LIGHT WEIGHTING AND THERMAL MANAGEMENT SOLUTIONS FOR ELECTRIC VEHICLE BATTERY PACK WITH SPECIALTY MATERIALS

Naajein Cherat, Nilajkar Vasudev, Hari Sharma, Nitesh Sheth, Arunachala P, Priya S, Saibal K B, Somasekhar Bobba

SABIC’s Specialties Business
SABIC’S SPECIALTIES BUSINESS

A SOLUTION PROVIDER
FOR ADVANCED CHALLENGES
LET’S PICTURE INNOVATION
### APPLICATION REQUIREMENTS FOR BATTERY HOUSINGS

<table>
<thead>
<tr>
<th>FR</th>
<th>MECHANICAL</th>
<th>PHYSICAL</th>
<th>ELECTRICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Cl, Br FR V0 ≥ 0.8 mm preferred</td>
<td>High stiffness and impact strength</td>
<td>Dimensional stability (low warpage)</td>
<td>Electrically insulating</td>
</tr>
<tr>
<td></td>
<td>Low temperature impact resistance</td>
<td>Chemical resistance, e.g., electrolyte, coolants</td>
<td>Thermal resistance (RTI w/ impact &gt;100 °C)</td>
</tr>
<tr>
<td></td>
<td>Weld-line strength</td>
<td>Compatible with secondary ops. e.g., UV curing</td>
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<td></td>
<td></td>
<td>Good processability → High flowability</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Lightweight (low density)</td>
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</table>
# SPECIALTY MATERIALS FOR BATTERY ENCLOSURES

<table>
<thead>
<tr>
<th>Running Applications</th>
<th>Battery Enclosure</th>
<th>Battery Enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Properties</strong></td>
<td>High Stiffness</td>
<td>Impact &amp; FR</td>
</tr>
<tr>
<td><strong>Chemistry</strong></td>
<td>PPE / HIPS-GF20</td>
<td>PPE/Nylon blend-GF10</td>
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<tr>
<td><strong>Structure</strong></td>
<td>Amorphous</td>
<td>Amorphous</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>1.30 g/cm³</td>
<td>1.21 g/cm³</td>
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<tr>
<td><strong>Safety</strong></td>
<td>V0 ≥ 0.75 mm</td>
<td>V0 ≥ 1.5 mm</td>
</tr>
<tr>
<td>FLAME PERFORMANCE (UL94)</td>
<td>CTI PLC 3</td>
<td>CTI PLC 1</td>
</tr>
<tr>
<td>TRACKING RESISTANCE (UL 746)</td>
<td></td>
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</tr>
</tbody>
</table>

Manufacturability and optimization with multi-material solutions – to drive longer distances
# APPLICATION REQUIREMENTS FOR BATTERY MODULE ENCLOSURES & BRACKETS

<table>
<thead>
<tr>
<th>Category</th>
<th>Requirements</th>
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## SPECIALTY MATERIAL PROPERTIES
**FOR BATTERY MODULE ENCLOSURES & BRACKETS**

### APPLICATIONS
- **NORIL™ NHP5054 resin**: Mild hybrid battery housing
- **NORIL™ NHP6011 resin**: End plates
- **NORIL™ GTX4610 resin**: Module bracket
- **CYCOLOY™ CX7240 resin**: Module top covers

### PROPERTIES
- **NORIL™ NHP5054 resin**: High Stiffness
- **NORIL™ NHP6011 resin**: Robust FR
- **NORIL™ GTX4610 resin**: Impact & FR
- **CYCOLOY™ CX7240 resin**: High flow

### POLYMER CHARACTERISTICS
- **CHEMISTRY**
  - NORIL™ NHP5054 resin: PPE / HIPS-GF20
  - NORIL™ NHP6011 resin: PPE blend-GF8
  - NORIL™ GTX4610 resin: PPE/Nylon blend-GF10
  - CYCOLOY™ CX7240 resin: PC EXL/ ABS blend
- **STRUCTURE**
  - NORIL™ NHP5054 resin: Amorphous
  - NORIL™ NHP6011 resin: Amorphous
  - NORIL™ GTX4610 resin: Amorphous | Semi-crystalline
  - CYCOLOY™ CX7240 resin: Amorphous
- **DENSITY**
  - NORIL™ NHP5054 resin: 1.30 g/cm³
  - NORIL™ NHP6011 resin: 1.16 g/cm³
  - NORIL™ GTX4610 resin: 1.21 g/cm³
  - CYCOLOY™ CX7240 resin: 1.2 g/cm³

