Lithium-Ion Batteries for Stationary Energy Storage

Improved performance and reduced cost for new, large-scale applications

U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

Energy Storage Program

Pacific Northwest National Laboratory

Lithium-ion (Li-ion) batteries offer high energy and power density, making them popular in a variety of mobile applications from cellular telephones to electric vehicles. Li-ion batteries operate by migrating positively charged lithium ions through an electrolyte from one electrode to another, which either stores or discharges energy, depending on the direction of the flow. They can employ several different chemistries, each offering distinct benefits and limitations.

Despite their success in mobile applications, Li-ion technologies have not demonstrated sufficient grid-scale energy storage feasibility. Stationary applications demand lower energy and power densities than mobile applications, as they are not constrained by volume or weight. Instead, stationary Li-ion batteries must demonstrate longer battery lifetime and lower cost.

Overview

The Office of Electricity Delivery and Energy Reliability's (OE's) Energy Storage Program is funding research to develop longer-lifetime, lower-cost Li-ion batteries. Researchers at Pacific Northwest National Laboratory (PNNL) are investigating cost-effective electrode materials and electrolytes, as well as novel low-cost synthesis approaches for making highly efficient electrode materials using additives such as graphene, oleic acid, and paraffin. To address safety issues, researchers will also identify materials with better thermal stability.

Potential Technology Benefits

Li-Ion Batteries

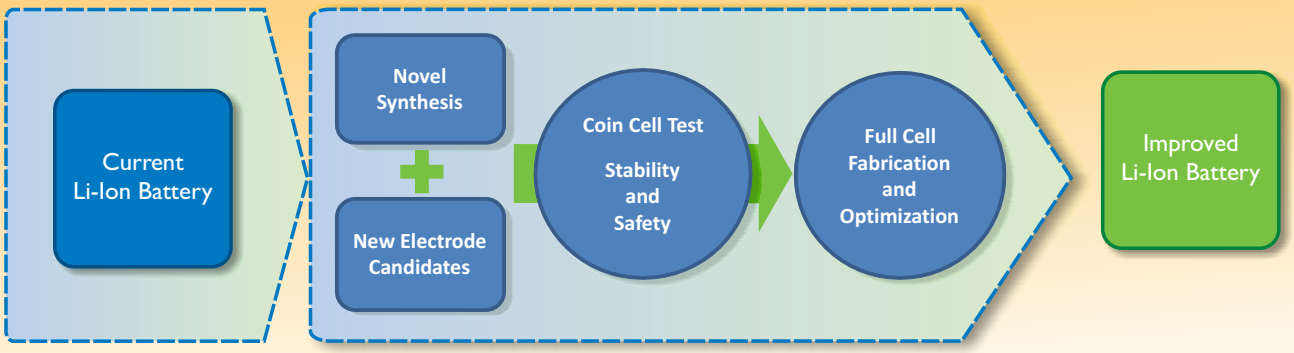
- High energy densities
- High power
- Near 100% efficiency
- Low self-discharge

Methods to Improve Performance

- Graphene improves recharging characteristics, such as reducing the recharging time and improving the battery's ability to recharge repeatedly after having been fully drained.
- Paraffin and oleic acid allow synthesis of nanomaterials through low-cost solid-state reaction.
- Surface modification of electrode materials improves rate performance and cycling stability.
- Novel materials with low electronic conductivity, created by thorough nanostructuring, will be investigated as next-generation Li-ion electrodes.

Technology Breakthroughs

Researchers at PNNL are investigating several different methods for improving Li-ion batteries. New cost-effective electrode materials and electrolytes will be explored. In addition, novel low-cost synthesis approaches for making highly efficient electrode materials using additives such as graphene, oleic acid, and paraffin will be investigated. To address safety issues, researchers will also identify materials with better thermal stability.



Project Timeline

Ongoing research and development will reduce the costs and increase the lifetime and safety of Li-ion batteries.

Graphene:

- March 2009: PNNL demonstrates proof of concept at laboratory scale
- October 2010: Established a Cooperative Research and Development Agreement (CRADA) with Vorbeck
- October 2010: R&D100 Award: Graphene Nanostructures for Lithium Batteries

Novel Synthesis:

- July 2010: Produced nanostructured $LiMnPO_4$ using Oleic Acid-Paraffin solid-state reaction
- 2012: Making nanostructured $LiMn_{0.8}Fe_{0.2}PO_4$ using Oleic Acid-Paraffin solid-state reaction ($LiMn_{0.8}Fe_{0.2}PO_4$ is more suitable to stationary storage than pure $LiMnPO_4$)
- 2012: Making nonconventional cathode materials

Electrode Matching Materials:

- March 2010: Tested coin cell using $LiFePO_4$-TiO_2/graphene combination
- May 2011: Enhanced $Li_4Ti_5O_{12}$ rate performance with surface modification
- August 2011: Fabricated 18650 cell using $LiFePO_4$-$Li_4Ti_5O_{12}$ combination in collaboration with K2 Energy Solutions; now being tested
- 2012: Fabrication of $LiFePO_4$-$Li_4Ti_5O_{12}$ 18650 cell with enhanced rate and cycling stability

Thermal Stability and Safety of Li-Ion Battery:

- June 2010: Characterized entropy changes on various cathodes and anodes
- October 2011: Investigate thermal stability and phase transformation of $LiMnPO_4$ cathode
- October 2011: Tested electrolyte stability on $Li_4Ti_5O_{12}$ anode
- 2012: Conduct calorimetric study on 18650 cells made with $LiFePO_4$-$Li_4Ti_5O_{12}$ electrode materials

Challenges

- Short cycle life
- High costs
- Issues regarding heat management, safety, and reliability
- Current electrolytes are unstable and potentially flammable at high voltages
- Narrow operational temperature window
- Significant heat generation during operation
- Inherently high risk of electrical shorting

Project Partners

- Vorbeck Materials (CRADA)
  http://www.vorbeck.com
- Princeton University
  http://www.princeton.edu
- State University of New York at Binghamton
  http://www.binghamton.edu
- Pennsylvania State University
  http://www.psu.edu
- K2 Energy Solutions
  http://www.peakbattery.com

For More Information

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Related Reading

Sandia National Laboratories, "Energy Storage Systems Program (ESS)," *http://www.sandia.gov/ess/*.

Tri-city Herald newspaper, "PNNL developing better batteries," July 2010, *http://www.tri-cityherald.com/2010/07/14/1091667/pnnl-developing-better-batteries.html*.

R&D Magazine, "Wax and soap can help build electrodes for cheaper lithium ion batteries," August 2010, *http://www.rdmag.com/News/2010/08/Energy-Batteries-Wax-And-Soap-Can-Help-Build-Electrodes-For-Cheaper-Lithium-Ion-Batteries/*.

R&D Magazine, "The heat is on for rechargeable batteries," June 2011, *http://www.rdmag.com/News/Feeds/2011/07/energy-the-heat-is-on-for-rechargeable-batteries/*.

Importance of Energy Storage

Large-scale, low-cost energy storage is needed to improve the reliability, resiliency, and efficiency of next-generation power grids. Energy storage can reduce power fluctuations, enhance system flexibility, and enable the storage and dispatch of electricity generated by variable renewable energy sources such as wind, solar, and water power. The Office of Electricity Delivery and Energy Reliability Energy Storage Program funds applied research, device development, bench and field testing, and analysis to help improve the performance and reduce the cost of energy storage technologies.

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