CELGARD

A POLYPORE Company

USABC Battery Separator Development

ES 007

June 2010

POLYPORE International, Inc.

POLYPORE

DARAMIC | CELGARD | MEMBRANA Underlining Performance

Lead Acid Batteries	Lithium Batteries	Medical Membranes
Industrial	Derma Patches	Dialysis
Specialty	Gas Diffusion	Plasma Separation
	Food Packaging	Oxygenation
	Specialty	O2 & CO2 Removal
		Food & Beverage
		Ink Processing
		Industrial

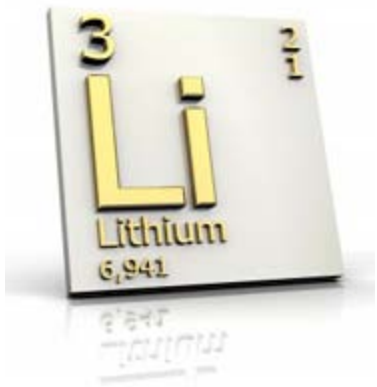
World-class Microporous Membrane Processing Technologies

POLYPORE Presence

Strategically located facilities and service offices throughout the world

*** Indicates technical center in addition to manufacturing facility**

Celgard



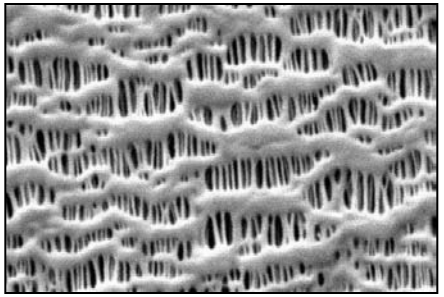
Lithium Battery Separators

Celgard is a global leader in the development and production of specialty microporous membranes.

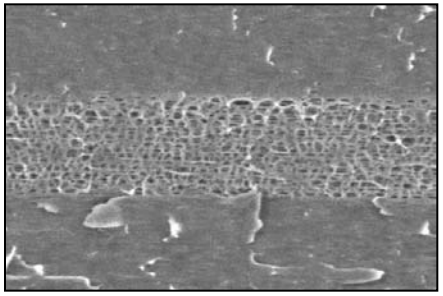
Celgard has the broadest portfolio of products available in the lithium battery separator industry.

Unparalleled Product Portfolio

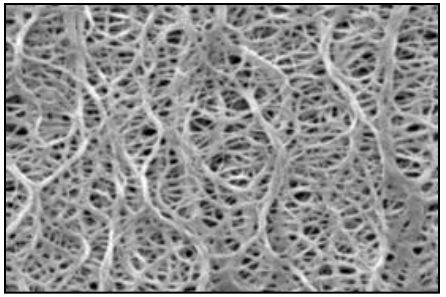
- Celgard is the only supplier with a full range of products to meet customer needs:
  - Monolayer Polypropylene (PP)
  - Trilayer (PP/PE/PP)
  - Monolayer Polyethylene (PE)
  - Coated and Laminated Products



Monolayer PP



Trilayer PP/PE/PP



Monolayer PE

Celgard's Current USABC Project

Overview

TIMELINE

- Start – September 2008
- Finish – August 2010 (Extended)
- Percent Complete – 75 %

BARRIERS

- Lack of Testing Standards
- Meeting High Temperature Melt Integrity (HTMI) 220° C

BUDGET

- Total Project Funding
  - DOE share - $ 1.03 mil
  - Celgard share - $ 1.27 mil
- Funding Received in FY 2008 - $0.3 mil
- Funding for FY 2009 - $1.2 mil
- Funding for FY 2010 - $0.8 mil

Program Critical Goals & Associated Risks

- Goal 1:
  - Develop a test method to consistently define and measure High Temperature Melt Integrity (HTMI)
    - No defined industry standard for film testing
    - Numerous methods used across the industry
- Goal 2:
  - Develop a material that best demonstrates the characteristics identified through the work completed in Goal 1

Technical Approach

Develop a Standard for Measuring HTMI
- Industry Standardized Testing
- Product Characteristics

Correlate Film Tests to Battery Performance
- High Temperature Stability
- Mechanical Integrity

Film Tests for Properties of HTMI
- Shrinkage
- Z Direction Strength
- High Temperature Stability

Baseline of Existing Products
- Array of Technologies
- Commercially Available

Standardized Testing For HTMI

Film Properties

- Shrinkage
- Z Direction Strength
- High Temperature Stability

Film Tests

- Thermal Mechanical Analysis (TMA)
- Hot Electrical Resistance
- Hot Tip

Test standards are still being finalized.

Film tests were conducted without battery electrolyte.

Standardized Testing For HTMI

Film Properties

- Shrinkage
- Z Direction Strength
- High Temperature Stability

Film Tests

- Thermal Mechanical Analysis (TMA)
- Hot Electrical Resistance
- Hot Tip

Battery Tests

- Hot Box
- Nail Penetration

Best (most reliable) results are achieved from tests conducted in a battery system.

Hot Tip data does not correlate as strongly as other tests.

Film Development

- Multiple Approaches Evaluated:
  - New materials
  - New processing methods
  - Commercial viability

Future Work

- Finalize Material Development
  - Several approaches under review
- Manufacturing Methods
  - Similar to the separator design there are multiple ways to manufacture advanced materials

Summary

- Standard methods for evaluating High Temperature Melt Integrity (HTMI) for battery separators should include:
  - TMA
  - Hot Electrical Resistance
  - Hot Tip
- Material development continues
- Manufacturing methods will be a focus area for future work