E-mobility: Passive safety provided by flame retardants
Future challenges & requirements

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Agenda

- Why flame retardant thermoplastic polymers
- Regulations, legislations and standards in the industries
- Function and nature of FR systems in thermoplastic polymers
- Electro corrosion - the halogen free topic: some facts and applications

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Technical Evolution in Automotive

Golf I

750 kg

Golf VII

1205 kg

1974	1978	1980	1981	1995	1996	2010	2012	2013	2015	2016
	ABS	airbag	belt pretensioner	ESP	emergency brake assist	lane departure warning system	Blind spot assist	indulgence assist	Adaptive cruise control	e-mobility / autonomous cars

Electrification of cars due to safety, assistant and entertainmain systems - as well as electric powertrains (e-mobility) – will change the requirements to plastics materials in the automotive industry

Source: Volkswagen AG

Increasing hazard of fire in automotive

- **Increase of "unattended" electrification**
  - Alarm system
  - Air-conditioning
  - Auxiliary heating
  - Charging of electric vehicles
- **Increase of ambient temperature**
- **Increase of electric voltage**

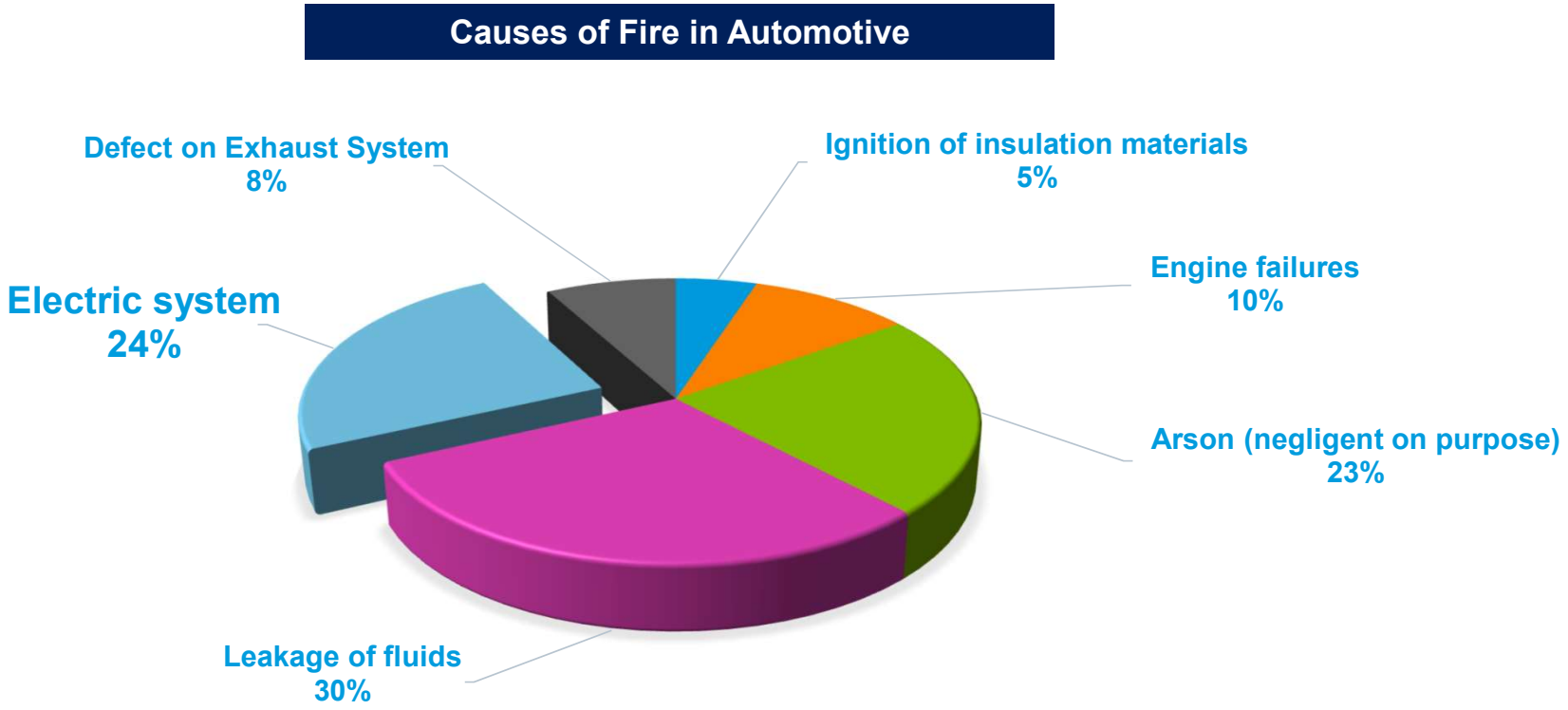
- **Electric vehicles**
  - Increase of electric current and voltage
  - Fire hazard of Li-Ion batteries
    - Using housings of Titanium
    - Using solid-state batteries

