EV Everywhere Workshop
July 26, 2012

BATTERIES

BEYOND LITHIUM ION BREAKOUT

Breakout Session #1 – Discussion of Performance Targets and Barriers

Comments on the Achievability of the Targets

- 1 – **Zn-Air** possible either w/ or w/o electric-hybridization; also possible with a solid electrolyte variant
- 2 – **Multivalent systems** (e.g Mg), potentially needing hybrid-battery
- 3 – Advanced Li-ion with **hybridization** @ cell / molecular level for high-energy and high-power
- 4 – **MH-air**, **Li-air**, **Li-S**, all show promise
- 5 – **High-energy density** (e.g. Na-metal) **flow battery** can meet power and energy goals
- 6 – **Solid-state batteries** (all types)
- 7 – New **cathode chemistries** (beyond S) **to increase voltage**
- 8 – New **high-voltage non-flammable electrolytes** (both li-ion and beyond li-ion)
- 9 – **Power to energy ratio of >=12 needed** for fast charge (10 min) → So liquid refill capable needed
- 10 – **Safety/reliability/lifetime needs to be focus** from the onset to have features Li-ion cannot have → intercalation based battery with solid electrolyte
- 11 – Use of **replaceable/refillable/swappable powder/composite anode/cathode materials** → enables recycling, repeat dealer service business, reduces customer cycle /calendar life concerns, reduces initial capital costs

Breakout Session #1 – Discussion of Performance Targets and Barriers

Barriers Interfering with Reaching the Targets

- 1 – **Low-conductivity** and **low-cost preparation of solid electrolytes**. No way to predict materials that will allow provide high-conductivity. Materials must have adequate mechanical strength (mechanical shock, vibration, etc.)
- 2 – **Complete rethought about how batteries are designed and constructed** is needed to meet \$110/kWh EVE goal → need breakthrough in materials, construction, or even rethinking the concept of using cells
- 3 – **Complete suppression/control of dendrite growth**
- 4 – **Interfacial issues** (control/formation of SEI, resistance, morphology changes),
- 5 – **New electrolytes** needed **for mulivalent systems**
- 6 – **Activation and transfer kinetics** (solid product formation)
- 7 – **If industry has raw material processing capability available** to support ultimate production scale-up (esp. Li)
- 8 – **Air purification/scrubbing** (e.g. membranes)
- 9 – **Advancing pace of research/engineering to validate the science to meet 10-year EVE goal timeframe** → have 5-years from now to get to a prototype able to be integrated into a vehicle.
- 10 – **Low volumetric energy density** (important in short –term, not necessarily for platforms designed as EVs)
- 11 – **Ensure don't introduce new problems that need to be solved** (esp. high-cost ones)
- 12 – **Defining what "hybridization" means**, hybrid (high-power/high-energy) battery system demands need to be quantified better
- 13 – **Charge acceptance for low capacity systems** (e.g. PHEV40) a concern
- 14 – **Status of incumbent battery performance** → Li-ion and improvements it will see over 10 years

Breakout Session #2 – Discussion of Breakthroughs and Research Needs to Overcome Barriers and Reach Performance Targets

Technology Breakthroughs Needed

- 1 – **Solve the lithium cycling issue** (affects multiple chemistries)
- 2 – **Prediction of safe high-transport solid electrolytes**
- 3 – **Stability of carbon-based air-electrolytes** → replacement/modification of carbon electrodes
- 4 – **Interface ion- and electrolyte transport** and **SEI control**
- 5 – **Development of stable safe non-volatile electrolytes**

"Out-of-the-Box" Ideas

- 1 – **High-energy density** (e.g. Na-metal) **flow battery** can meet power and energy goals
- 2 – Use of **replaceable/refillable/swappable powder/composite anode/cathode materials** → enables recycling, repeat dealer service business, reduces customer cycle /calendar life concerns, reduces initial capital costs
- 3 – Cannot meet EVE cost goals with current battery design → **Rethink the concept of using cells**
- 4 – **Hybrid (electric-electric) energy system** (high-power & high-energy) (battery-battery, battery-ultracap, fuel cell-battery, etc.)
- 5 – **Liquid or powder refill capable batteries** (helps solve rapid charge issue esp. with high energy, high mileage batteries)
- 6 – **Self-regulating batteries**

Breakout Session #2 – Discussion of Breakthroughs and Research Needs to Overcome Barriers and Reach Performance Targets

Research Suggestions

- 1 – Mn-H_2 batteries
- 2 – Improvement of air-electrode catalytic performance and substrate stability
- 3 – Metal anode rechargability improvements
- 4 – Materials and electrolytes capable of mechanical (liquid/powder) and electrochemical recharging
- 5 – Develop additives to electrolyte
- 6 – Develop air-stable solid electrolyte(s) (both for manufacturing and in-use)
- 7 – Develop low-temperature solid electrolytes
- 8 – Materials that enable a high-energy flow battery
- 9 – Electric-hybridization taken from device-level down to cell level (similar to advanced –lead-acid batteries)
- 10 – Develop prediction tools for safe high-transport solid electrolytes
- 11 – Develop prediction tools for cycle/calendar life for new chemistries

Breakout Session #3 – Discussion of Action Plans and Next Steps

Comments Regarding the Other Technical Areas Being Discussed

- 1 – Advanced materials (e.g. solid electrolytes) and high-voltage electrolytes modeling/simulation/advancements are all backwards compatible to li-ion as well as beyond li-ion tech.
- 2 – Disagree that adv. Li-ion can meet all EVE cost/performance goals → believe beyond li-ion can meet goals and be more cost-effective, so is needed for EVE.
- 3 – Many commonalities with adv. Li-ion group needs - Lithium electrodes, adv. materials, high-voltage electrolytes, li-electrode rechargability, need for improved testing capabilities at Nat'l Labs, and testing protocol developments, predictive capability for cell scale-up, etc.
- 4 – Battery packaging and cell manufacture apply to both adv. Li-ion and beyond li-ion, but need to identify gaps that would negatively impact beyond li-ion
- 5 – Self-regulating batteries help other groups too (e.g. may minimize battery management system, improves safety)
- 6 – Flow battery or mechanically refillable battery could enable a field-serviceable battery (includes both failures and periodic service to rejuvenate performance)
- 7 – Work with pack integration group to develop standardized battery/pack needs (dimensions, connections, voltage, etc.)
- 8 – Need to identify first early adopters market for in-use testing and field data collection

Breakout Session #3 – Discussion of Action Plans and Next Steps

Next Steps for Reaching Targets (including roles for DOE and industry, e.g., lead or support)

Beyond li-ion already in DOE profile (ARPA-e, DOE BES, BFRC), but additional needs are:

- 1 – Need materials synthesis foundry available to EVE performers
- 2 – Need incubator with cell processing capability for pre-pilot production
- 3 – Need clearinghouse testing facility to perform baseline performance testing to quantify any new battery technology to justify to DOE as a step before funding is granted
- 4 – Need material and/or screening process to evaluate and downselect/grade for further funding/work before handoff to next step at DOE
- 5 – Need mechanisms for different parts of the EVE development process to interact, both within a program (e.g. batteries) and inter-programs (e.g. batteries, power electronics)
- 6 – Develop research oriented tasks to develop: prediction of safe high-transport solid electrolytes, multivalent systems, improved air electrodes, etc. (see list in proposed research tasks for complete details)