### SAFETY
- **FLAME PERFORMANCE (UL94)**
  - NORIL™ NHP5054 resin: V0 ≥ 0.75 mm
  - NORIL™ NHP6011 resin: V0 ≥ 1.5 mm
  - NORIL™ GTX4610 resin: V0 ≥ 1.5 mm
  - CYCOLOY™ CX7240 resin: V0 ≥ 0.75 mm
- **ELECTRICAL PERFORMANCE TRACKING RESISTANCE (UL 746)**
  - NORIL™ NHP5054 resin: CTI PLC 3
  - NORIL™ NHP6011 resin: CTI PLC 2
  - NORIL™ GTX4610 resin: CTI PLC 1
  - CYCOLOY™ CX7240 resin: CTI PLC 3
## EV BATTERY MODULE APPLICATIONS

### Running Applications

<table>
<thead>
<tr>
<th></th>
<th>Cell Retainer</th>
<th>Spacers</th>
<th>Busbar Frame</th>
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<tr>
<td><strong>Properties</strong></td>
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<tr>
<td>Dimensional stability</td>
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<td>Chemical resistance</td>
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<td>FR downgauging</td>
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<td><strong>Polymer Characteristics</strong></td>
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<td>1.11 g/cm³</td>
<td>1.19 g/cm³</td>
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<td><strong>Processing</strong></td>
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<td>FLOWABILITY MFI</td>
<td>56 g/10min</td>
<td>25 g/10min</td>
<td>25 g/10min</td>
</tr>
</tbody>
</table>

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Classification: General Business Use
# APPLICATION REQUIREMENTS FOR EV BATTERY MODULE PARTS

## FR
- Non-Cl, Br FR V0 ≥ 0.8 mm preferred
- V0 ≥ 1.5 mm must

## MECHANICAL
- High stiffness and impact strength
- Crash resistance

## PHYSICAL
- Dimensional stability (low warpage)
- Chemical resistance, e.g., electrolyte, coolants
- Good processability → High flowability
- Hydrolytic stability

## ELECTRICAL
- Tracking resistance: min. CTI PLC 2
- Thermal resistance (RTI w/ impact >100 °C)
- Electrical insulation

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**TREND: Increasingly strict UL94 FR requirements**
SABIC’S SPECIALTIES BUSINESS

STRUCTURAL AND IMPACT REQUIREMENTS
OPTIMIZE TO DRIVE LONGER – LIGHT WEIGHTING WITH MULTILATERAL SOLUTIONS

Modular approach for battery enclosure using thermoplastic solutions
- Light weight
- Repeatability
- Ease of manufacturability by reducing the machine tonnage and number of feed drops

Multi material approach for battery enclosure
- Light weight
- Improved performance

CAE Simulations

Drop Test
Drop Height 1m

Shock Loads
25G acceleration in 15ms duration

Stone Penetration
High Speed Impact

No permanent damage observed in all simulated load conditions
PERFORMANCE EVALUATION – CAE SIMULATIONS

Shock Loads

- Aluminum top cover
- Thermoplastic (NORYL™ 5054 resin) top cover

25G acceleration applied in vertical axes in 15ms duration

Drop Test

- Aluminum top cover
- Thermoplastic (NORYL™ 5054 resin) top cover

1m drop height (flat drop)

Stone Penetration

- Aluminum base plate
- Aluminum base plate with thermoplastic (NORYL™ 5054 resin) honeycomb

ϕ50mm ball with mass of 0.176 Kg and velocity 17.78 m/s

Thermoplastic solution is observed to perform similar/better compared to incumbent aluminum
ROCKER REINFORCEMENT FOR EV BATTERY CRASH PROTECTION

KEY APPLICATION REQUIREMENTS

Low temperature energy absorption
- NORYL GTX™ resin honeycomb (HC) based hybrid solution absorbs robust energy, especially down in a range of -20 to -40 °C

E-coat capability
- High heat resistance to withstand the high temperatures required in e-coating process (180 to 220 °C over 30 mins)

ENABLING TECHNOLOGY

NORYL GTX resin
- Balance of heat resistance, low temperature impact and flow

Global Application Technology support
- Design, testing, processing, material expertise

NORYL GTX resin addresses the critical assembly requirements before & after e-coat process
SABIC’S SPECIALTIES BUSINESS