E-mobility car fire, Landeck, October 2017

A battery fire can be extremely dangerous and burn strong, but Tesla's firewalls inside the battery pack clearly worked since it not only left enough time for the driver to evacuate but also for the firefighters to stop the fire before it spread to the entire battery pack.

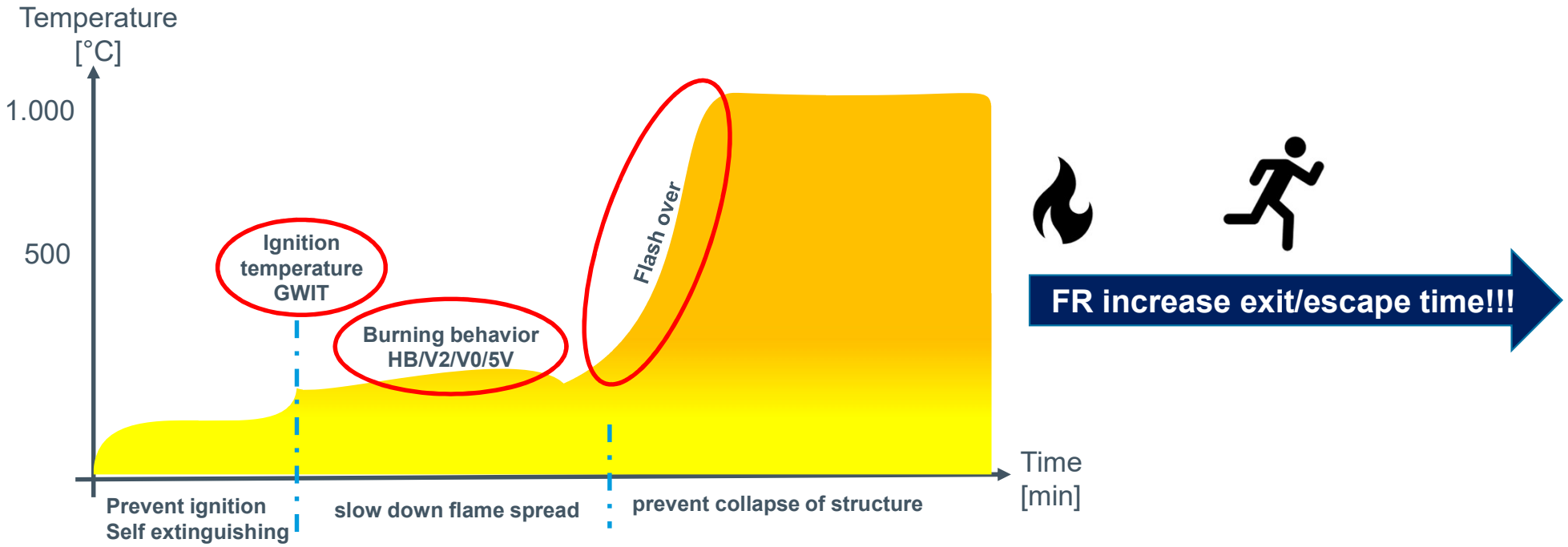
Source: electrek

Fire in Automotive



Source: NFIRS

The condition of a fire



Flame retardants work at the ingnition temperature or/and the flame spread (speed) to shift the time until point of flash over. Exit/escape time is the most critical criteria to save lifes in case of fire.

