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Fire safety in E-Mobility

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Executive Summary

Electric Vehicles have different fire risks compared to combustion engines because of high voltages and currents. Modern flame retardants combine technical performance with a favorable sustainability profile and are already widely used in e-mobility.

Keywords: fire safety, flame retardants, halogen free, electric vehicles, plastics.

1 Introduction

Electric Vehicles have different fire risks compared to combustion engines because of high voltages and currents during charging and the battery with a large amount of electro-chemical energy. The battery as well as peripherals need to be protected against fire risk by using appropriate, flammability rated material. If lithium-ion batteries short-circuit, cells can enter a state known as "thermal runaway," in which they continue heating up to a point where they can eventually ignite. In addition, Batteries can catch fire long after the initial damage has occurred.

Modern flame retardants combine technical performance with a favorable sustainability profile and are already widely used in e-mobility. New capacities are under construction and challenges for the use in automotive are addressed in developmental projects.

2 Importance of Fire Safety

Polymeric materials are used in a variety of applications from automotive to aerospace and in various modern gadgets for consumer electronics that make our lives comfortable. However, polymers are based on organic matter and tend to burn in the event of a fire. Use of fire retardants slow down the spread of a fire and potentially can overcome runaway reactions thereby allowing occupants of a building to escape in time safely. Flame retardants protect property and save lives. While electric vehicles are generally considered safer than conventional internal combustion engines (ICE) and hybrids, the challenges posed by electric cars in a fire scenario are quite severe. The main risk for fire in an electric car is due to the lithium battery, which can be considered as the heart of the vehicle. Any defect in the battery configuration can cause a fire risk while charging or even when the car is at rest as has been reported in a few cases in the press or in the case of a crash. Due to the significant amount of energy stored in a lithium battery, the potential for what is known as a thermal runaway or exothermic reaction is highly probable resulting in a huge conflagration. Such fires are quite difficult to put out by common firefighting techniques. In fact, in several cases the only solution is to dump several thousands of gallons of water to quench the fire and prevent it from restarting again. The need for flame retardants can be better understood with an illustration as shown in Figure 1 and explained in detail by PINFA or Phosphorus, Inorganic, Nitrogen Flame Retardants Association on their website.[1]

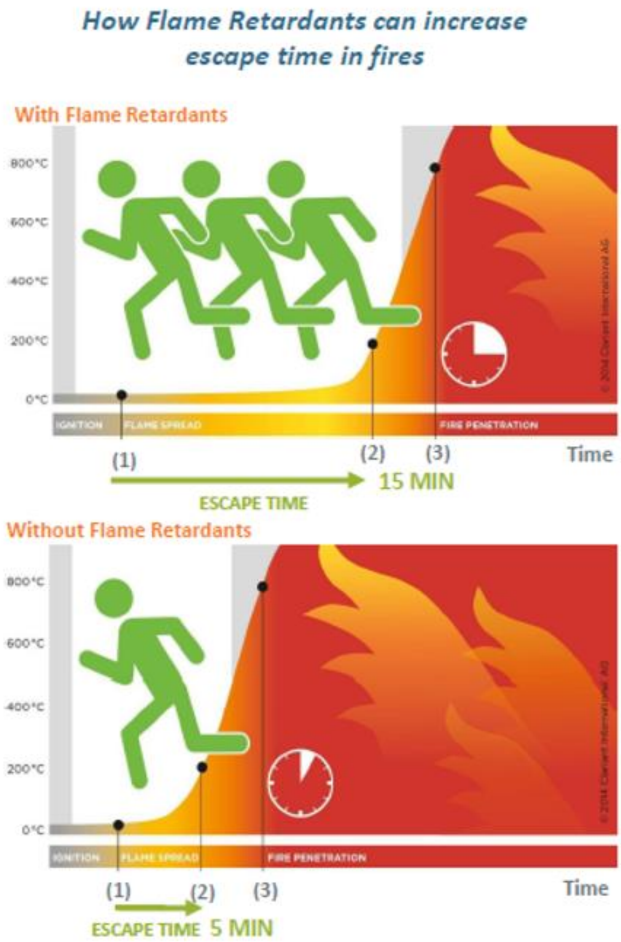

Figure1: Illustration of escape time in case of fire when flame retardants are used (Source: PINFA)

3 Electric vehicles and need for flame retardants

Typically, batteries are often enclosed using a metal cover for protection, but once a fire initiates, then the metallic framework can intensify the fire propagation because of its high thermal conductivity. One way to overcome this is by the use of Thermoplastics or Thermoset materials that offer better resistance, and they can also be protected using flame retardants which are used in conventional applications. For instance, where thermoset materials are used, such as Epoxies or Unsaturated polyesters that are typically reinforced with glass or carbon fibers, these can be properly designed for fire safety using what are known as Intumescent fire retardants (IFR). Typically, IFR work via a condensed phase mechanism in which the heat or fire triggers the appropriate reactions resulting in the formation of char that also undergoes expansion. This expanded char causes an insulation barrier around the polymer matrix thereby protecting the rest of the material and preventing heat transfer. Several manufacturers of traditional composite materials used in Building and Construction as well as conventional automotive vehicles for structural parts have used the same principles for designing battery covers or enclosures.[2] Such composites offer lightweight structures that can also be shaped and stamped as well as processed using IFRs.

