

## ARGONNE'S INTEGRATED R&D PROGRAM ADDRESSES

- » Increased operating time
- » Increased power
- » Increased calendar life
- » Reduced cost
- » Improved safety
- » Improved energy density

## THROUGH ADVANCES IN:

### CATHODES

- » Higher capacity (up to 270 mAh/g), with high voltage compatibility and greater stability
- » Improved current capability, environmental compatibility and stability at lower cost

### ANODES

- » Higher capacity (up to 2000 mAh/ml)
- » Materials that are safer than graphite and have greater life
- » Improved stability

### ELECTROLYTES

- » Polymeric electrolytes that have high ionic conductivity, enhanced safety, larger cell capacity and improved voltage stability
- » Additives that provide reduced gas generation and first cycle capacity loss plus longer life and enhanced safety

### PACKAGING

- » Flexible packaging that provides lower cost and improved shape control
- » Nanocomposite material that provides extended life in flexible packaging

### SAFETY

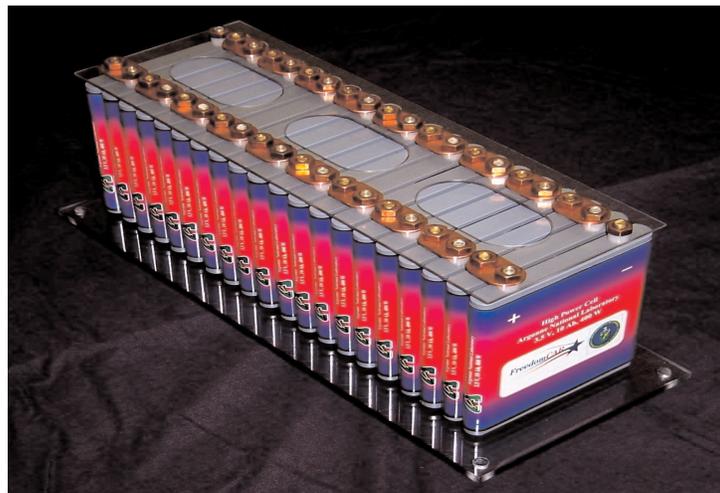
- » Advanced additives that provide improved flame retardancy and stabilized electrode surfaces

## PROFILE: *Argonne Lithium Ion Battery Technologies*

# LI-ION BATTERIES WITH LONGER LIFE, LOWER COST, AND BETTER SAFETY

Argonne National Laboratory is developing advanced cell components that will enable new market applications for lithium-ion (Li-ion) batteries. This technology promises to play an important role in expanding the medical, transportation and portable device battery markets.

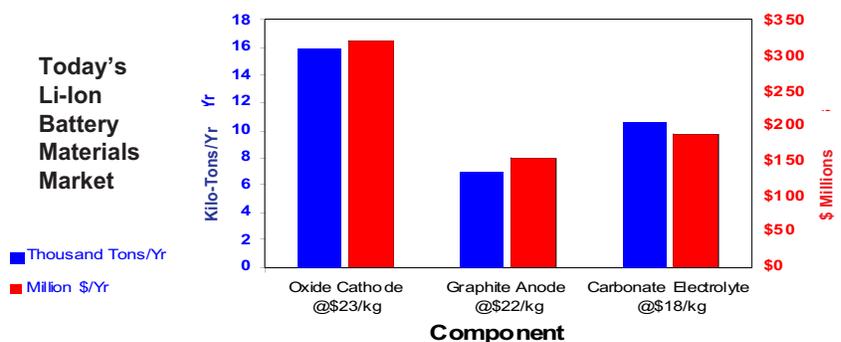
Lithium-ion batteries offer significant advantages in weight and energy density over other rechargeable batteries. They have proven to be ideal for small-scale portable electronic applications such as cellular phones and laptop computers. Emerging applications in implantable medical devices also take advantage of the high cycle life, light weight and other benefits of Li-ion batteries.



20-cell 80-volt 8-kW Li-ion battery module designed by ANL for Hybrid Electric Vehicle Application

### Burgeoning Market for Materials Suppliers

Because of the unique features of Li-ion technology, the market for Li-ion batteries has become substantial, not only for the cells and batteries, but also for the raw materials that go into the cell components. Argonne is internationally recognized for its expertise in developing and testing innovative battery materials. The Argonne intellectual property portfolio for Li-ion technology has over 30 pending or issued patents, with additional inventions presently under consideration for patent applications.



