FLAME RETARDANT THERMOPLASTICS FOR EV BATTERY PACK APPLICATIONS

CHEMISTRY THAT MATTERS™

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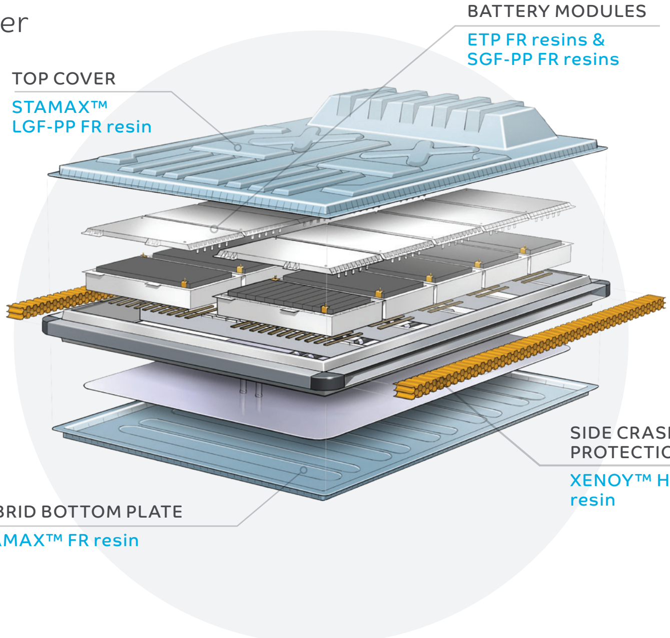
Electric vehicles represent a growing category for automakers. SABIC is doing its part to help them make this shift, with our base of proven thermoplastics to help enable the next generation of EV battery packs. One area of focus for the industry: addressing concerns and challenges around the possibility of thermal runaway. Here, too, SABIC can help. We have built strong competence in fire-polymer interaction when it comes to EV battery packs and related applications, in addition to a portfolio of flame retardant materials that can enable automakers to comply with battery safety requirements and regulations.

The benefits of SABIC thermoplastics for EV battery packs and related components are many. Our materials are inherently light, which means manufacturers can remove significant weight, translating to improved performance and extended range. Corrosion resistance contributes to durability and long life. Beyond lightweighting, cost savings are possible with low-cost thermoforming and injection molding manufacturing processes. In addition, SABIC plastics can provide exceptional thermal and electric insulation properties for enhanced thermal stability compared to some metals.

EV BATTERY PACK APPLICATIONS WITH SABIC FR POLYMERS

Our thermoplastics can meet requirements for a number of EV battery pack components, as illustrated. ▶

For the various applications, we have a number of high performance flame retardant (FR) materials available from our families of SABIC® polypropylene compounds (PPc) and STAMAX™ long glass fiber (LGF) PP resins and from our portfolio of of engineering thermoplastics (ETP) such as LEXAN™ polycarbonate (PC) resins and several polybutylene terephthalate (PBT), polyester (PET) and PC blends. Applying these materials to the design of various EV battery pack components – including our set of non-halogenated, intumescent FR systems – can deliver a holistic, higher-performing battery pack solution.



UNDERSTANDING FIRE SAFETY REQUIREMENTS

Understanding fire safety requirements for EV battery packs is essential, especially considering extreme thermal abuse scenarios under high battery load, as well as thermal runaway conditions.

Relevant international and industrial standards include the bonfire test scenario and occupant protection in case of runaway reactions . When it comes to use of FR thermoplastics, based on typical automotive standards and OEM requirements under a battery thermal runaway scenario, they must pass specific abuse tests as highlighted below.

FLAME RETARDANT	Bonfire and flame test at 1,100°C and above for at least 5 minutes
PRESSURE RATING	Holds pressure at up to 2.5 bar under high temperature
GRIT RESISTANCE	Rigidness with grit impingement during battery thermal runaway

PLAQUE-SCALE FIRE TEST CAPABILITIES

Our electrification team has various fire testing capabilities in place, both in-house and with partners, to help support our ongoing work with the industry.