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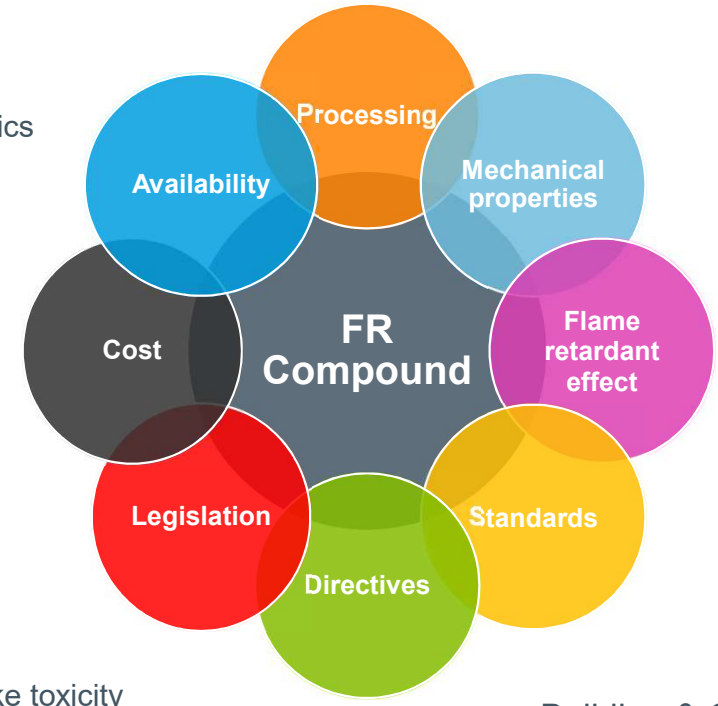
Flame retardant compounds and their dependences



- Chemical tax on electronics

REACh

WEEE

European railway
EN 45545

- LOI
- Smoke toxicity
- Smoke density
- Heat release

- Burning rate

- Yellow Card
- V-0, V-2, 5V
- RTI
- CTI
- HAI
- HWI

- VDE approval
- GWFI
- GWIT
- CTI

Building & Construction
DIN 1402
EN 13501-1

- Burning behavior
- Dripping behavior
- Smoke behavior

Standards for flame-retardant markets

- **Building & Construction**
  - Materials are tested for the degree of **flammability** and **combustibility** with additionally tests on **smoke emission** and dripping behavior.
- **Electric & Electronics**
  - Different types of **flammability** and **ignition** tests, the ignition can be caused by:
    - **Flame**, like UL94 (V-2, V-0, 5VA)
    - **Glowing wire**, like GWFI, GWIT, HWI
    - **Electricity** current or voltage, like HAI, CTI
- **Railway EN45545**
  - Different types of **flammability** and **combustibility** tests, with additionally taking care on **smoke -density** and **-toxicity**.
- **Automotive**
  - Well known is the FMVSS 302, horizontal burning rate <100 mm/min ➔ no need of flame-retardant materials.
  - Increasingly important is the vertical flammability test acc. UL94 V-0, ➔ the material has to be self-extinguished within 10 s after removal of flame-source.

GWFI = Glow Wire Flammability Index
HAI = High Amp Arc Ignition
GWIT = Glow Wire Ignition Temperature
CTI = Comparative Tracking Index
HWI = Hot Wire Igniition
FMVSS = Federal Motor Vehicle Safety Standard

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The action of Flame Retardants

Performance comparison of flame retardants

	Halogenated	Phosphorus based	Nitrogen based	$Al(OH)_3$ / $Mg(OH)_2$
Acting site	gas phase	condensation / gas phase	condensation / gas phase	condensation / gas phase
Mode of action	chemical	chemical / physical	chemical / physical	physical
Efficiency	+	+	+	-
Polymer compatibility	+	0	0	0
Fire siede effects	-	+	+	+
Corrosiveness (processing)	-	0	0	0

Criteria definitions: ("+" = good; "0" = neutral; "-" = bad)

Efficiency: the amount of chemical to be used

Polymer compatibility: how well does the FR interact with the polymer

Fire side effect: the volume and toxicity of the smoke and formation of corrosive gases

Corrosiveness: the use of steel with an amount of >12% chrome is recommended to avoid corrosion on mold and molding machine

