Dry Process Electrode Fabrication

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Project ID: ES134

Overview

Timeline

- Project start date: Oct. 2011
- Project end date: Oct. 2014
- Percent complete: 10%

Budget

- Total project funding:
  - DOE share $2,992,743
  - Contractors share $1,247,136
- Funding received in FY11 $978,320 (obligated)
- Funding for FY12
  - DOE share $1,160,263
  - Contractors share $481,775

Barriers

- Conventional slurry casting processes drive the cost of lithium ion battery electrodes.

Partners

- Maxwell Technologies is subcontractor to A123 Systems.

Objectives of this study

- The Phase I objectives of this program are:
  - The binder presently used by Maxwell is not electrochemically stable in a lithium battery anode. Therefore phase I will define a binder system for dry process anode fabrication that is stable over 500 cycles to full state of charge.
  - Identify the thickness limit for dry process cathodes that can meet EV rate and cycle life criteria
- The Phase II objectives of this program are:
  - Produce a dry-process anode material that capacity matches the Phase I cathode.
  - Produce at least 250m of free standing dry process cathode at thickness >200 µm thickness.
  - Validate cost model by running pilot coating line at >25 m/min.
  - Deliver 24 cells in A123 SOA EV cell format (>60Ah prismatic can)

Project Milestones and Decision Points

Milestones	Metric	Date
1. Acceptance of mgt plan revisions		1
2. Nanophosphate morphology and mixing conditions specified		6
3. Demo. lab prototype cell w/ dry process Nanophosphate	>100 μm cathode	12
4. Deliver interim cells with dry process Nanophosphate/wet anode	18 cells, 14 Ah pouch	18
5. Produce pilot cathode film	100 m	22
6. Lab prototype cell dry anode/dry cathode	Pass EV life test	24
7. Produce pilot cathode film at production rate	250 m at >25 m/min	28
8. Deliver final cells dry Nanophosphate/dry anode	24 cells, >14 Ah prismatic can	30
Decision Points		
D1 Is dry process feasible for Nanophosphate at EV loading?	500 cycles at 1C	12
D2 Down-select anode binder that meets EV performance	500 cycles at 100% DOD	18
D3 Is the cathode production-ready?	50% cost reduction	24

Approach

- Establish baseline for oxide electrode materials.
- Modify PO_4 electrode powder for compatibility with dry process.
- Increase PO_4 cathode loading to 2X limit of baseline slurry casting process.
- Operate cathode process at pilot scale.
- Validate cathode manufacturing cost reduction.
- Identify dry-processible binder with electrochemical stability at anode potential.
- Meet anode mechanical and electrode interface requirements at lab scale.
- Demonstrate SOA PHEV/EV cell to validate materials utilization cost reduction.

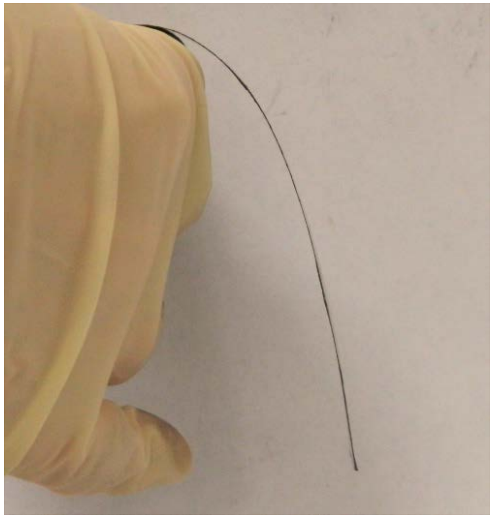
Progress Update - Cathode

- Prior trials conducted with $LiFePO_4$
  - Design of experiments conducted to determine film making characteristics of nano-phosphate material
  - Initial nano-phosphate processing results
    - Thick film formation was successful
    - Single-sided free standing film down to 175 micron with reasonable flexibility achieved
    - *Challenge: Films thinner than 175 micron became very stiff*
      - Incapable of rolling without fragmentation/crumbling
      - Films were very dense
  - Initial blends of nano-phosphate materials have shown a resistance to thin electrode film formation
    - Further work will consider formulation, particle morphology and processing parameters to achieve good thin film properties

