Energy Storage of the Future: Innovation in the Lithium Ion Battery Space

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Different energy storage applications with different specifications

- Grid storage
- Home/microgrid
- Battery electric vehicles
- Plug-in hybrid vehicles
- Grid frequency regulation
- Consumer electronics
- Power tools

Discharge time:
- Days
- Hours
- Minutes
- Seconds

Energy capacity:
- Wh
- kWh
- MWh
- GWh
Lithium ion batteries can be used for many applications
Big players benefit.
High volume production decreases costs

Large manufacturers benefit from economies of scale.

By 2020, materials projected to be > 70% of cell cost.

Price trends for electric vehicle batteries

Total Battery Consulting, xEV report, February 2016.

- Pack price
- Cell price
- Cell materials
Decreasing material cost is challenging

Battery grade graphite costs ~5 $/kg

Graphite mine in Sri Lanka

Large manufacturers pay less for materials.
Big players dominate the lithium ion battery market

- Use same technology for different markets
- Benefit from economies of scale.
- Pay less for materials

Innovation must be disruptive or provide a solution that is compatible with existing processes and infrastructure
Inside a lithium ion battery
How can we improve a lithium ion battery?

Energy density

Charge / discharge speed

Lifetime

Materials

Structure
Disruptive Innovation

Active materials make up less than 50% of mass and volume in today’s lithium ion batteries

Volume fraction

\( \{ \approx 35\% \)
Disruptive Innovation

Semi-solid flow cell

Flow cell concept abandoned

Manufacturing approach?

“Incremental” Innovation

Sony’s commercial LIB

1991

Cathode: lithium cobalt oxide
Anode: soft coke carbon
Separator: polymer membrane
Electrolyte: organic solvent + salt

2016

Cathode: lithium nickel manganese cobalt oxide
Anode: graphitic carbon
Separator: thinner, more wettable membrane
Electrolyte: complex solvent mixtures, salt & additives

~3x higher energy density
Understanding lags behind development needs

Interdisciplinary approach needed: tools, techniques, etc.
X-Ray tomographic microscopy

Complex interplay between electrochemical and mechanical effects
Silicon-carbon composite anodes

**Graphite**: 372 mAh/g  11% volume expansion  
**Silicon**: 3578 mAh/g  280% volume expansion

20 wt.% silicon in graphite: 1013 mAh/g

Structure of graphite anode limits battery charging speed

Today’s technology

BATTERY technology

Li+
Conclusions

- Lithium-ion batteries will continue to be a dominant storage technology in the next decade
- The myth of new technology with “X-fold” improvement
- Complex, dynamic system where understanding lags behind development
- Continuing innovations in materials and manufacturing will improve lifetime, energy density, rate capability while maintaining low costs