## STATUS

Argonne is seeking industrial partners to develop and apply these platform technologies to the next generation of Li-ion batteries. These advanced systems are available to industry via license or other partnering scenarios.

## CATHODES

The combination of a lithium manganese oxide spinel cathode and a new liquid electrolyte solvent and salt with improved stability cuts material costs by nearly half while extending the life, improving the rate capability and enhancing safety. The new formulations have been proven in the laboratory environment.

Layered lithium-manganese-oxide cathodes offer less expensive alternatives to the present commercial cathodes. These alternative layered cathode materials are more stable and offer enhanced safety and longer life compared to commercial cathodes.

## ANODES

Intermetallic anode materials operate at potential levels well removed from the potential of metallic lithium, relative to carbon-based anodes. This enhances safety and reduces the need for expensive battery circuitry designed to avoid the formation of metallic lithium during charging of carbon anodes.

## ELECTROLYTES

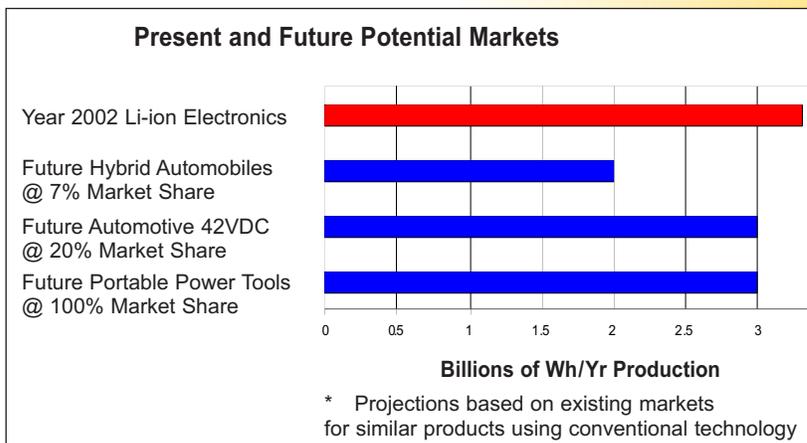
Argonne's introduction of the polysiloxane electrolyte is a major step forward in safety. By moving away from volatile and flammable materials, the prospect for large capacity cells and batteries is now a reality.

## PACKAGING

Argonne has developed a flexible, low-cost and long-life packaging system with a break-through in barrier layer technology. The technology employs a combination of organoclays dispersed in an inexpensive polymer system. This achieves an extremely high reduction in permeation of air and moisture into the cell, and electrolyte materials out of the cell, and provides an entirely original and economic Li-ion package.

## New Applications Offer Market Growth Potential

The growth potential for the Li-ion battery market is promising for the next generation of batteries. Most significant is the market associated with new applications, which could quadruple today's \$3+ billion worldwide market. These new applications, however, require significantly greater battery cell capacities and/or higher power than today's technology can competitively and safely support.



## Li-ion Battery Development

Argonne is addressing critical development issues through a closely integrated R&D effort that addresses the barriers to market growth. There are four key constraints to the broad adoption of Li-ion batteries with cells larger than 10Ah. First is the safety issue associated with graphitic anodes and volatile, flammable electrolytes. Second is the power fade due to increased cell impedance attributed to the metal oxide cathode. Third is capacity fade associated with the loss of lithium through parasitic side reactions. Power and/or capacity fade control battery life. Fourth is the cost of components, particularly the cathode and cell packaging. Argonne has focused on the safety and life issues with new electrolytes and additives that promote the formation of stable passivation films at the electrodes, as well as more stable cathode materials. Argonne is also developing less expensive cathode materials and innovative packaging that greatly reduces costs.

Existing Li-ion cell designs use liquid organic electrolytes that, while successful in small electronic devices, have safety limitations that preclude their use in larger-battery applications. Many applications, particularly military, seek maximum energy density beyond even today's notable performance. Argonne has developed new electrolytes and rechargeable chemistries that can improve capacities from 120 Wh/kg to 200 Wh/kg and from 350 Wh/l to 500 Wh/l.

Although much of the industry's long-term research focus is on larger batteries (e.g., hybrid electric vehicles), Argonne's program results are presently finding application in products such as medical devices and portable electronics. Soon, the rapidly growing power tools market is also expected to benefit from Argonne's advanced technology.

**Contact:** Dr. James Gleeson (630) 252-6055  
Office of Technology Transfer, Argonne National Laboratory  
9700 South Cass Avenue, Argonne, IL 60439

