Electrochemical Energy Storage for the Grid

Yet-Ming Chiang
Department of Materials Science and Engineering
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- **A123 Systems**
  - 2MW, 0.5 MWh Li-ion battery

- **Fisker Karma PHEV**

- **Daimler Orion/BAE Systems**

- **F1**

- **Ohio State Univ Buckeye Bullet 2.5**

- **Hymotion PHEV**

Funded in part by the ARPA-e Program of the U.S. Department Of Energy
Energy Storage Systems Program Review, Nov 4, 2010
Example of impact of research-driven innovation:
Collective revenue of active companies founded by MIT graduates today equals the 17th largest world economy*
(Note: Up from 23rd largest world economy 10 years ago)

*Edward B. Roberts and Charles Eesley, Entrepreneurial Impact: The Role of MIT, 2009
U.S. DOE Provided Support Along Entire Cycle of Innovation and Commercialization
There is more than one “Valley of Death”

1. Is the researcher/professor serious about impact beyond academic glory? (Are you the chicken or the pig? Example: Deshpande Center at MIT)

2. Does the technology actually work? What’s your first product? (And how many strikes do you get before you’re “out?”)

3. Can you scale? How much capital to get to volume manufacturing? Or do you partner? (Licensing is a consolation prize if not an outright failure.)

4. Is your global competition foreign companies, or foreign governments? (Industrial policy)
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New Type of Battery Offers Voltage Aplenty—at a Price

By William M. Bulkeley

A NEW GENERATION of rechargeable batteries—delivering far more power than their predecessors—is energizing the power-tool industry and generating widespread interest in applications in everything from vacuum cleaners to ride-on lawn mowers to hybrid cars. The new lithium-ion batteries—loved by producers already on the market and envied by others—hold the promise of providing a vital battery boost to electric cars, opening up a market that is expected to grow to $5 billion by 2012, according to an industry report.

Black & Deckers Corp. says that early next year it plans to introduce a family of 14.4-volt power tools based on lithium-ion cells that are expected to add sales of $500 million to its top line. The company’s new line will include a “ hypertension” battery tool, a battery-powered lawn mower that will run for 24 hours on a single charge, and a cordless drill.

DeWalt, Inc., the world’s largest manufacturer of power tools, says it is planning to introduce several new lithium-ion products in the coming months.

DeWalt says that it has already developed a new 12-volt lithium-ion battery that will allow users to use their existing power tools.

Drilling for nanotech gold

One US nano technology start-up has hit the jackpot—but for others the prospect of such overnight success seems remote. Colin MacKinnon reports.

The story is the tale of Proteus, a start-up that has been able to turn a small amount of scientific knowledge into a profitable business. The company has developed a new type of battery that can be used in a variety of applications, from portable electronics to hybrid cars.

The battery, called the “nano battery,” is based on the use of nanotubes, which are tiny tubes made of carbon that can hold a large amount of charge. The company has been able to produce the batteries at a cost that is comparable to that of existing batteries, and it is now interested in exploring new applications for the technology.

The success of Proteus has not gone unnoticed, and other start-ups are now looking to the company as a model for success. The company has received funding from several investors, including North Bridge Venture Partners, and has hired a number of experienced engineers.

The company is now working on developing a new type of battery that could be used in a variety of applications, from portable electronics to hybrid cars. The company is also exploring the possibility of using the technology in other areas, such as medical devices, where it could be used to power small implants.

Proteus is not the only company looking to the nanotechnology field as a way to develop new products. There are several other start-ups that are exploring the use of nanotubes in batteries and other applications.

The challenge for these companies will be to find a way to make the technology economically viable. The cost of producing nanotubes is currently high, and it is not clear how long it will take for the technology to become cost-competitive.

Despite these challenges, the potential of nanotechnology is huge, and many companies are looking to the field as a way to develop new products and technologies. The success of Proteus is a提醒 that with the right approach, the potential of nanotechnology can be realized.
Benchmark in High Power Li-Ion: Formula 1 Racing

- McLaren-Mercedes - A123 olivine based Kinetic Energy Recovery System (KERS)

- Opening race of 2009 F1 season in Melbourne, AUS

- Lewis Hamilton, 2008 World Champion, starts in 18th position (out of 20) and finishes 4th
OSU Buckeye Bullet VBB2.5: Electric Drive Land Speed Record

World’s Fastest Electric Car: 307.7 mph
Li-Ion Powered Hybrid Buses: >50 Million Road Miles (since 2007)

Daimler Receives Orders for 1,052 Orion VII Diesel-Electric Hybrid Buses; Majority to Use Li-Ion Battery Pack

17 December 2007

Daimler Buses North America has received orders totaling 1,052 Orion VII Next Generation diesel-electric series hybrid transit buses. MTA New York City Transit has ordered 850 and the City of Ottawa (OC Transpo) has ordered 202. These buses will be powered by BAE Systems’ HybriDrive diesel-electric hybrid propulsion system and delivered into 2010.

