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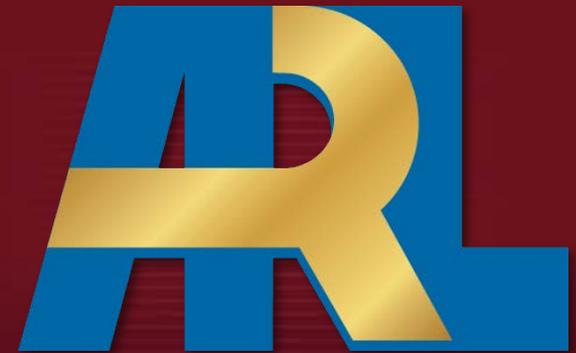
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U.S. Army Research, Development and Engineering Command

# High Cycle Life Cathode for High Voltage (5V) Lithium Ion Batteries



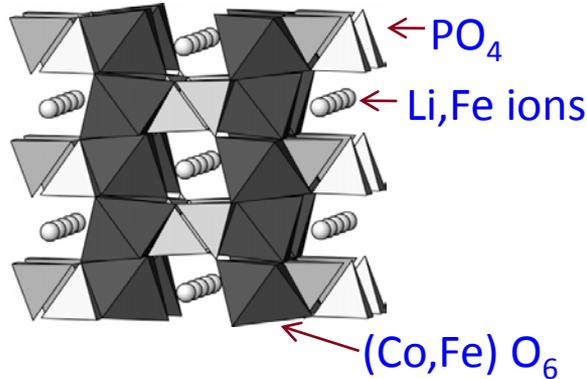
***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

**Inventor: Dr. Jan L. Allen**

## Technology Overview

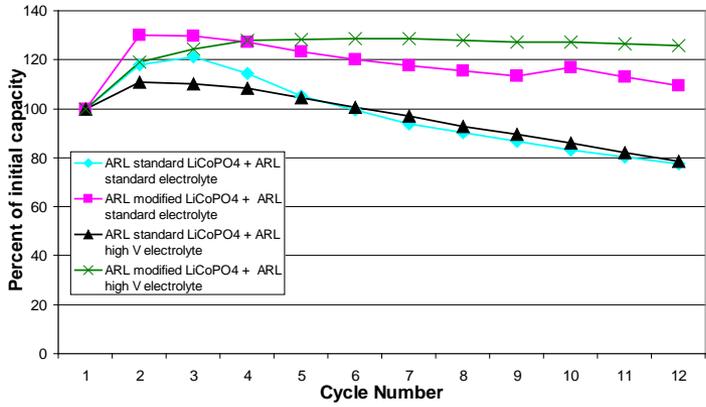
- There is a huge, growing demand in commerce and the military for high energy density rechargeable batteries.
- In response to this need, we have developed a high voltage, high cycle life Li-ion cathode material based on lithium cobalt phosphate ( $\text{LiCoPO}_4$ ) that provides higher energy density (15% >  $\text{LiFePO}_4$  demonstrated, up to 40% greater with further R&D).
- The invention combines the safety of a phosphate system with a high energy content. Safety advantage arises from abuse tolerance of phosphate.
- Previous attempts to use  $\text{LiCoPO}_4$  have generally resulted in rapid charge-capacity fade and an extremely short cycle life (e.g., greater than 50 percent loss after only 10 cycles).
- The innovation is the partial substitution of lithium and cobalt by iron, which stabilizes electrochemical cycling and greatly reduces capacity loss. The capacity retention is more than 80 percent after 500 cycles with high coulombic efficiency.

# Technology Overview



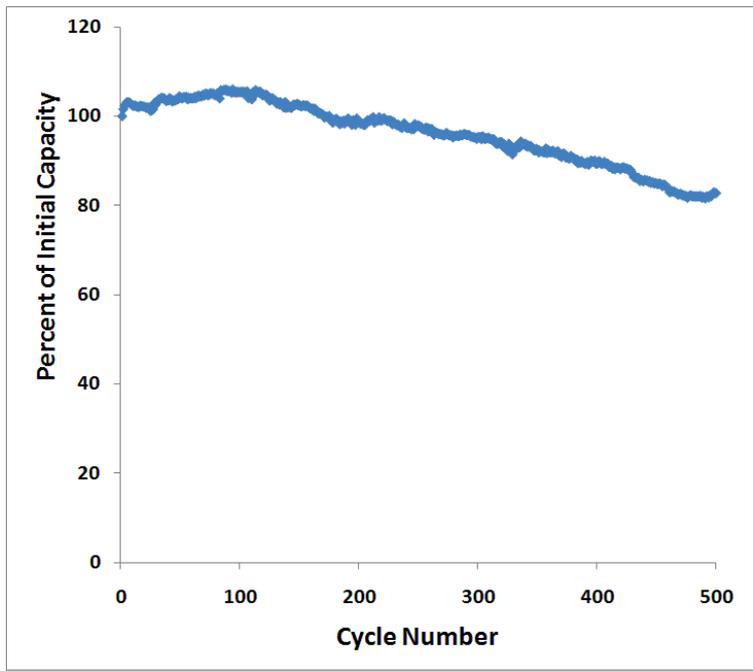
ARL innovation of partial substitution of Li and Co by Fe stabilizes the electrochemical capacity of  $\text{LiCoPO}_4$  cathode

## Comparison to standard $\text{LiCoPO}_4$ and standard electrolyte



- Cathode expected to last far beyond 500 cycles
- Preparation method adaptable to existing cathode process lines
- IP includes novel composition of matter and preparation method

Substituted  $\text{LiCoPO}_4$  with ARL-SEDD high voltage stabilized electrolyte demonstrates high cycle life (capacity retention of >80% at 500 cycles shown here) with about 97% coulombic efficiency.



