pinfa
Phosphorus, Inorganic & Nitrogen Flame Retardants Association

Your newsletter for non-halogen fire safety solutions n° 158 March 2024

CEFIC AND PINFA IN ACTION

pinfa-NA free webinar: "Still not Safe"

20th March, 16h30-17h30 CET. Lessons from Golden Age Nursing Home fire: author and HSE professional, Eric Ebinger. November 1963. 63 residents die in tragic nursing home fire. "The Great Fires of Chicago in 1871 and Boston in 1872 ushered in a trove of laws and policies to protect innocent civilians from massive fires in our large metropolitan areas. But accidents still happen". Based on first-hand account, the facts which led to this disaster and improvements to fire safety which have followed.

Webinar "Still not safe: the fire that woke a nation", 20th March 2024, 11h30-12h30 EST USA (16h30 – 17h30 CET Brussels Paris time)
https://www.pinfa-na.org/stillnotsafe

The Antwerp Declaration for a European Industrial Deal

Industry calls for European Industrial Deal

Over 70 industry leaders call for a European Industrial Deal to complement the Green Deal and keep high quality jobs. On 20th February, almost 20 industrial sectors including Cefic (the European Chemical Industry Council), presented 'The Antwerp Declaration for a European Industrial Deal' to Belgian Prime Minister, Alexander De Croo, and to Commission President, Ursula von der Leyen. The declaration underlines the commitment of industry to Europe and its transformation and outlines urgent industry needs to make Europe competitive, resilient, and sustainable in the face of difficult economic conditions. It outlines 10 concrete actions, calling for a European Industrial Deal to be at the core of the upcoming EU Strategic agenda 2024-2029. These actions include improving the single market, increasing EU's raw materials security, a new spirit of law-making and facilitating innovation, among others. There are currently over 700 signatories and growing. Companies, organisations and associations can sign and support the Declaration here.

"The Antwerp Declaration for a European Industrial Deal", European Industry Summit: a business case for Europe, 20th February, Antwerp, Belgium https://antwerp-declaration.eu

POLICY AND REGULATION

EU consultation on melamine

To 5th April: ECHA consultation on inclusion of melamine in REACH Annex XIV (Authorisation List). If a chemical is on the Authorisation list, then any company wishing to use it (for specified uses/conditions and after a specified "sunset" date) must obtain case-by-case authorisation from the European Commission. ECHA (European Chemicals Agency) is looking for additional information on uses of melamine, on the supply chain, on possible exemptions from Authorisation and on socio-impacts of inclusion on the Authorisation list. The proposed Authorisation would concern uses of melamine uses > 10 000 t/y "as additive in foams and coatings, use in resins". It is pinfa's understanding that this would concern use of melamine as such in intumescent fire protective coatings and in polymers, but would not concern production or use of melamine derived compounds as PIN flame retardants (e.g. melamine phosphate, melamine cyanurate, melamine polyphosphate, melamine-poly(zinc phosphate), melamine pyrophosphate, melamine cyanurate).

For further information, see pinfa Q&A on melamine-based flame retardants. – EMPA (European Melamine Producers Association) information on regulatory status of melamine https://melamine.cefic.org/regulatory-status/ and EMPA Q&A EMPA Q&A for clarification: https://melamine.cefic.org/wp-content/uploads/2024/03/FAQ_Melamine_SVHC_QA_EMPA.pdf

ECHA (European Chemicals Agency) "Consultation on draft recommendation for inclusion in the Authorisation list", public consultation open to 5th April 2024. The consultation also concerns possible Authorisation of four other chemicals. https://echa.europa.eu/draft-recommendation-for-inclusion-in-the-authorisation-list-consulation

EU consultation: aromatic brominated FRs

To 5th April: ECHA public call for evidence and information on aromatic brominated flame retardants. This initiates implementation of the ECHA Regulatory Strategy for Flame Retardants (European Chemicals Agency, March 2023, see pinfa Newsletter n°147) which also identifies most PIN flame retardants as low hazard - no regulatory action needed now (e.g. mineral, nitrogen, inorganic phosphate and several types of organo-phosphorus FR) and recommends further data collection and assessment of some organo-phosphorus FRs. This ECHA public call for evidence is requesting information on uses of aromatic brominated FRs (in which sectors and end-uses, which polymers and at what doses?) volumes used, losses to the environment and end-of-life. ECHA identifies 50 concerned brominated FRs and indicates that information on other FRs will also

be collated. The data collected will support the Commission decision on whether or not to request ECHA to prepare a restriction dossier on aromatic brominated FRs. It is stated that a second consultation will be launched soon on alternatives to aromatic brominated FRs. pinfa has started preparing information on PIN FR alternatives to input to this second consultation.