Thermoplastics are good substitutes for metals used as battery covers or enclosures and can be protected from fires using halogen free flame retardant (HFFR) that can be activated in case of a fire. They help in reducing the flame spread and delay the onset of conflagration, thereby allowing the occupants of a vehicle to safely exit and seek cover. HFFR have been used for many decades in diverse applications for electrical and electronics parts in Appliances, Automotive, Aerospace as well as Buildings. Engineering thermoplastics such as Polyamides and Polyesters are often the choice of materials of construction and offer adequate mechanical as well as electrical properties needed for such applications. For conventional applications usually end products include high voltage connectors, circuit breakers, power distribution systems etc. Invariably these parts are glass filled to provide mechanical strength and stiffness. Flammability tests like the globally recognized UL 94 V tests from Underwriters Laboratories are well established and have been in use for many years. While this test and other related tests can be used for initial screening for applications like battery covers, more rigorous tests are being developed by UL and other research facilities to address the heat release from such fires and escape times needed for occupants in an actual fire scenario.

The use of polymeric materials in an electric vehicle is increasing with the need for light weighting. As shown in Figure 2, several other parts or peripherals in an electric car use plastics or polymers also need to be flame retarded. For instance, there are several high voltage connectors that are usually made from polyamides like PA-6 or PA-66 or high temperature or high-performance polyamides (HPPA). These are typically glass reinforced to offer the right mechanical properties and can be quite challenging to flame retard. Halogen free flame retardant (HFFR) have been used in such applications for decades and well proven to meet the challenges for E-mobility applications as well. Typically, the HFFR can help meet stringent flame retardancy tests like UL-94 V-0 and 5V. Clariant is a global specialty chemicals company that offers halogen free flame retardants under the Exolit® tradename

Battery module housing or covers discussed earlier above can be made using thermoplastics or thermosets and HFFR based on various chemistries can be effectively used in such applications. Busbars are used in electric vehicles and are metal bars made from aluminum or copper for carrying current in lieu of cables. Busbars prevent overheating due to the huge amount of heat generated by the batteries. However, busbars do need protection from electrical breakdown and fires and are typically made with a polymer insulation using polyamides like PA-6 or PA-12. These polyamides can be easily flame retarded using HFFR to ensure V-0 ratings.

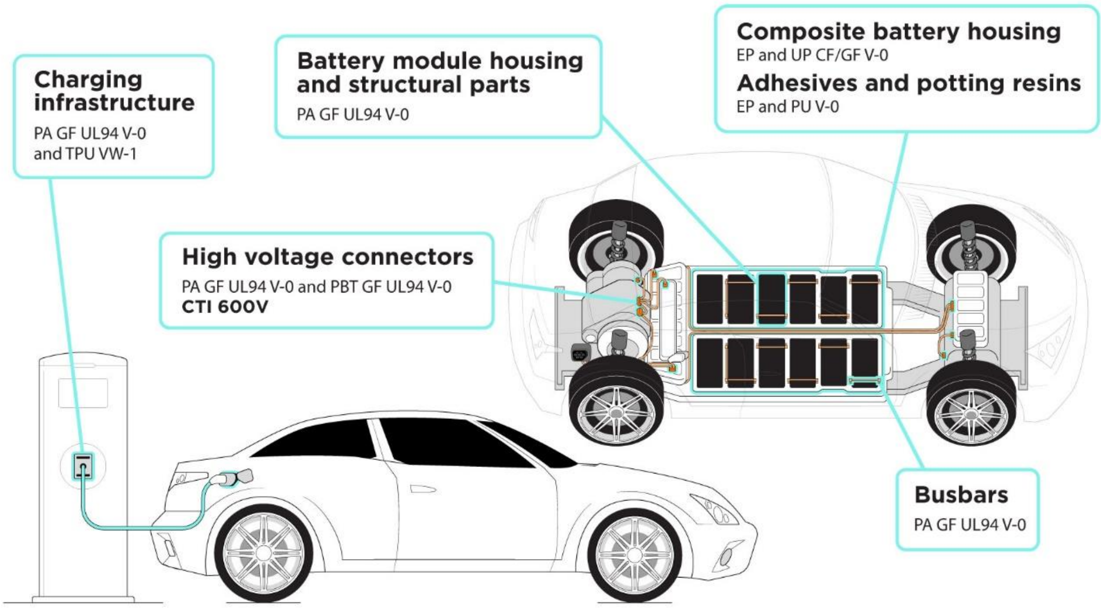

Figure 2: Schematic of electric vehicle showing use of flame retardants in various parts