Through these capabilities, we can assess, understand and verify the limits of material performance in meeting temperature, pressure and grit impingement requirements. In addition, we can mitigate the risks posed by proposed design solutions and help ensure quality in composite manufacturing, hybrid structures and overall assembly designs.

TABLE 1. SELECTED FIRE TEST FACILITIES AND CONFIGURATIONS.

	SABIC Automotive Development Center, Wixom, MI, US	**Partner 1**	**Partner 2**	**Partner 3**
Test type	Bunsen burner and torches	Radiative kiln	Pyrotechnic test	Battery thermal runaway
Test standard	SABIC internal	GB 38031 - 2020	OEM specified	UL 2596
Test part size (mm)	250x250	360x360	250x250	100x100
Heat source	Butane/Propane/Air	Electric heater	Weco 4851 (BAM-0589-T1-0025)	5x5 lithium-ion 18650 battery pack
Heating duty (W)	660-3268	11520	9000	3400-3500 mAh/cell
Temperature (°C)	800-1200	800-900	~1300	>800
Pressure (bar)	1	1	1	Up to 2.5
Grit impingement (g/s)	NA*	NA*	>1.5	Not specified
Specimen setup	Horizontal/Vertical	Horizontal	Vertical	Horizontal
Target application	Pack cover, tray, module enclosures, busbar	Pack cover, tray	Pack cover, tray	Pack cover, tray

*Not applicable

THERMOPLASTIC FIRE TEST RESULTS

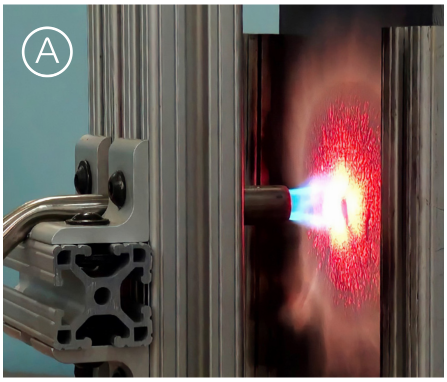
Our team has completed extensive fire testing with our thermoplastics on horizontal and vertical test benches with thermocouple and infrared camera temperature measurement systems. We assessed the FR performance of our materials based on the extent of fire damage, fire extinction, thermal insulative properties and flame retardant characteristics under specific fire conditions for battery tray, cover, module and cell thermal barrier applications.

Below are some images from typical fire abuse tests, including the flame torch test, pyrotechnic abuse and the battery pack thermal runaway test.

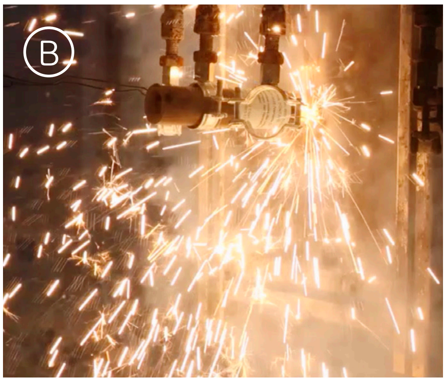
In these tests, our FR thermoplastic materials passed the high temperature, pressure, and harsh grit impingement tests – based on specific engineering designs for different EV applications.

In addition to the various fire tests, our experts have developed advanced Computational Fluid Dynamics (CFD) models to understand the pyrolysis physics (combustion and flame interaction with the polymer surface, intumescence, charring, secondary combustion of pyrolysis products, etc.) and heat transfer phenomena in the flame exposure. Our ongoing work in this area continues to provide insights and guidelines to help optimize application performance and safety.

