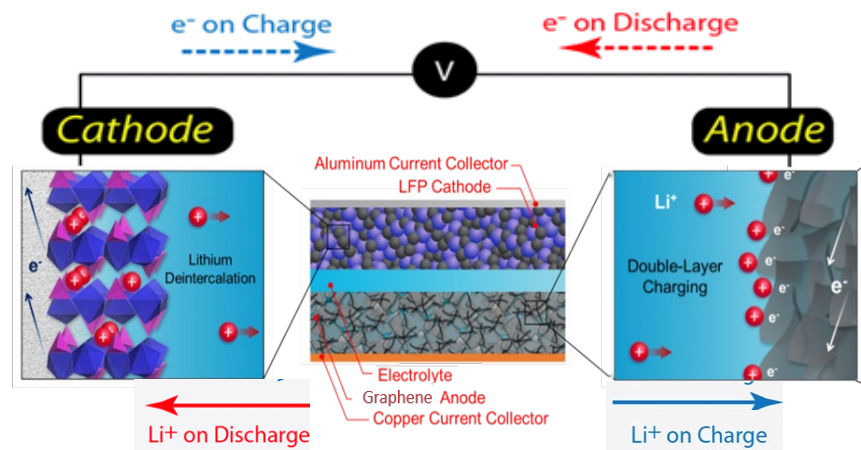




# Development of Graphene Batteries for Use in Space Applications

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Lithium-Ion Batteries (LIBs)



## Objective

Mature use of graphene in LIBs for space applications through development of pre-lithiated anodes

## Benefits of Graphene

- High capacity
- Light weight
- Flexible structure
- Good electrical & thermal conductivities



## Technical Challenges

- Graphene re-stacks during electrode preparation and losses advantages over graphite
- Irreversible Li insertion, capacity loss with cycling
- Dendrite growth



# Technical Approach

## Graphene Materials

holey graphene

hybrid graphene - carbon nanotube

added lithiophilic sites

- Pyridinic N
- Pyrrolic N
- Graphitic N
- Carbon - C



## Prelithiation

SEI

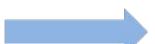
anode

Li<sup>+</sup> Li<sup>+</sup> Li<sup>+</sup> Li<sup>+</sup>

dendrite free

smooth Li<sup>+</sup>

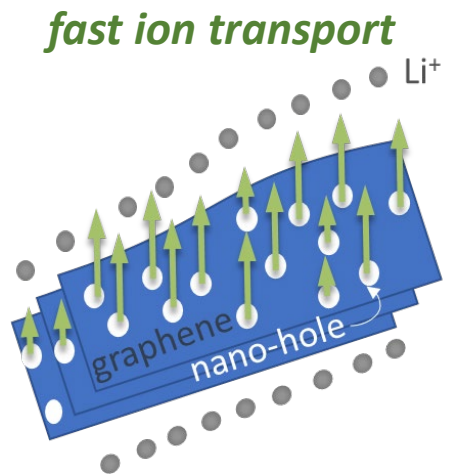
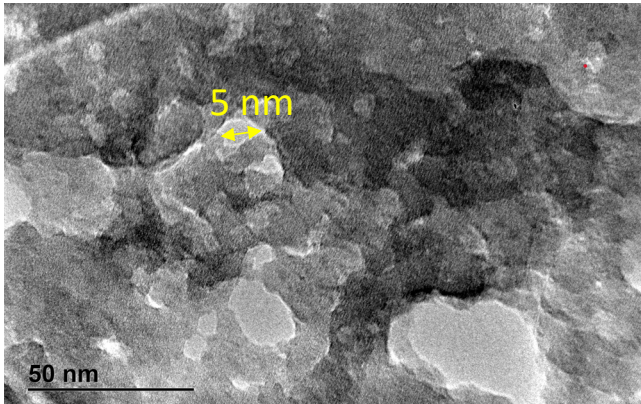
functionalized anode