As the field of battery design and packing is evolving, it is critical that there is proper insulation between the cells. Pressure sensitive adhesives (PSA) and potting resins are often used in a variety of applications such as cell to cell bonding to bond pouch or prismatic cells together. Acrylics, epoxies and polyurethanes are often the choice of materials and need to be flame retarded as well. In the case of these resins which are usually thermosetting or cross-linked in nature, both 'additive' as well as 'reactive' type HFFR can be used to effectively provide fire protection. Similarly, another area of application is Gap fillers which provide a means of transferring heat from the battery to the cooling plate. It is imperative that gap fillers also need to be protected using flame retardants. Typical resin chemistries include polyurethanes that can be effectively flame retarded using HFFR.

Last but not the least, charging infrastructure which are stand-alone units also need to be flame retarded. Polyamides are often used in such applications and as discussed above excellent HFFR are available for PA-6 and PA-66 type resins.

While flame retardancy is the most critical property that is vital for meeting stringent flammability requirements, other properties like electrical and mechanical properties are also important. Light weighting of parts is gaining traction in electric vehicles and the use of HFFR in plastics affords a significant reduction in density as shown in Figure 3.

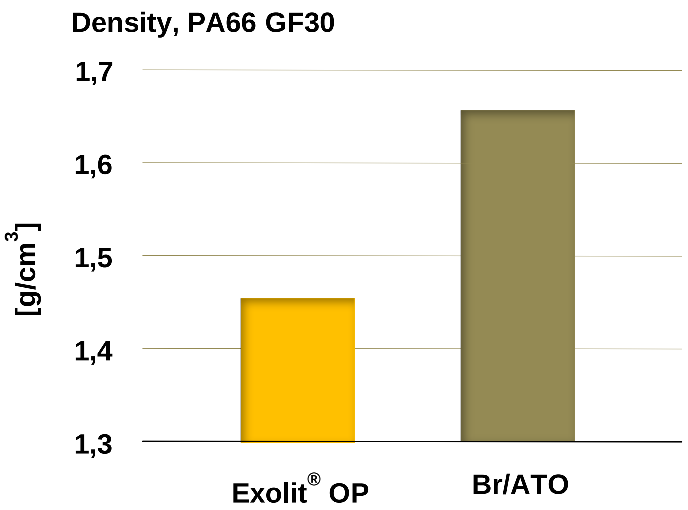

Figure 3: Density advantage resulting in lightweight parts with Exolit OP flame retardant in polyamides

One such property is the comparative tracking index (CTI) which has been a critical requirement in electrical parts for traditional applications. Since the electric vehicle is subject to rapid charging, plastic parts used in cars need to be able to withstand the high voltages without any electrical breakdown. While current requirements are CTI of up to 400V, more and more car and battery manufacturers are requiring high voltages up to 800 or even 1000V. At present the HFFR used in engineering plastics like PA and PBT can meet 600 V fairly easily. But with increasing demands for higher voltages, research is ongoing to ensure that the right test equipment is available for measuring say up to 1000 V without any air arcing. Some resin manufacturers are currently offering materials with high temperature nylons that are said to meet CTI of 800V, which is very encouraging. Figure 3 shows a comparison of CTI for polyamide 66 and PA-66 containing Exolit OP HFFR and a traditional halogenated or brominated flame-retardant system.