## Technology Advantages

### The High Cycle Life Cathode's advantages:

- Provides potentially up to 40% greater energy density than standard  $\text{LiFePO}_4$
- Higher voltage at cell level may reduce number of cells required for application
- Easy and inexpensive method to prepare
- Offers safety advantage of phosphate based cathodes without trade-off in energy density.
- It is a “drop-in” technology (no new processing methods are required)

## Technology Differentiation

### Military application

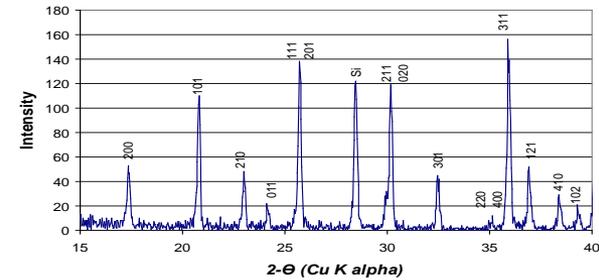
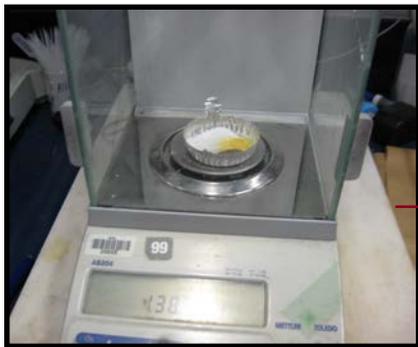
- A soldier currently required to carry 50 lbs of batteries could potentially reduce the overall weight by about 20 lbs.
- Current military vehicles consume immense quantities of fossil fuels. Cost to bring forward fuel to the battlefield is enormous in terms of dollars and lives. Hybrid electric vehicles based on this technology will consume less fuel.

### Improvements over existing products

- The BB2590, the current soldier rechargeable battery, constructed with this cathode material has a projected energy density of about 170 Wh/kg relative to current specifications of about 120 Wh/kg. Mission time can increase by 40% or weight of batteries can be reduced by 40%.

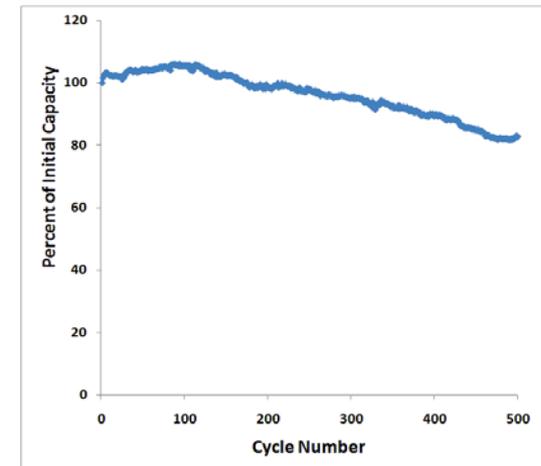
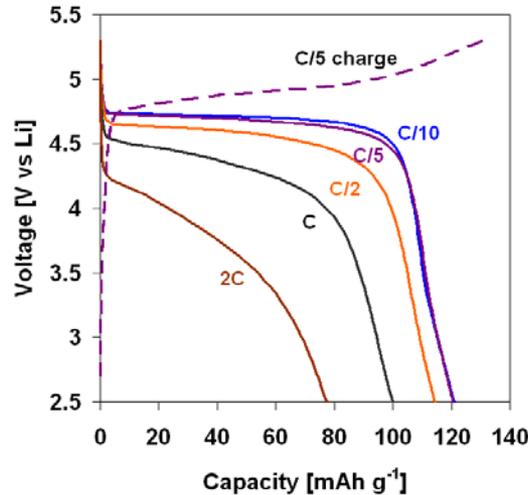
# Technology Proof of Concept

## Method of Preparation



**X-ray diffraction**

## Cathode coated with standard methods and tested in coin cells demonstrating long cycle life



**Currently about TRL-4**

**APPROVED FOR PUBLIC RELEASE Rate capability not compromised**

**Long Cycle Life**

## Military Applications

### Envisioned military applications include:

- Soldier power for a longer life rechargeable Li-ion, e.g., BA-2590
- “More-electric” vehicles: starting, silent watch
- Military electronics
- Projected \$500 Million military/aerospace market for Li-ion by 2015\*



Military Electronics



Soldier Power



More-electric vehicles

\*Frost & Sullivan, March 2010, N779-27, US Battery Market for Military/Aerospace Applications.

## Commercial Applications

40% Increased battery life for application to:

Three major markets

- Electric Vehicle, Hybrid Electric Vehicle
- Consumer Electronics
- Large scale stationary energy storage

Overall, Li ion market is about \$18 billion in 2010  
(Sanyo estimate)\*

Projected By 2015 (Sanyo estimate)\*:

- \$18 Billion in Automotive applications
- \$18 Billion in Consumer electronics
- \$24 Billion in Large scale stationary energy storage



Large Scale Stationary storage (utilities)



Consumer Electronics



Hybrid Electric & Electric Vehicles

\*As reported in Bloomberg Businessweek.com, 11/17/2010 author: Mariko Yasu

## Technology Agreements

- A patent license and CRADA is sought. The current technology would benefit from a collaboration between the inventor team and the commercialization partner. This would most readily be done through a patent license / CRADA agreement.
- TRL 4– Fully functioning cell prototypes using the invented cathode.
- A Provisional patent application has been filed.