



CELGARD

A **POLYPOR** Company

USABC Battery Separator Development

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Celgard, LLC

Project ID# ES007

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This presentation does not contain any proprietary,
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Timeline

- Start – September 2008
- Finish – September 2010

Budget

- Total Project funding
 - DOE – \$1.05M
 - Contractor – \$1.28M
- Funding received in FY08: \$167k
- Funding received in FY09: \$545k
- Funding received in FY10: \$338k

Barriers Addressed

Abuse Tolerance, Reliability and Ruggedness

- No standard testing exists to examine high temperature melt integrity (HTMI) behavior
- Materials must be developed to confirm the test validity

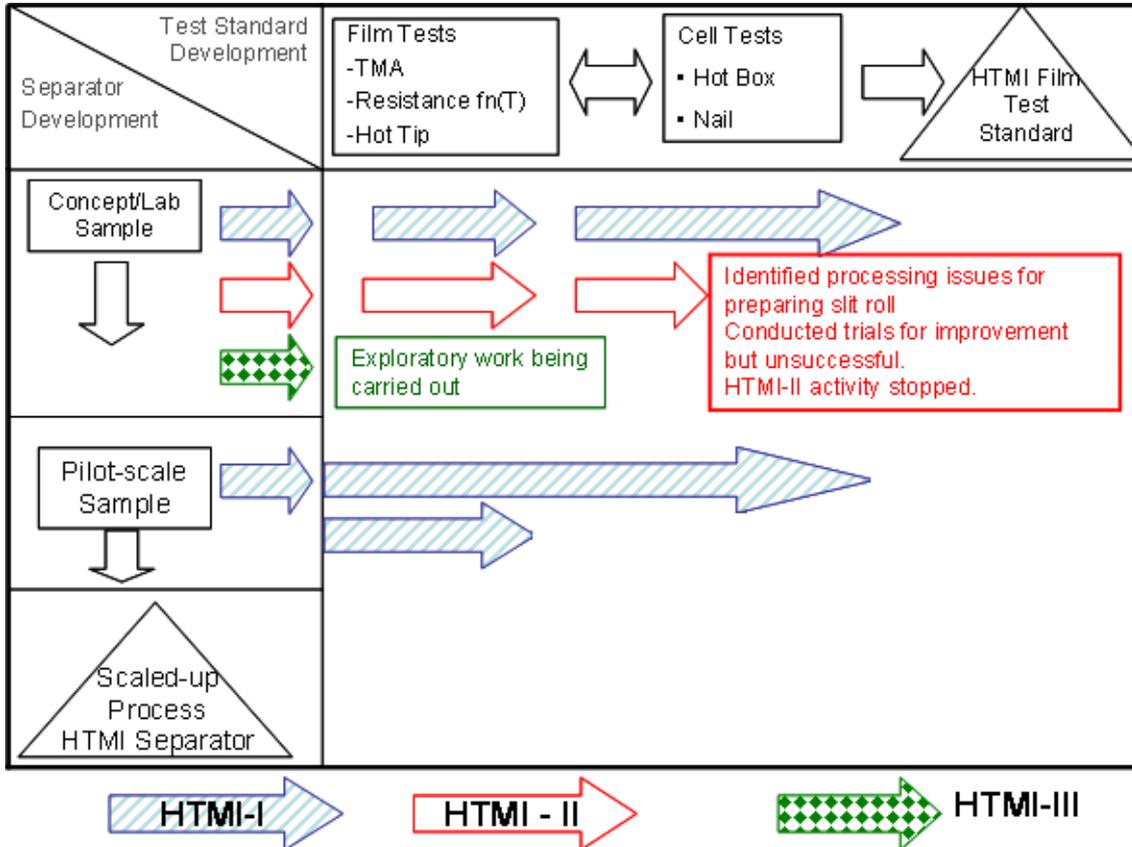
Partners

Sandia National Laboratory

FY08/FY09/FY10 Project:
USABC Battery Separator Development
(Close)

- Develop a standard testing protocol for evaluating high temperature melt integrity (HTMI) properties in lithium-ion battery separators
- Design and develop a separator product that demonstrates HTMI criteria