Source: www.flameretardants-online.com

The action of Flame Retardants

Pro and contra of various FR-systems

	Halogenated	Phosphorus based	Nitrogen based	$Al(OH)_3$ / $Mg(OH)_2$
Mechanical properties	+	0	+	-
Electrical properties	-	+	+	+
Thermal stability	+	0	-	+
Smoke density	-	+	+	+
Light and weather stability	-	0	0	+
Processing	+	+	0	-
Recycling	-	+	+	+
Coloring	0	0	0	-
Environmentally friendly	-	0	0	+
Plastics	PS, ABS, PC, PP, PBT, PA, Blends	PC/ABS, PBT, PP, PA, PBT	PA	PP, PA

Criteria definitions: ("+" = good; "0" = neutral; "-" = bad)

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Electro Corrosion - Halogen-free vs. Halide-free

- **Halide is defined as any compound containing a halogen**
  - Table salt NaCl or Calcium Chloride $CaCl_2$
  - Heat stabilizer for Polyamide, like Potassium Iodide (KI) or Cupper Iodide (CuI)

- **What has happened in the electronics industry is, that the use of the term halides is actually referring to "halide ions". A halide in the ionic form, such as $Br^{(-)}$ or $Cl^{(-)}$, reacts with metals in the presence of moisture to cause corrosion and dendritic growth.**
  - Electrical neutral (EN) requirements are well known in the market
  - EN is considered to be linked to the halogen content of the material
  - The halogens are suspected to facilitate electrical corrosion
  - 100 ppm halogen content is established as acceptance criteria for EN applications

- **Nevertheless new automotive electrical designs getting smaller and more complex resulting in the discussion whether the acceptance criteria needs to be re-considered**
  - Current discussion seem to establish 30 ppm as new acceptance criteria
  - Even on request no TIER 1 or OEM could confirm the level of a final acceptance criteria

Electro Corrosion - Halogen-free vs. Halide-free

- **Halide containing**
  - Heat stabilizer for Polyamide, like Potassium Iodide (KI) or Cupper Iodide (CuI)
  - The Halides are “free movable” ions Cl^-, Cr^-, I^- and ionic bonded
  - Halides are Oxidizable

Could lead to electrochemical corrosion

- **Halogen containing**
  - Flame-retardant (e.g. brominated polymers)
  - The halogens are covalent bonded on the polymer
  - Halogens are not “free movable” and not oxidizable

Should not lead to electrochemical corrosion

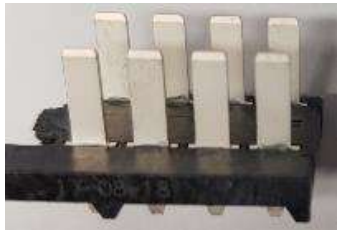
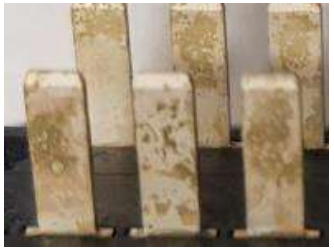
Halogen containing compounds are used in E&E applications!

Electro corrosion Quick Test - set up and test condition

- **Test equipment:** Thermal chamber
- **Sample:** Plastic pellets 20 g
- **Metal contacts:** Silver –plated contacts
- **Liquid:** Fully demineralized water
- **Preparation:** Immersion of metal contacts and plastic pellet into liquid in sealed glass bottle
- **Test parameters:** 85°C / 7 days

Source: LyondellBasell

Set up and test condition

Connector with Silver-plated pins Initial	Results after 7 days immersion @ 85°C			
	Pure fully demineralized water	PA66 GF30 inorganic heat stabilized	Schuladur A3 GF 30 PBT/ASA GF30	Schuladur A3 GF30 FR1 PBT/ASA GF30 halogenated flame retardant
				
				

Halogenated flame retardant does not lead to electrochemical corrosion

Source: LyondellBasell

Transportation (automotive – e-mobility)

- **Plugs and Charger in E-mobility**
  - Key requirements
    - Good dimensional stability
    - Excellent high impact properties
    - UL 94 V-0