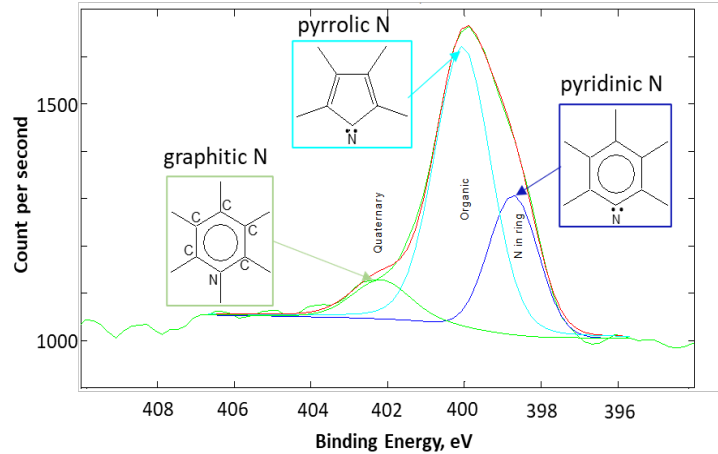
## Next Generation Lithium Ion Battery



- high energy density
- light weight
- safe dendrite free
- high cycling stability
- long calendar life
- conformal design
- scalable manufacturing



- Graphene with *in-plane* nanoholes for fast ion transport and dense packing
- Carbon nanotubes for mechanical strength and flexibility
- Incorporation of lithiophilic heteroatoms to guide uniform Li nucleation for dendrite-free graphene anode
- Anode prelithiation using cost-effective, electrochemical process in combination with additives for increased battery life



**increased capacity & dendrite prevention**

## Doped Lithiophilic Sites

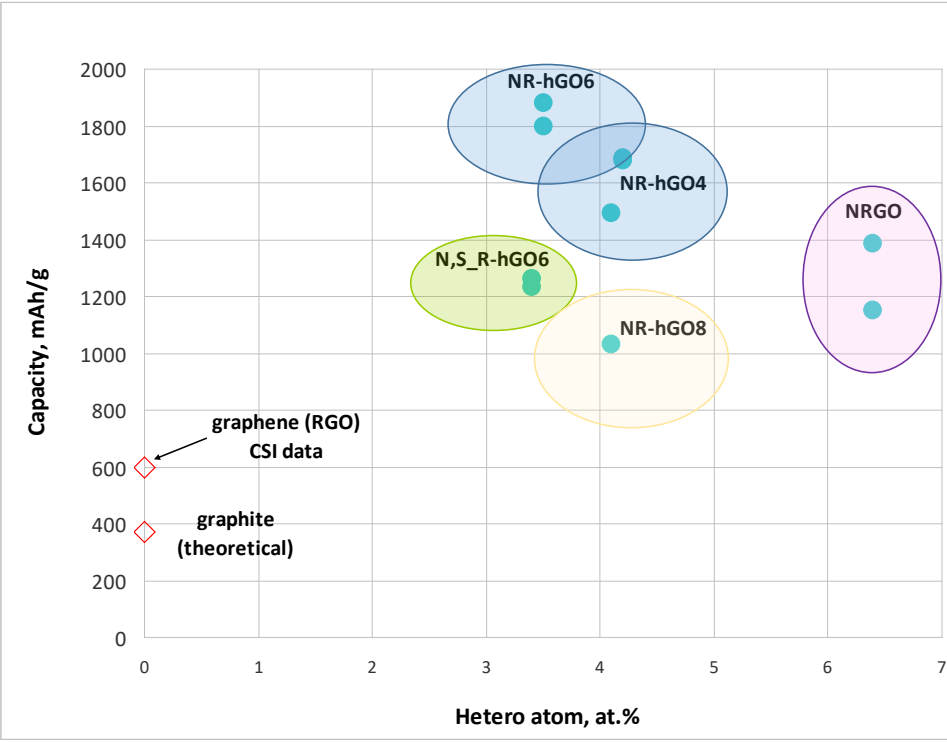
- Pyridinic N
- Pyrrolic N
- Graphitic N
- Carbon - C