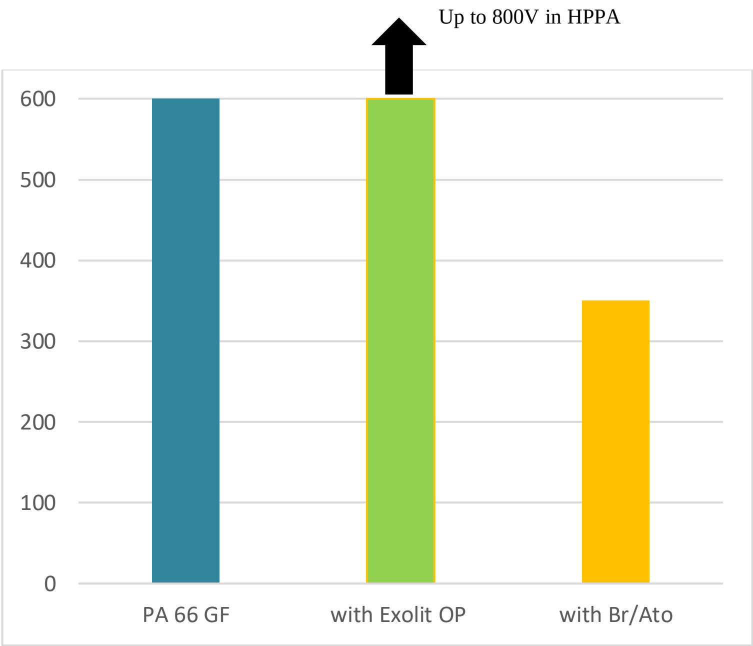

Figure 4: Comparative Tracking Index (CTI) of flame retardants in various parts

Another requirement is the Glow Wire Ignition Temperature (GWIT) which denotes the lowest temperature at which the material ignites and burns for longer than 5 seconds, in the case of unattended appliances or equipment's. (IEC 60695-2-11). As more and more polymeric materials are used in electric vehicles this test requirement becomes very critical. Clariant has recently introduced new grades of Exolit® OP HFFR that meets the 800 °C requirement for GWIT. Clariant's Exolit® flame retardants also offer low smoke density and smoke toxicity which is becoming more and more important in many applications for transportation especially.

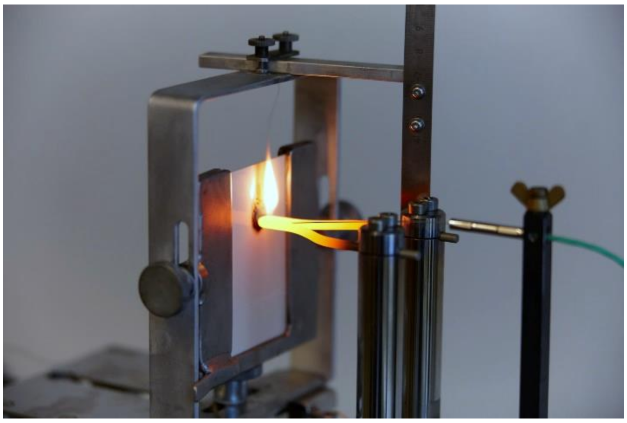

Figure 4: Glow wire ignition temperature (GWIT) test equipment

Plastics containing Exolit® flame retardants can also be recycled as demonstrated by the Fraunhofer Institute[2] and still retain its efficacy as a flame retardant as shown in Figure 5. This study demonstrates the potential for materials recycling and extends the useful life of a plastic material containing HFFR.

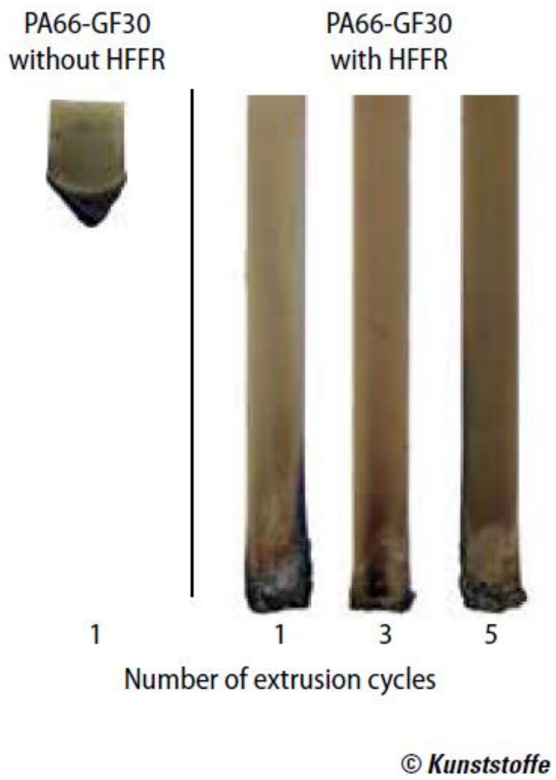

Figure 5: Polyamide-66 with HFFR showing excellent retention of flame retardancy in the UL-94V test after multiple heat histories

References

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Presenter Biography

Dr. Subra Narayan is currently Senior Technical Business Development Manager for Flame Retardants at Clariant Corporation in North America. Prior to joining Clariant, he worked at Chemtura Corporation and Chemir Labs in R&D, Applications Development and Global Technical Service functions. Subra received his Bachelor's degrees in Chemistry and Technology of Plastics, both from the University of Mumbai and his Ph.D. in Polymer Science from the University of Missouri-Rolla. He has more than thirty years of experience working with polymeric materials, processing techniques and materials characterization, and has several journal publications and patents

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