3M™ Battery Enhancement Material
3M Automotive and Aerospace Solutions Division
About 3M
Our Vision

3M Technology Advancing Every Company
3M Products Enhancing Every Home
3M Innovation Improving Every Life
Today we leverage 23 technology platforms to power EV batteries

- Adhesives (Ad)
- Biomaterials (Bi)
- Ceramics (Ce)
- Electronic Materials (Em)
- Films (Fi)
- Fluoromaterials (Fl)
- Metamaterials (Mm)
- Nanotechnology (Nt)
- Nonwoven Materials (Nw)
- Performance Materials (Pm)
- Release Materials (Rm)
- Microreplication (Mr)
- Precision Coating and Web Processing (Pc)
- Particle and Dispersion Processing (Pd)
- Polymer Processing (Pp)
- Analytical Science (An)
- Inspection and Measurement (In)
- Process Design and Control (Pr)
- Sustainable Design (Sd)
- Accelerated Weathering (We)
- Energy Components (Ec)
- Flexible Electronics (Fe)
- Thermal Management (Tm)
A True Global Supplier
Regional Supply in 5 Continents....

...Same High Quality Products
Product Overview
Improving vehicle range:
3M™ Battery Enhancement Material

Battery pack insulation minimizes the effects of outside extreme temperatures on lithium-ion battery cell performance to help maximize battery range and life.

**Parked Car – Midwest Battery Cell Temp**
- Battery placed in -30°C environment
- 3M BEM treatment in 2 thicknesses
- Keeping cell temp above 0°C helps reduce charge time / warm up time
- Insulating slows cell temp degradation

**Parked Car – AZ Summer Battery Cell Temp**
- Battery placed in 42°C environment
- 6mm 3M BEM treatment on all 6 sides of battery pack
- Preventing cell temp from reaching high temp can prolong battery capacity
- Insulating reduces cell temp increase

*Results from 3M BEV Battery Pack

*Results from Modeling Simulation
Product Overview

3M™ Battery Enhancement Material 1807S

- Thin, lightweight, and minimally fiber shedding passive thermal insulation for the battery pack
- Reduces battery usage for cooling, heating, and faster battery warm-up
- Enables extended driving range
- Offers flame resistance (UL 94 V-0)
- Offers high compressibility and recovery properties
- Provides excellent cavity filling
- Performs well in high temperature applications
<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantages</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low thermal conductivity</td>
<td>• Good thermal insulation</td>
<td>• Helps maintain optimal temperature with the battery pack</td>
</tr>
<tr>
<td>UL 94 V-0 non-flammable</td>
<td>• Contributes to fire safety within the battery cavity</td>
<td>• Helps customers design towards improved safety</td>
</tr>
<tr>
<td>Compressible and cavity filling</td>
<td>• Easy to conform to complex 3D shapes</td>
<td>• Less material required to meet thermal management targets</td>
</tr>
<tr>
<td></td>
<td>• Better workability and ease of handling</td>
<td>• Does not require special handling associated with other solutions</td>
</tr>
<tr>
<td>Permeability</td>
<td>• Helps enable moisture control</td>
<td>• Helps reduce moisture within the battery cavity</td>
</tr>
<tr>
<td>Advance fiber technology</td>
<td>• Offers high performance, lightweight absorber</td>
<td>• Provides increased thermal management performance and acoustic absorption within the battery</td>
</tr>
<tr>
<td></td>
<td>• High temperature resistant fibers</td>
<td>• Improved aging durability</td>
</tr>
<tr>
<td>Lightweight</td>
<td>• Lighter weight product than most current battery thermal management solutions</td>
<td>• Helps OEMs meet weight reduction targets</td>
</tr>
<tr>
<td>Stable roll good</td>
<td>• Can be converted into shapes and configurations</td>
<td>• Design flexibility to meet any application needs</td>
</tr>
</tbody>
</table>
Key Feature: Superior thermal insulation performance

• Good performance in high temperature applications
  • Combined thermal conductivity coefficient less than 0.035 W/K-m at 25°C at the original thickness
  • Combined thermal conductivity coefficient 0.028 W/K-m at 25°C when compressed to half the thickness (original thickness is 6 mm)
  • Many battery packs can have an air gap, which can cause higher thermal conductivity when the temperature outside battery pack is different than inside the battery pack
  • 3M BEM thermal conductivity decreases the more it is compressed

Key benefit: better thermal insulation reduces battery usage for cooling, heating and faster battery warm-up
Battery Enhancement Material for the Battery Thermal Management System

