PRODUCING A NEW CLASS OF COMPOSITE CATHODES FOR LITHIUM-ION BATTERIES

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Introduction

This invention achieves a prototype for production of a breakthrough class of cathodes developed specifically for secondary (rechargeable) lithium ion (Li-ion) batteries. Researchers at the U.S. Army Research Laboratory-Sensors and Electron Devices Directorate (ARL-SEDD), Adelphi, Maryland designed and successfully tested a novel synthesis process to create composite cathode active materials with superior cell characteristics. The composite material has the general formula $LiFe_{1-x}M_xPO_4$-C, where *M* represents the optional inclusion of a small amount of one or a combination of selected transition metals (*e.g.*, cobalt, nickel, vanadium). When synthesized via the SEDD process, the composite cathode results in a high performing Li-ion battery that is less expensive, safer and more environmentally benign than traditional cathode materials.

Concept

Since they were first available in 1991, Li-ion batteries have become ubiquitous in portable electronics, telecom devices and the transportation industry. They are presently manufactured at a rate of several million units per month, and production continues to expand to meet growing demand. Yet, there are two major problems limiting wider application of Li-ion cells: cost and safety. This is particularly so with cathodes common in today's batteries that use cobalt and similar expensive and toxic metals.

The SEDD innovation could improve large-scale Li-ion batteries designed for use in mass transit vehicles (source: DOE)

Lithium iron phosphate ($LiFePO_4$) was first proposed in 1997 as an alternative to the standard cathode composition, lithium cobalt oxide ($LiCoO_2$). A cathode featuring iron phosphate instead of cobalt is attractive for a number reasons: better thermal stability, safer at a fully charged state, low reactivity with electrolyte and no toxic metals. Plus, iron phosphate is prepared from raw materials far less costly than cobalt. Unfortunately, $LiFePO_4$ has far lower electronic conductivity, which translates to weak power output. However, there has been worldwide research activity to find methods to remediate this shortcoming. The SEDD response focuses on a new method of preparation of the cathode. Their process includes compositing $LiFePO_4$ with carbon and, if needed, doping with transition metals to tailor operating characteristics.

Invention Overview

- *Enables a new family of cathodes that are less expensive, safer and more environmentally benign*
- *Method is straightforward and compatible with current large-scale synthesis processes*
- *Yields cell for multiple applications including consumer electronics and electric vehicles*
- *TRL 5 – Fully functioning laboratory scale prototypes featuring cathodes created using SEDD process*
- *Laboratory test data available; results published, "Optimization of reaction condition for solid-state synthesis of $LiFePO_4$-C composite cathodes" Journal of Power Sources 147 (2005) 234–240*
- *U.S. Patent 7,824,802 B2*

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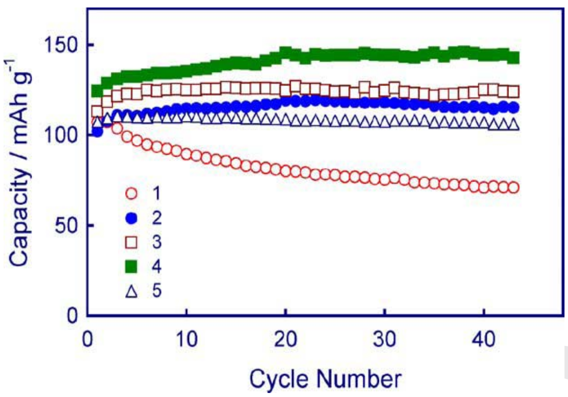
TECHNOLOGY FACT SHEET

Features/Capabilities/Intellectual Property

There are two main approaches to overcome low power capability of $LiFePO_4$ cathode. One is to coat the cathode materials with an electron-conducting layer, or by doping with conductive metal cations. The other is to reduce particle size of the material by modifying the synthesis conditions, which can be accomplished using the solution method or the solid-state reaction method. The solution method involves chemical reaction in the liquid phase. This offers some advantage in creating a homogeneous mixture; however, the process requires additional care to remove solvent. In contrast, the solid-state reaction offers an easier and more practical approach, and it is more suitable for large-scale production.

SEDD researchers optimized their process by testing several combinations of starting materials (*e.g.*, different forms of carbon) and processing steps, which include heating, grinding, pelletizing and reheating. While each combination yielded different performance traits (see chart), SEDD researchers confirmed that the novel composite cathode, $LiFePO_4$-C, shows much better performance in terms of the discharge capacity and cycling stability than $LiFePO_4$ alone.



All the cells with $LiFePO_4$-C cathodes (2-5) exhibited much more stable capacity with increasing cycle number than the $LiFePO_4$ control cell. (source: SEDD)

Other features/capabilities/intellectual property offered by this invention include the following:

- Improved conductivity, higher rate capability, and longer life ($LiFePO_4$-C vs. $LiFePO_4$)
- Scalable for use in large and small format batteries
- IP includes process for forming the composite cathode material

Potential Markets/Applications

The improved conductivity of the less costly, safer, more benign cathode material expands opportunities for Li-ion batteries in a variety of areas:

- Transportation – US auto manufacturers have announced development of transportation systems featuring lithium iron phosphate technology

- Electric Grid Services – Contingency capacity provisions are used by power plants to keep a portion of their capacity on reserve for emergencies

- Commercial Markets – Power tool manufacturers are using lithium iron phosphate technology in their product lines

Key Advantages & Benefits

- *Ionic conductivity $LiFePO_4$–C comparable to the more expensive $LiCoO_2$ cathode material*
- *At room temperature, $LiFePO_4$–C achieves stable capacities of 159 mAh/g at 0.02C and 145 mAh/g at 0.2C*
- *Uses materials of construction common to the industry*
- *No additional cost anticipated for manufacturing cathode materials with $LiFe_{1-x}M_xPO_4$-C composition as compared to metal oxide cathodes, such as $LiCoO_2$*
- *Inventor team available to work with commercialization partner*

Contact Information

This technology was developed by ARL-SEDD. It is now available for licensing and CRADA opportunities.

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