Progress Update - Cathode

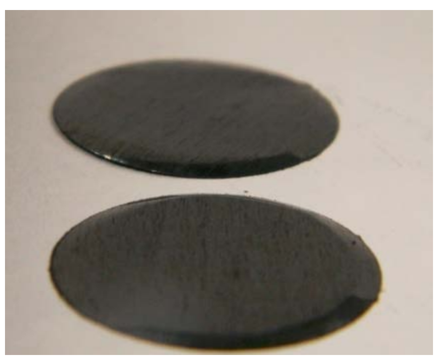
- Establish baseline with oxide electrode materials
  - Mixed metal oxides other than nano-phosphates show good initial results
    - Films down to 85 microns were formed
      - Density slightly higher than target
      - Films demonstrate reasonable flexibility
    - *Films at 100 micron thickness show very good properties*
      - Flexible with good mechanical properties
      - Loading approaching targets
      - Process parameter optimization necessary to make thinner films with better density characteristics

Images of dry process mixed metal oxide cathode materials.



100 micron thick film draped over hand of researcher

Trimmed active film, 85 microns thick, good uniformity and integrity, a bit too stiff to ensure good processability

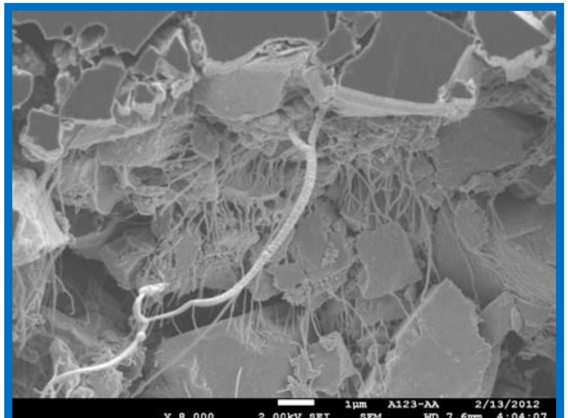


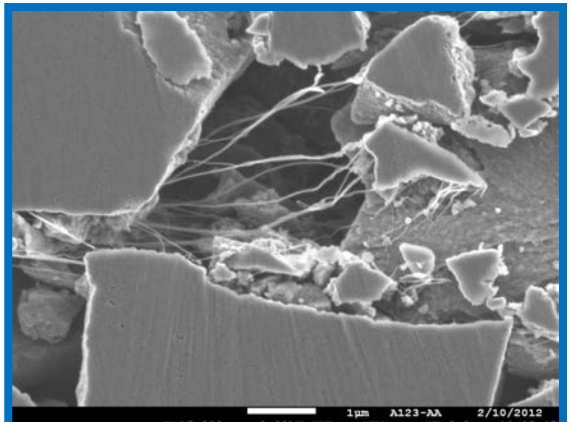
Coin Cell sized 85 micron thick cathode disks

Progress update – Screen New Anode Binders

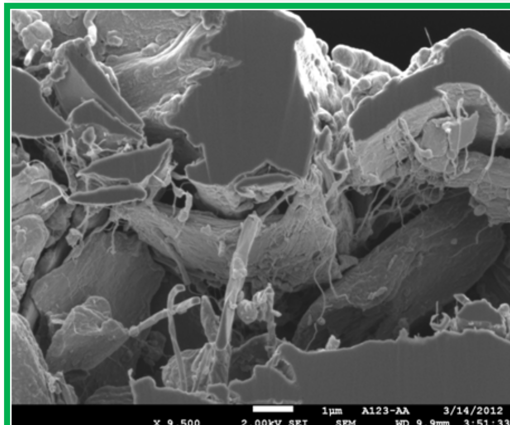
- 4.1 Developed bench scale binder screening process* that reproduces dry process electrode microstructure similar to electrodes produced at the commercial scale