Background Information and Testing

• Current Thermal Management Systems (TMSs) use dynamic thermal control (i.e. battery energy)

• Battery enhancement materials will make the battery TMS more efficient by controlling the battery optimum temperature range longer without drawing battery power

• This enables:
  • Less battery cooling usage
  • Less battery heater usage
  • Increased driving range

• We continue to push the boundary to provide thin, lightweight insulation
  • Flame resistant – (UL 94 V-0)
  • High temperature performance
Key Feature: Light weight, highly compressible and highly conformable

- 3M BEM 1807S is less than 300 grams per square meter (gsm) in surface basic weight
  - Provides excellent cavity filling
- High compressibility and recovery properties allow 3M BEM 1807S to fit into the limited space available in battery packs
  - Few current insulation materials can fit in the limited space available
- Dust free encapsulation, minimal fiber shedding

Key benefits: weight saving properties help increase driving range
Ease of compression and recovery allows 3M BEM to conform to irregular geometries.
# Product Properties

## 3M™ Battery Enhancement Material 1807S

### Typical performance data

<table>
<thead>
<tr>
<th>Property</th>
<th>Typical Value(^A)</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Black</td>
<td>Visual</td>
</tr>
<tr>
<td>Basis weight</td>
<td>290 gsm</td>
<td>Mass per unit area</td>
</tr>
<tr>
<td>Initial Thickness(^B)</td>
<td>6 mm</td>
<td>SAE J1355</td>
</tr>
<tr>
<td><strong>Thermal properties:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-Value(^C)</td>
<td>K-Value(^D)</td>
<td>&gt; 0.17 m²K/W</td>
</tr>
<tr>
<td>Surface Electrical Resistance(^E)</td>
<td>1.1X10⁹ ohm</td>
<td>@ 25°C, 50% RH</td>
</tr>
<tr>
<td>Flame resistance</td>
<td>Pass</td>
<td>UL 94 V-0</td>
</tr>
</tbody>
</table>

\(^A\): All the property value here are the Typical Value; not a standard value, but test data from 3M lab.

\(^B\): Nominal thickness is measured using a 12 in² plate with 0.002 psi applied to the sample per SAE J135.

\(^C\): R-Value is the thermal resistance of the insulation measured at the corresponding thickness per ASTM C518.

\(^D\): k-value is thermal conductivity of the insulation material per ASTM C518

\(^E\): The surface Electric resistivity may change under different temperature and humidity condition.
Modeling Data
Range Extension Examples – FEA Modeling

Scenario
Drive car to work, park outside in parking lot for 10 hours. Winter time, outside temperature is -6.7°C or 20°F.

Parameters
• 2 m X 1.5 m X 0.5 m battery box
• Aluminum pack – 3 mm thick
• 5 temperature sensors in battery
• Heater on at 15°C and off at 25°C
• External temps of -6.7°C (20°F)

Assumptions
• 275 W-hrs to move a car 1 mile
Model Introduction

- Aluminum case thickness = 3mm; Air Gap/3M BEM thickness = 6mm
- Heater = copper
- Temperature monitoring points: T1, T2, T3, T4, T5
- Due to symmetry, 1/4 of the domain is modeled (T2=T3=T4=T5)
- $T_{avg} = (T1 + 4T2) / 5$ was used to trigger the heater
Results

Modeling with Air Gap at -6.7°C

Modeling with 3M BEM at -6.7°C

The difference in the start times of the 3M BEM vs. non-3M BEM heaters is the energy saved by installing 3M BEM
## Summary of FEA Modeling Results

### FEA Modeling – Heater Start Time Difference

<table>
<thead>
<tr>
<th>Starting Temp (°C)</th>
<th>Ambient Temp (°C)</th>
<th>3M BEM (Y/N)</th>
<th>Heater On (min)</th>
<th>Heater Start Time Delta (Min)</th>
<th>Heater Power (W)</th>
<th>Energy Savings (W-hrs)</th>
<th>W-hrs/Mile</th>
<th>Range Miles Saved during Delay (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>-6.7</td>
<td>N</td>
<td>348</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>-6.7</td>
<td>Y</td>
<td>543</td>
<td>195</td>
<td>1800</td>
<td>5850</td>
<td>275</td>
<td>21.3</td>
</tr>
</tbody>
</table>
Addressing Hot Temps - Internal Testing

• The temperature of chamber is 50°C, and the initial temperature of the battery is 23°C
• The gray line shows the battery’s internal temperature change with 3M BEM
• The gold line shows the battery’s internal temperature change without 3M BEM