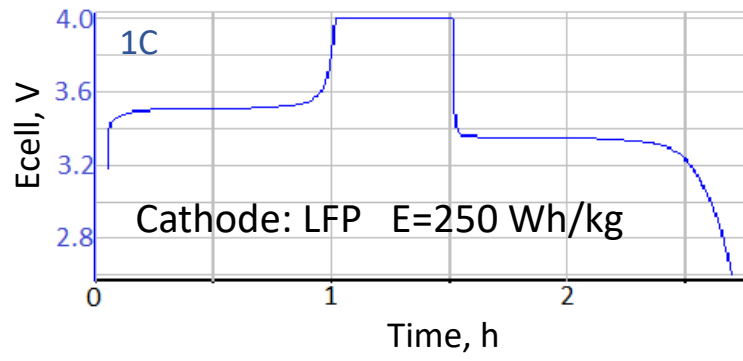
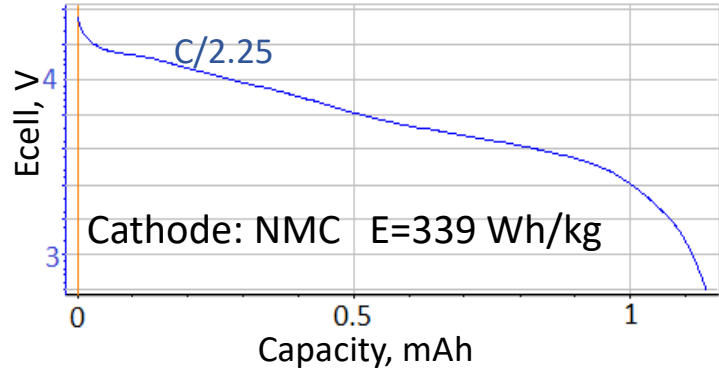
# Graphene Battery Performance

## High Capacity: heteroatom-doped graphene

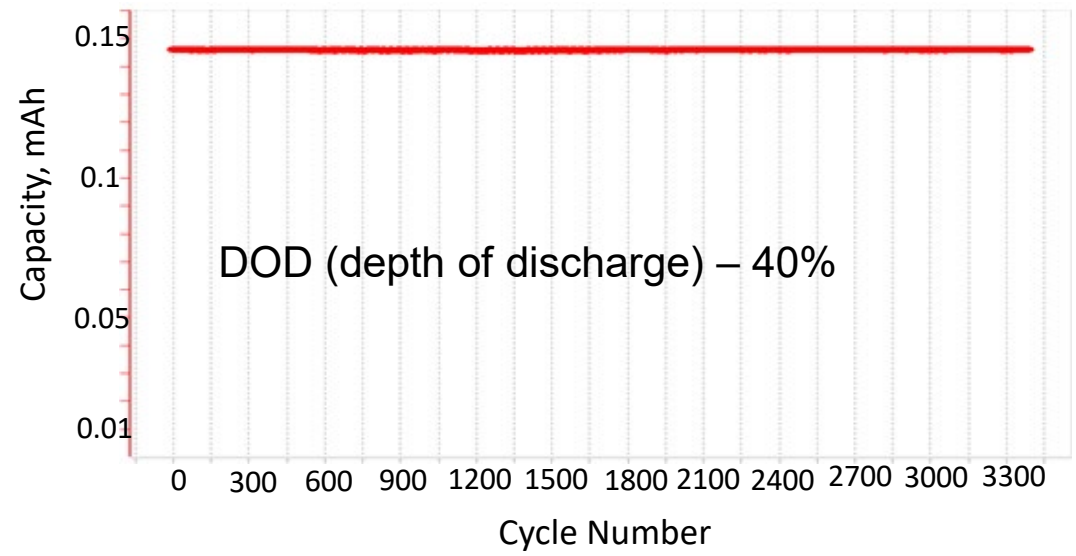
Capacity of Graphene Materials as a Function of Hetero-atom Content



## High Energy Density LIBs: prelithiated graphene anodes



## Stable LEO Cycling



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