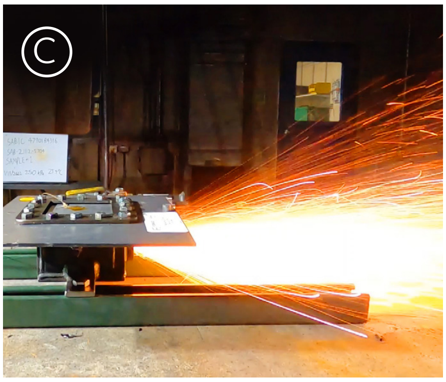
Our team also conducted comprehensive analytical measurements on thermoplastic plaques before and after flammability testing to characterize the materials' thermal and mechanical properties.



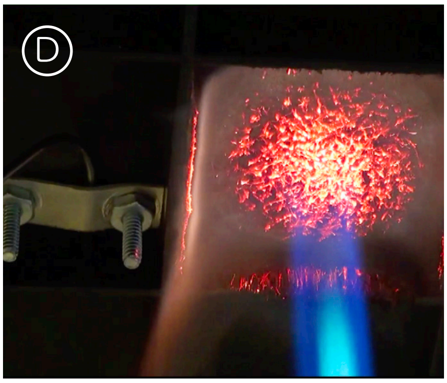
1100ºC flame test of a 4 mm plaque in a vertical setup, after 5-minute flame exposure.



Pyrotechnic abuse test with grit impingement on a 3 mm (w/ 2 mm Organo sheet laminate) plaque.

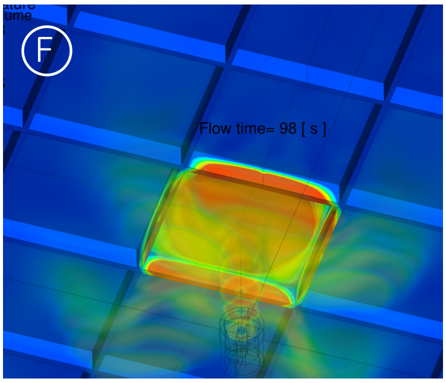


UL2596 battery pack thermal runaway test on a 4 mm plaque.



1100ºC flame test on a 4 mm ribbed structure in a horizontal setup.

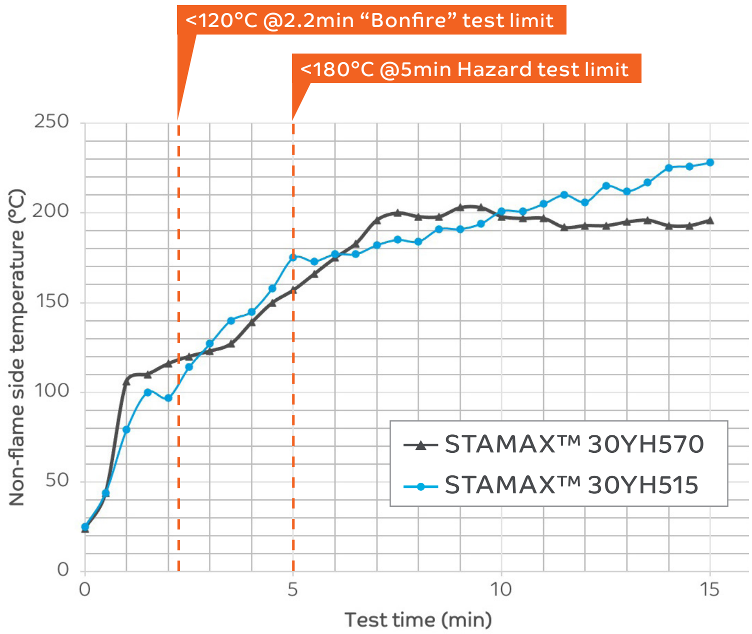
A view of the post-test plaque after the flame test shown in D



A CFD simulation of the fire-polymer test highlighted in D, showing the intumescence and char formation on the polymer.