Key Finding: 3M BEM prevents hot outside temperatures from warming the battery by 33%
Test Data
Battery Pack Heat Preservation Test

Testing condition and procedure

- Chamber temperature is set as -30°C
- Temperature monitoring points are on the busbar of the battery modules
- Battery pack gets stable temperature of 23°C before putting in the chamber
- Put the battery pack in the temperature chamber, then monitor the temperature decreasing curve, record the time when the monitoring points hit 0°C, named “Heat Preservation time”
Heat Preservation Test Results – Internal 3M Tests

3M BEM Solutions

Test results
- Original solution without 3M BEM is 3.8 hours
- 3M BEM coverage with 5mm bottom thickness prolongs the time to 5.4h, 42% increase
- 3M BEM coverage with 10mm bottom thickness prolongs the time to 6.6h, 74% increase
Additional Test Methods

- **Warm Up Time**
  - In-vehicle test
  - Measure time and amount of energy used for battery to heat up from -20°C to 10°C
  - Compares 3M BEM to Air Gap (no insulation)

- **Charging time**
  - In-vehicle test
  - Measuring amount of time to charge from 10% to 90% after being parked outside overnight in winter
Application Information
Potential Applications

3M BEM can be placed on the bottom, top or all around the battery pack.

3M BEM can be used in all of these types of battery for thermal insulation:

- Prismatic
- Pouch
- Cylindrical
This video shows 3M BEM being applied to the base of the battery pack. It can also be placed in the lid or all around the battery module.
Where does 3M Battery Enhancement Material go?

Battery Anatomy

- Full Electric Vehicle pack size = 2 Meters x 1 Meter
- Includes a Heating & Cooling System
- All battery packs have an air gap between pack lid and battery modules

3M Battery Enhancement Material applied during battery pack assembly on to lid or wrapped around module
How do I use 3M BEM?

3M BEM is wrapped around the battery to thermally insulate the battery from outside environment. It is used in applications where UL 94 V-0 flammability rating is required.

How much material do I need?
The amount of material required varies based on the battery size and thermal management requirements. Please work with a 3M Application Engineer for specific applications.

Where do I put 3M BEM?

3M BEM can be placed on the bottom, top or all around the battery pack.

How much more affective is 3M BEM if I wrap it around the whole battery pack instead of only applying it on top?

If 3M BEM is placed only on top of the battery pack, the preservation time is 5 hours. By adding 3M BEM to the bottom of the battery pack, the preservation time will increase to 7 hours, which is a 40% increase in time.

What is the temperature range the material can handle?

-40°C - 150°C. Tested at -40°C for 24 hours; at 150°C for 168 hours; and 120°C for 500 hours.
Application Guidelines

Is a special environment required when I apply this material?
3M BEM should be installed at less than 50% humidity level.

What’s the minimum amount of space I can have in the battery pack?
Our 3M BEM can be used in a gap of < 2 mm.

What is the mounting method?
You can use a double-sided adhesive tape on the whole side or a partial area to mount 3M BEM.

What is the attachment method?
3M BEM can be attached using a double-sided adhesive tape.

Does 3M BEM go over or under the cooling plate?
3M BEM is typical applied under the cooling plate.
Summary

3M™ Battery Enhanced Materials contribute to battery efficiency by controlling the battery optimum temperature range by reducing draw from battery power.

- Reduces battery usage for cooling, heating and faster battery warm-up.
- Flame resistant (UL 94 V-0).
- Performs well in high temperatures and offers high compressibility and recovery properties.
- Launched July 2019.
Thank you!
Patent Pending

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Appendix
UL 94 Tests

- Surface burn (UL 94 5VA and 5VB) tests the resistance of a material which is exposed to flame on one side only.
- Vertical burn (UL 94 V-0, V-1 and V-2) tests the burning area at the bottom of the strip of material, allowing the heat to interact with the material above the flame, causing the generation of additional flammable gases.
- Horizontal burn measures the rate of burning along the length and width of the plastic sheet or film.
- UL 94 5VA (burn 5 times) is considered to be the toughest.
Battery Pack Heat Preservation Modeling

Polaris GEM

32 Battery Cells
32 T/Cs

w/o and w/ 5mm thick 3M BEM

External temp: -30°C
Cells initial temp: 25°C
Monitor the time for the average cell temp to reach 0°C

Increased 96%

External temp: 50°C
Cells initial temp: 25°C
Monitor the time for the average cell temp to reach 37°C

Increased 93%

4.3 8.3