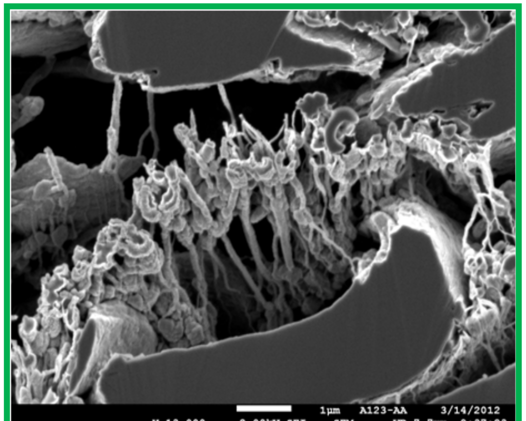
COMMERCIAL ULTRACAPACITOR

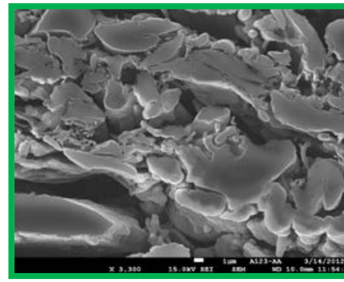


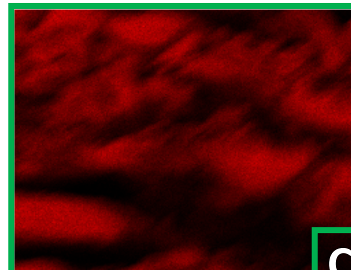


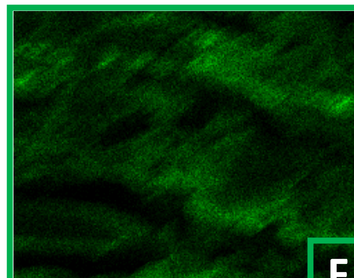
A123 BENCH SCALE PROCESS











Low resolution SEM/EDS shows uniform coverage of carbon particles ("C") with binder ("F")

*total mass processed is 25 gram/batch

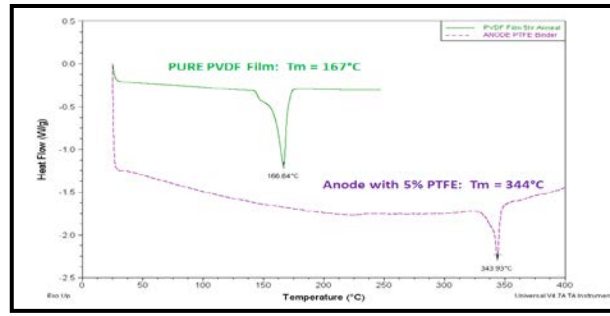
Progress update – Screen New Anode Binders

A123 SYSTEMS

Maxwell TECHNOLOGIES

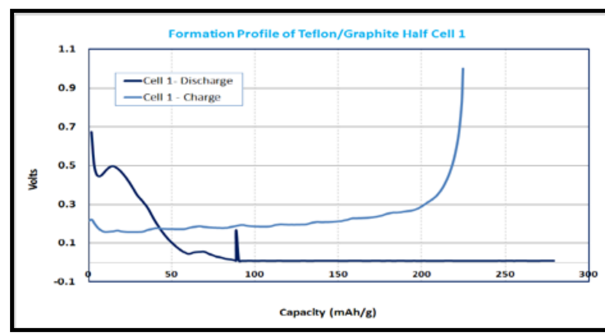
- 4. 2 – Benchmarked anode processing parameters and electrochemical performance using the traditional cathode binder – Teflon. PTFE has high ICL in anode (expected).
  - **Mechanical Properties - as Physical Properties – Tg, Tm**

ANODE BINDER	Tg (°C)	Tm (°C)
Baseline NMP soluble PVDF	-35	167
Teflon Latex	160	344