TEMPERATURE VS TIME

The chart below shows the non-flame exposure side surface temperature profiles of 4 mm plaques with ribbed structures, made with STAMAX™ FR 30YH570 and 30YH515 resins, from a 1,100°C flame test in a horizontal setup (test condition D).



Each of these materials demonstrate outstanding flame retardant performance, with the non-flame exposure side temperature below 250°C, no evidence of burn-through (as shown in exhibit E on the previous page), and rapid self-extinguishment after removal from the heat source after the 15-minute test duration.

The temperature profiles also demonstrate that these STAMAX FR resins pass two additional tests: the "Bonfire" test with the non-flame side temperature below 120°C after 2.2 minutes; and the thermal runaway hazard test with the non-flame side temperature below 180°C after 5 minutes.

METALS AND PLASTICS: A CLEAR DIFFERENCE

Above, one of our team members holds two plates: one based on aluminum (left) and one based on STAMAX FR resin. We had subjected both plates to 5-minute flame tests with temperatures exceeding 1,100°C. While a hole burned through the aluminum plate within 30 seconds, the one in STAMAX resin had no burn through after five minutes.

Below, in Table 2, is an overview of key FR PP materials from SABIC with their FR ratings, flame exposure and thermal runaway test performance and mechanical properties.

Based on test results, the table highlights material thickness recommendations to pass the 5-minute 1100°C flame test, the 20-second pyrotechnic abuse test and the UL2596 thermal runaway tests without burn through or significant deformation.

TABLE 2. SABIC FR PP MATERIALS – FIRE TEST PERFORMANCE AND MECHANICAL PROPERTIES

	STAMAX™ 30YH570 resin, 30% long glass fiber (LGF-PP)	STAMAX™ 30YH515 resin, 30% LGF-PP	SABIC® PPcompound GF H1030 resin, 30% short glass fiber (SGF-PP)
FR ratings and performance (thickness required to pass test, in millimeters)			
UL94 V0	1.3 mm	1.5 mm	1.5 mm
5 min 1100°C flame test	4 mm	4 mm	4 mm
20 sec pyrotechnic test	3mm (w/ 2mm Organo sheet laminate)	N/A*	4 (w/ 2mm UD tape laminate)
Battery thermal runaway test at 2.5 bar	4 mm	N/A*	N/A*
Mechanical properties (at room temperature)			
Tensile modulus (MPa)	7700	7600	8700
Yield Stress (MPa)	80	79	100
Break Stress (MPa)	80	79	100
Elongation at yield (%)	2.1	2.1	3
Charpy Impact Notched ISO 179/eA (KJ/m^2)	14	15	8