- Test standards and HTMI materials developed in parallel



Film tests

- TMA
- Temperature Dependent Resistance
- Hot Tip

Cell tests

- Hot Box
- Nail Penetration

HTMI separators

- HTMI – I: Coating (FY09-FY10)
- HTMI – II: Compounding (FY08-09)
- HTMI – III: Other concepts (Future)



Composition

	X1	X2	X3
Binder	Polymer A	Engineering Polymer A	Engineering Polymer B
Ceramic Type	Inorganic	Inorganic	Inorganic
Coating Trial	Off-site Trials, pilot scale		
Base Film	16 μm		13 μm

Properties

Property	X1	X2	X3
Thickness (μm)	21	24	17
JIS Gurley (s)	272	298	237
Puncture Strength (g)	604	581	502
Tensile Strength kgf/cm^2	1252	1023	1251

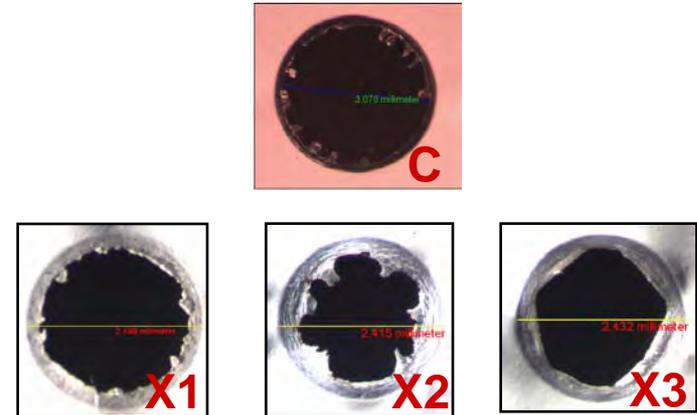
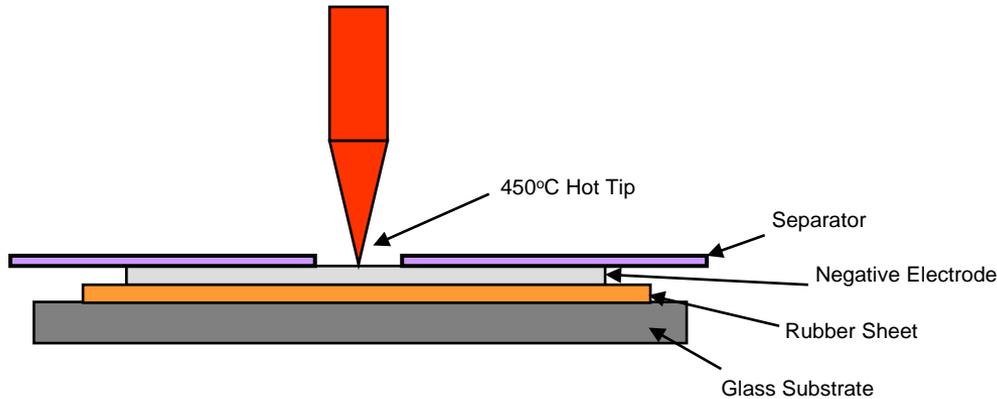
Technical Accomplishments: Separator Development – Coating

- Target: Meet USABC defined goals for high temperature performance

Parameter	Units	Goal	X1	X2	X3
Thickness	μm	<25	21	24	17
Permeability : Gurley	sec	<35	Compliant	Compliant	Compliant
Wettability		Wet out in electrolytes	Compliant	Compliant	Compliant
Chemical Stability		Stable in battery for 10 years	Compliant	Compliant	Compliant
Pore size	μm	< 1	Compliant	Compliant	Compliant
Puncture Strength	g	> 300 g/25.4 μm	604	581	502
HTMI Shrinkage		Equivalent to current product at 90°C	Compliant	Compliant	Compliant
Z-direction strength		No short @ 220°C	200 °C*	155 °C	195 °C
Tensile Strength	< 2% strain at 1000 psi		Compliant	Compliant	Compliant
Skew	mm/m	< 2	Compliant	Compliant	Compliant
Pin removal		Easy pin removal for winding machines	Compliant	Compliant	Compliant
Shutdown†			Compliant	Compliant	Compliant