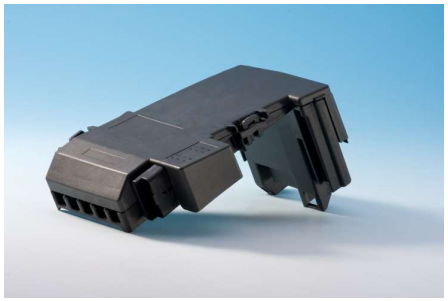
- **Products: PA/ABS blend and PBT unreinforced**
  - ***Polyflam*® RMMK 125**, PA/ABS, unreinforced, high impact, V-0 @ 0,8 mm
  - ***Schuladur*® *A MV14 SHI FR1***, PBT, unreinforced, high impact, V-0 @ 0,8 mm

Source: LyondellBasell, Phoenix Contact

Transportation (public and automotive)

- **Batterie housing / Batterie connector / Fusebox**
  - Key requirements
    - Good dimensional stability
    - Good mechanical properties
    - UL 94 V-0
    - Railway: meet standard EN 45545-2 in terms of LOI, smoke density and –toxicity

- **Products: PP-FR**
  - ***Polyflam*® RIPP 4000 OSD**, PP copo, unfilled, V-0 @ 0.75 mm, **halogen-free**
  - ***Polyflam*® RIPP 3125 CS1**, PP copo, 25% talc filled, V-0 @ 1.5 mm
  - ***Polyflam*® RIPP 3625 CS1**, PP copo, 25% mineral filled, V-0 @ 1.5 mm



Source: LyondellBasell

Transportation (automotive)

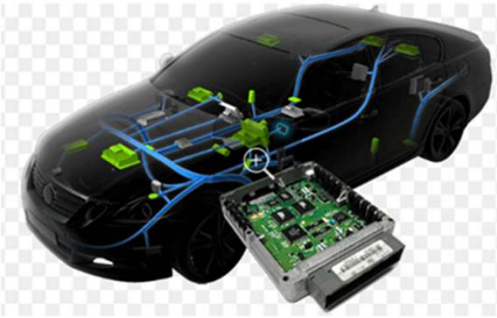
- **Batterie connector / Fusebox**
  - Key requirements
    - Low warpage
    - Good mechanical properties
    - UL 94 V-0

- **Products: PA6 and PA66, reinforced**
  - ***Schulamid*® 6 GBF 3015 FR2**, PA 6, 30% glass fiber, -beads filled, V-0 @ 0.75 mm, **halogen-free**
  - ***Schulamid*® 6 GBF 3015 FR4**, PA 6, 30% glass fiber, -beads filled, V-0 @ 1.0 mm
  - ***Schulamid*® 66 GBF 3020 FR4**, PA66, 30% glass fiber, -beads filled, V-0 @ 1.5 mm

Source: LyondellBasell

Transportation (automotive)

- **Power control unit**
  - Key requirements
    - Good dimensional stability
    - Low warpage
    - Good mechanical properties
    - UL 94 V-0



- **Products: PBT/ASA-FR, reinforced**
  - ***Schuladur*® A3 GF 20 FR1**, PBT/ASA blend, 20% glass reinforced, V-0 @ 0.75 mm
  - ***Schuladur*® A3 GF 30 FR1**, PBT/ASA blend, 30% glass reinforced, V-0 @ 0.75 mm

Source: LyondellBasell

Transportation (automotive)

- **Radar housing / Connector**
  - Key requirements
    - Good dimensional stability
    - High flowability
    - Good mechanical properties
    - UL 94 V-0

- **Products: PBT-FR, reinforced**
  - ***Schuladur*® A GF 30 HF2 FR1**, PBT, 30% glass reinforced, V-0 @ 1.5 mm
  - ***Schuladur*® A GF 30 HF2 HI FR1**, PBT, 30% glass reinforced, high impact, V-0 @ 1.5 mm

Source: LyondellBasell

Summary

- Flame retardant plastics are becoming more important in the automotive industry
- Electrification and miniaturization are the key driver of FR plastics (48V)
- Standards and regulations have to be defined and carefully to be discussed
- Halogenated flame retardants do not lead to electrochemical corrosion and are used in the field

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