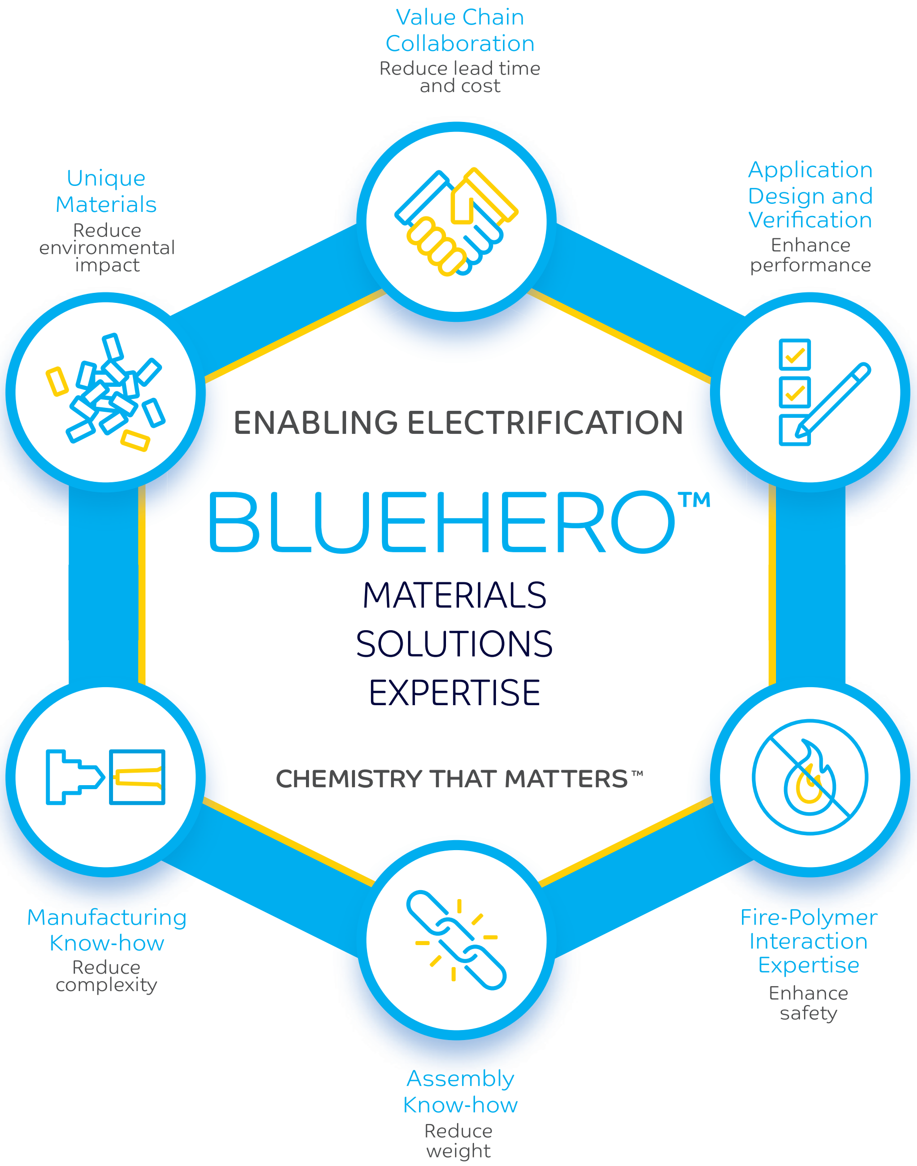
Table 3 lists select FR ETP materials with their FR ratings, flame testing performance and mechanical properties. Based on our testing and analysis, we highlight material thickness recommendations to pass the relevant testing.

TABLE 3. SABIC FR ETP MATERIALS: FIRE TEST PERFORMANCE AND MECHANICAL PROPERTIES

	VALOX™ 420SE0 (30% glass fiber)	LEXAN™ 3412ECR (20% glass fiber)	CYCOLOY™ C3650
FR ratings and performance (thickness required to pass test, in millimeters)			
UL94 V0	0.71 mm	1.5 mm	1.5 mm
UL94 5VA/5VB	2.0 mm (5VA)	3.0 mm (5VA)	2.5 mm (5VB)
Mechanical properties (at room temperature)			
Tensile modulus (MPa)	10000	6000	3000
Yield stress (MPa)	120	95	65
Break stress (MPa)	120	90	55
Elongation at yield (%)	2	3.1	3
Charpy impact notched ISO 179/eA (KJ/m^2)	7	6	48

Of course, a number of variables factor into the exact choice of material for EV battery pack components beyond fire testing and mechanical performance. Design considerations of the application, specific system requirements, the manufacturing approach (extrusion, thermoforming, injection compression molding, etc.), transparency, bonding solutions and cost—all may influence the choice of material.

*Data not available



SABIC support for EV applications fall under BLUEHERO™ – an expanding ecosystem of materials, solutions and expertise that can help accelerate the world's energy transition to electric power.

The company's starting point with BLUEHERO is support of the automotive industry's mission to create create safe and efficient electric vehicles (EVs), with emphasis on optimizing structural battery components with unique flame retardant materials and solution development expertise. BLUEHERO focuses our energy on the heroic collaboration and actions needed to enable electrification, achieve a clean air economy and address climate change.

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