† Shutdown requirement not part of current USABC proposal

* Sample reached temperature limits of test



Test Description

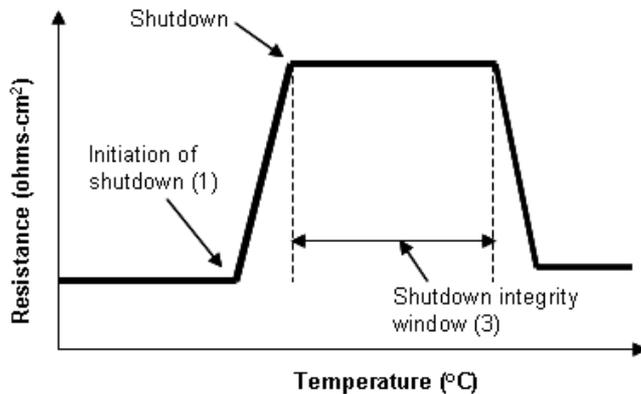
- Hot soldering iron tip contacts separator
- Resulting hole is measured

What it Measures

- Dimensional stability under point heating conditions

Basic Pass Criteria

- Hole produced by puncture sees minimal withdrawal



Separator	Shutdown	Melt Temp. (° C)
C	Yes	150
X1	Yes	>200
X2	Yes	155
X3	Yes	195

Test Description

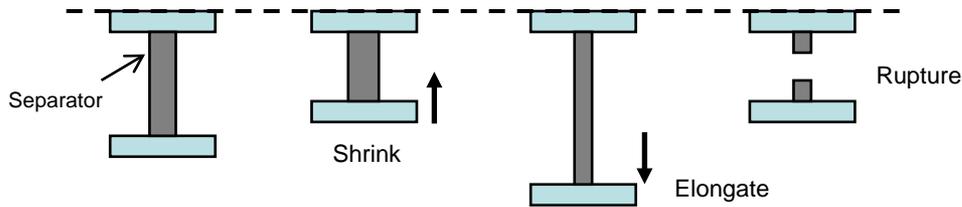
- Electrical resistance is measured as function of temperature

What it Measures

- Electrical resistance as a function of temperature. Can be translated into Z-direction stability