THERMAL LOADS
THERMAL MANAGEMENT SOLUTIONS USING SPECIALTY MATERIALS

Repeat units of cell, cell holder, separator held together with the help of endplates.
CASE SETUP AND BOUNDARY CONDITIONS

<table>
<thead>
<tr>
<th>Solver</th>
<th>FloEFD V 20.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governing equations</td>
<td>Mass, Momentum, &amp; Energy</td>
</tr>
<tr>
<td>Radiation</td>
<td>Discrete Order</td>
</tr>
<tr>
<td>Ambient Condition</td>
<td>$T_{\text{amb}} = 25^\circ\text{C}, 1\text{ atm pressure}$</td>
</tr>
</tbody>
</table>

Cells are assigned with 1 kW of heat power in the form of volumetric heating with uniform heat generation within the cell volume.

All the boundaries of the computational domain are assumed to be exposed to ambient air at $T_{\text{amb}}$ & 1 atm pressure.

Battery module

$Gravity\ Direction\ (-ve\ z-axis)$

Representative cooling plate
PERFORMANCE EVALUATION – CAE SIMULATIONS

Temperature profile at module level

Conductive thermoplastic solution for separators (LNP™ KONDUIT™ PX13012 compound)

Aluminum separator

Thermoplastic solution is observed to perform similar compared to incumbent aluminum
THERMAL MANAGEMENT - CYLINDRICAL CELL HOLDER

Metallization provided at the interface between top & bottom holders and the cells for better thermal management.

Module details with cell array

Exploded view of battery module

top holder

cells

bottom holder

LDS conductive coating
TEMPERATURE CONTOUR OF BATTERY

without LDS copper layer
$T_{\text{max}} = 59.2 \, ^{\circ}\text{C}$

with LDS copper layer
$T_{\text{max}} = 51.4 \, ^{\circ}\text{C}$

LDS copper layer reduces the overall module temperature by 8 degrees
MANUFACTURABILITY – PROCESSING AND FILL PATTERNS
LARGE PARTS NEED BIGGER TOOLS AND FILL PATTERNS

- 33 hot drops were needed to fill 1600 X 800 mm part
- Need for high tonnage and bigger tool to handle in single piece
MODULAR CYLINDRICAL CELL HOLDER CONCEPT

Modular approach proposed for the cylindrical cell holder

Modular cell holder connected through a metal rod
MANUFACTURING FEASIBILITY – CYLINDRICAL CELL HOLDER

- Complies with UL 94 V-0 standard down to 1.0 mm and UL 94 5VA standard at 3.0 mm
- Products that comply with UL F1 are available
- Excellent anti-draping properties
- Provides a non-brominated, non-chlorinated, non-phosphate, non-PTFE solution
- Improved flow and processability compared to standard clear FR polycarbonate
- CFR grades are transparent, CFR9111 (V0 @1.5 mm) Vs CFR9712 (V0@2 mm)
**CELL HOLDER – MF STUDIES – RESULTS COMPARISON**

**CFR9111**
- Fill Time: 2.7 sec.
- Max. Inj. pressure: 180 MPa.
- Inj. Pressure @ S/w: 86.5 MPa
- Overall part warpage: ~3.5 mm

**CFR9712**
- Fill Time: 2.7 sec.
- Max. Inj. pressure: 156 MPa.
- Inj. Pressure @ S/w: 69.5 MPa
- Overall part warpage: ~3.5 mm
NEW INNOVATIONS

ADDITIONAL DESIGN OPTIONS

WIRELESS CONNECTIVITY
NORYL™ FILM FOR THERMOFORMABLE INSULATION LAYER

Robust FR and CTI-0 high tracking index performance helping prevent ignition and electric breakdown issues

- EV battery self ignition & electric breakdown issues are concerns for EV OEMs
- EV battery pack protection film can help decrease the failure risk

0.5MM NORYL FILM with V0 CTI-0

<table>
<thead>
<tr>
<th>FR, UL94</th>
<th>V0 ≥ 0.5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTI</td>
<td>CTI-0</td>
</tr>
<tr>
<td>RTI</td>
<td>115 °C</td>
</tr>
<tr>
<td>Processability</td>
<td>Capable for film extrusion</td>
</tr>
</tbody>
</table>
WIRELESS CONNECTIVITY WITH LNP™ COMPOUNDS

WIRELESS COMMUNICATION

LNP™ KONDUIT™ compound
Radio frequency (RF) - transparency
THANK YOU

Contacts

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