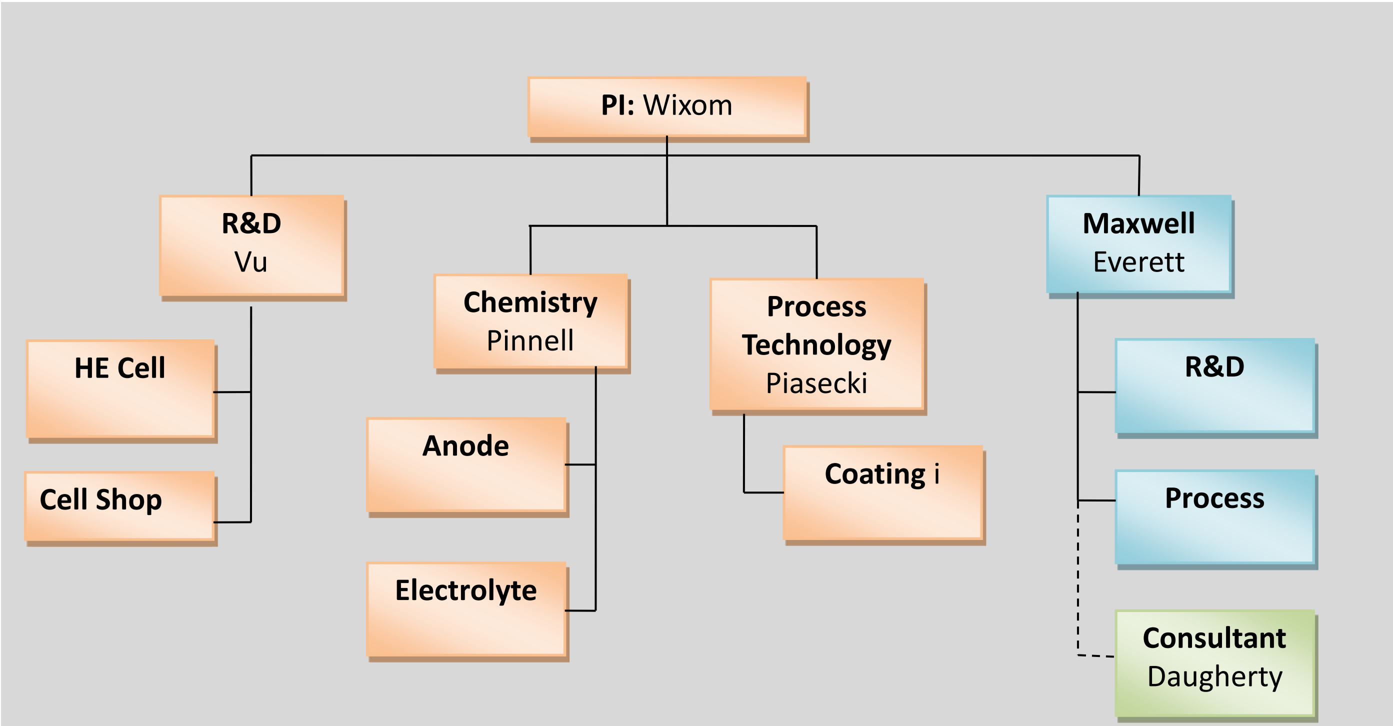


  - **Electrochemical Stability – as ICL (irreversible charge transfer in 1st charge/discharge)**

ANODE BINDER	Initial Capacity (mAh/g)	ICL (%)
Baseline: NMP soluble PVDF	330	6.81%
Teflon Latex	270	19.99%



Collaborations



- Maxwell R&D will lead the adaptation of their dry electrode process to new materials and current collectors used in lithium ion batteries.
- The Maxwell process team will scale up the dry fabrication process in existing pilot scale facility.

Future work

- Execute design of experiments on phosphate cathode materials to identify key control variables.
- Vary phosphate powder characteristics to improve mechanical and electronic properties of electrode.
- Optimize cathode binder type and volume fraction.
- Begin multi-variable cathode process optimization
- Screen electrochemically stable anode binder candidates.
- Establish bench scale process screening for anode fabrication trials.

Summary slide

- The dry electrode process innovation in this proposal will provide the ability to coat thick *and* fast, while eliminating solvents and saving energy.
- The projected readiness level is TRL 7 for the cathodes upon completion of the program, with confidence that the development path will closely follow the previous scale up of the dry process for ultracapacitor electrodes.
- Maxwell's sound mechanistic understanding of the dry process combined with A123's understanding of anode binder chemistry/electrochemistry will enable a new binder and dry process for anode.