Basic Pass Criteria

- Maintains resistance without shorting to 200+ C



Test Description

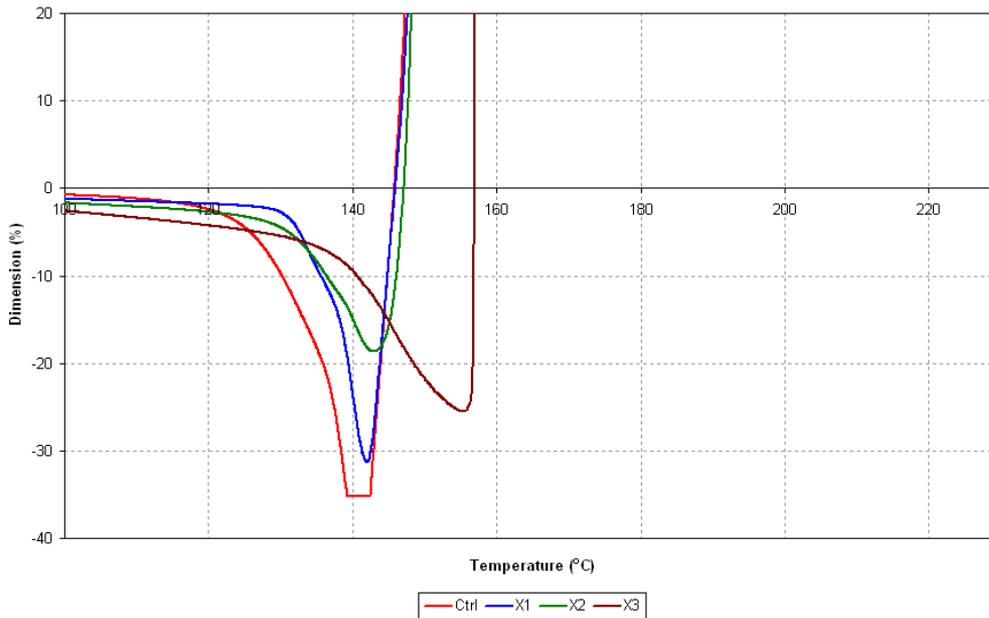
- Separator dimensions under load

What it measures

- X-Y Dimensional stability under load and temperature

Basic Pass Criteria

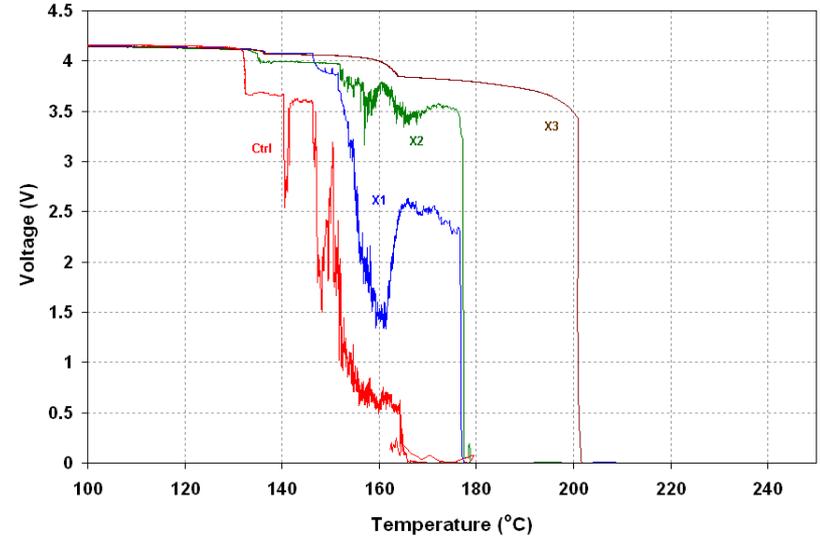
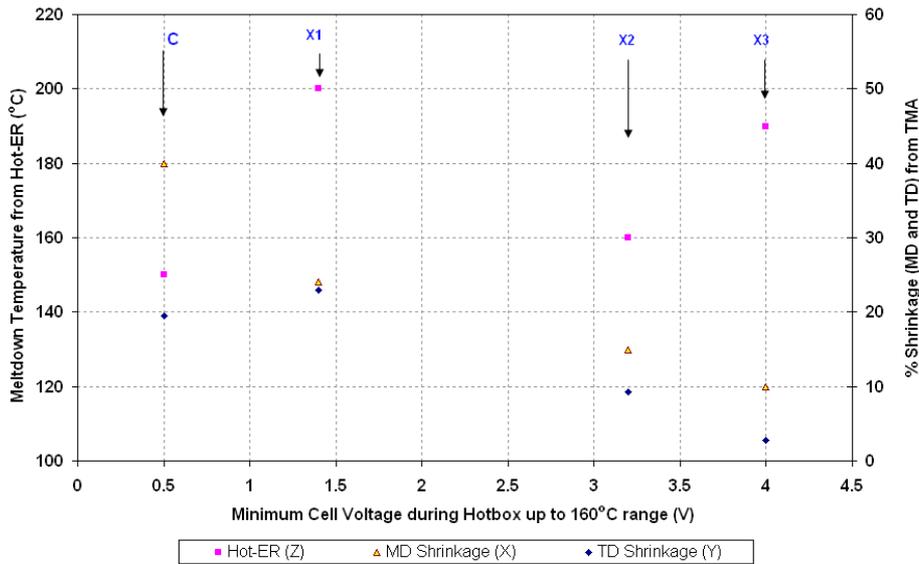
- Separator maintains dimensional stability past 200 °C