This order will bring MTA’s diesel-electric hybrid bus fleet to almost 1,700 units, making it the largest diesel-electric hybrid fleet in the world. With this order, Orion transit buses will account for almost 50% of MTA New York City Transit’s entire fleet.

OC Transpo has ordered 202 Orion VII Next Generation diesel-electric hybrid transit buses to be delivered by 2009. This delivery will make OC Transpo the third largest hybrid bus fleet in Canada.

The hybrid drive in the Orion includes a 6-cylinder, in-line, 5.9-liter Cummins diesel that delivers 194 kW (260 hp) at 2300 rpm; a 120 kW generator; a 32 kWh battery pack (initially lead-acid, but a majority of the new orders will use a lithium-ion battery pack with cells from A123Systems [earlier post], according to Daimler); and a 186 kW (250 hp) traction motor that delivers 2,100 lb-ft (2,847 Nm) of torque (continuous), with 2,700 lb-ft (3,661 Nm) peak.

Compared to standard diesel propulsion, these hybrid buses deliver up to 30% better fuel economy while greatly reducing emissions: 90% less particulate matter, 40% less NOx and 30% fewer greenhouse gases.

With 1,100 hybrid transit buses already on the road, 460 pending deliveries and the announced new orders, Orion has received more than 2,600 orders for the hybrid since the launch of the Orion hybrid bus in 2003.

Daimler Buses North America, headquartered in Greensboro, N.C. (United States), is a Daimler AG company. It combines three commercial bus brands under one corporate structure: Orion transit buses, Setra motorcoaches, and the Dodge Sprinter shuttle bus.
Today

A123 SYSTEMS

Materials Research and Automotive Applications: Michigan

Hymotion: Canada
HO and R&D: Watertown, MA
Pack and Systems: Hopkinton, MA

300,000+ s.f. of high volume, state of the art manufacturing space in Asia

Prismatic process development center: Icheon, Korea
Powder, cathode coating, cell plants: Changzhou, China
Quality, supply chain: Shanghai, China

Material science differentiation
Cell engineering innovation
Systems engineering value add
Low cost - high volume & quality manufacturing
Industry leading partners
Coating Plant – Changzhou, China

Built in 2007
A123 Systems Livonia Factory Grand Opening
September 13, 2010

Dave Vieau (CEO), Energy Secretary Chu, Yet-Ming Chiang (A123 co-founder), Bart Riley (CTO, co-founder), and Governor Granholm

Phone call from White House

Livonia Facility

Customer Panel

Senator Carl Levin

Senator Debbie Stabenow

Congressman John Dingell

Admiral Dennis Blair

Micky Bly, GM
Romulus, MI Powder & Coating Campus
The question of scale:

- A123’s Livonia plant can produce 30,000 PHEV/EV packs per year
- 33 such factories needed to meet target of 1 million EVs
- 270 million cars in the US today, growing to 500 million by 2030
Pumped Hydroelectric Is Lowest Cost Storage (~$100/kWh): Can this be done with electrochemical storage?

- 1872 MW output (21.5 GW total in U.S.)
- 15,000 MWh stored energy
- 2.5 x 1 mile, 842 acres
- Elevated 400 ft above Lake Michigan
Disagreement on Battery Cost Projections

(Chart by Cheah and Heywood, 2010)
Automotive Li-Ion Battery Development is Driving Down Battery Cost, Improving Performance, Enabling Grid Applications
Megapower using Nanophosphates:
Frequency Regulation with the World’s largest Li-Ion Battery

- 2 MW power, 90% round-trip efficiency
- 0.5 MWh stored energy
- 82,000 cylindrical 26650 cells
- 1.2 tonnes cathode material
- $2.3 \times 10^{17}$ nanoparticles (40 nm dia.)
Eight A123 Systems SGSSs™ units providing 16 MW installed on the grid in Chile, performing “spinning reserve” grid stabilization services.
Current Lithium Ion Battery Designs Have Too Much Mass, Volume and Cost Overhead


One Example of a New Approach: Semi-solid flow batteries using high energy density electrochemical “fuel”
Questions?