Technical Accomplishments

Battery Performance

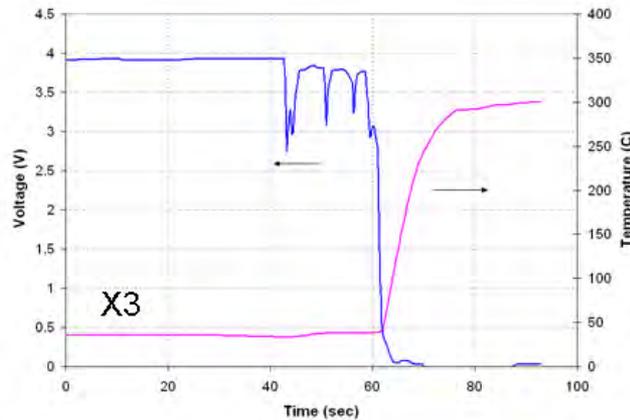
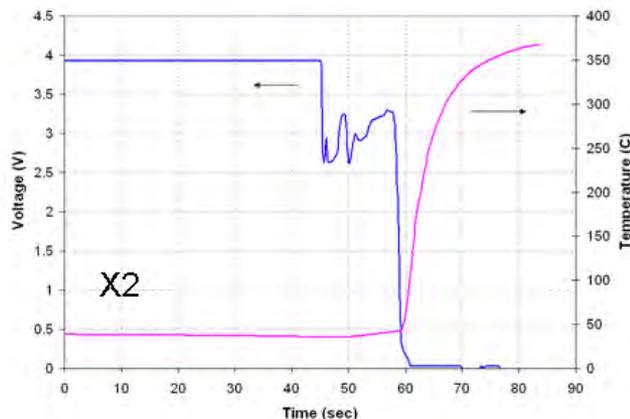
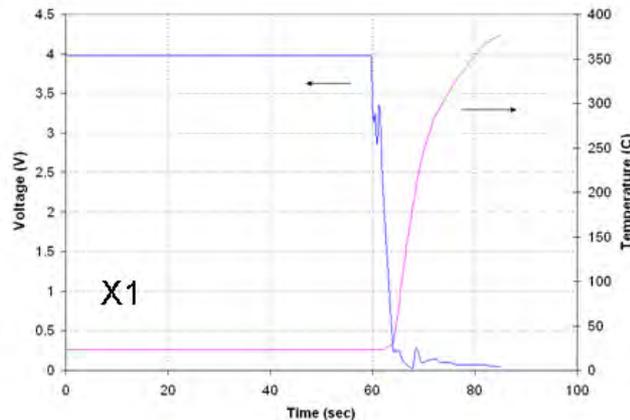
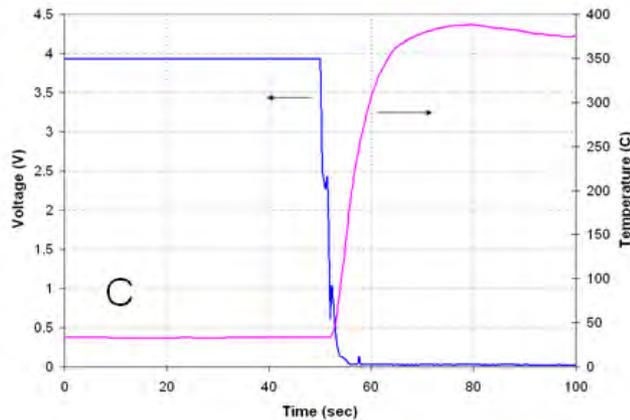
TMA/Hot ER correlation



Correlation of TMA (X-Y dimensional stability) and Temperature Dependent Resistance meltdown (Z direction stability) data (left) to hotbox cell tests (right).

- Lower shrinkage leads to higher heat resistance
- X3 has balanced thermal properties in all three dimensions

Technical Accomplishments: Battery Performance – Nail Penetration



HTMI coating did not prevent cell failure, but may delay exotherm onset.

- External validation of the developed HTMI materials will be performed at Sandia National Laboratories.
 - Delivered two 500 ft rolls for national lab evaluation

- Continue evaluation of ceramic based coatings for HTMI battery separators cost-benefit ratio
- Examine alternative, long-term technologies

- HTML coated separators were developed with USABC target properties as a primary goal
- A film testing suite was assembled to validate HTML properties
- Ceramic coated battery separator materials may provide some enhanced thermal properties