ECHA (European Chemicals Agency) public consultation "Call for evidence on aromatic brominated flame retardants", open to 5th April 2024. https://echa.europa.eu/calls-for-comments-and-evidence/-/substance-rev/75708/term

FIRE TRAGEDIES

Series of tragic fires in China

13 children dead in a school dormitory fire, 39 in a shop fire, 15 in an appartement building. Xi Jinping calls for resolute action. China has seen a series of tragic fires. 13 children died in a fire in the private Yingcai nursery and primary school, Yanshanpu village, near Nanyang, Hunan province, 20th January. At least 39 people died in a fire which started in the basement of a shop in Xinyu, Jianxi province, 24th January. 15 people died and more than 40 were injured in a fire which damaged several floors of a block of flats in Nanjing, North-West of Shanghai, 23rd February, possibly starting in an e-bike store (not confirmed). 26 people died and over 60 were taken to hospital from a fire in an office building, Luliang City, Shanxi province, 23rd November 2023. 29 died in a fire in the Changfeng Hospital in Fengtai district, Beijing, probably started when a spark from renovation work ignited paint, 18th April 2023. China's President, Xi Jinping, is cited as calling for "deep reflection" on efforts to "curb the frequent occurrence" of such incidents, and has demanded authorities safeguard lives and properties and enact "resolute containment" of fire deaths.

"China: 13 dead after school dormitory fire in Henan province", BBC, 20 January 2024 https://www.bbc.com/news/world-asia-68038976

"Xinyu: Dozens dead after fire breaks out in China shop", BBC, 24 January 2024 https://www.bbc.com/news/world-asia-china-68082908

"China: 15 dead and dozens more injured in Nanjing flat fire", BBC, 24 February 2024 https://www.bbc.com/news/world-asia-68390274

"China: 26 dead and scores in hospital after Shanxi building fire", BBC, 16 November 2024 https://www.bbc.com/news/world-asia-china-67435673

"A hospital fire killed 29 in Beijing, but residents were kept in the dark for hours", CNN, 19 April 2023 https://edition.cnn.com/2023/04/19/china/china-beijing-fire-censorship-intl-hnk/index.html

Photo Commons Wikimedia https://www.youtube.com/watch?v=kqIdWwAq3FA https://commons.wikimedia.org/w/index.php?curid=145798714

10 dead, 14 injured in Valencia flats fire

pinfa shares the grief of all those impacted by the devastating fire in two blocks of flats, Campanar, Valencia, 22nd February. Flames engulfed a 14-storey apartment block, and then spread and destroyed a second adjoining 10-storey block. The flats were built in 2008 by FBEX who went bankrupt in 2010. Officials are not commenting on the possible initial cause of the fire, which started from a flat around half way up the building. Some sources suggest that fire may have started with an electrical fault in an external awning motor on a balcony. Other sources suggest that the fire started inside a flat. The fire spread rapidly over the whole of the two buildings and this is attributed to strong winds and to Aluminium Composite Material cladding (ACM). ACM panels can offer high performance thermal insulation (see e.g. Bonner & Rein, 2018), but the air gap behind them can cause a chimney effect, leading to rapid fire spread if appropriate fire safety precautions are not ensured. This is the same general type of cladding which contributed to the Grenfell Tower fire tragedy, London, 2017, in which 72 people died (pinfa Newsletter n°146). Fire standards for such cladding panels have been tightened following the Grenfell fire, but the Valencia flats' panels were from before these new requirements. It is to date not clear what insulation materials were present in the ACM cladding used on this building. Spanish media indicate that such cladding can either be flame retardant or not, and that no official information is yet available concerning the panels on these buildings. The BBC and other media suggest that the panels on the building were 'Larson' panels from the company Alucoil, but that information is not available on whether or not they were fire safety treated.

The Spanish Rigid Polyurethane Industry states that there is no evidence that the cladding panels contained polyurethane: https://www.feique.org/ipur-no-hay-evidencias-de-que-el-poliuretano-fachada-del-edificio-incendiado-en-valencia/

The company 3A Composites (Alucobond) states that, contrary to some media reports, the panels on the building were not their products, and that, to ensure building safety, they only supply panels with flame-retardant or non-combustible cores. https://alucobond.com/news/house-fire-in-valencia

BBC "Valencia fire: Grenfell-style cladding fear after blaze", 28 February 2024 https://www.bbc.com/news/world-europe-68415802

PINFA EVENT SUMMARIES

Flame retardants in EU Energy Transition

pinfa keynote at European Bureau for Conservation & Development meeting in European Parliament.

Adam, Jarubas, Member of the European Parliament, opened the meeting underlining there can be no green transition without the formulation of clear solutions to guarantee fire safety across the Union. The green transition will mean increased use of electrical energy and of wood as a renewable materials, bringing new and increased fire risks.

Adrian Beard, pinfa Chairman and **Clariant**, further explained the fire risks of new technologies such as data centres, batteries, renewable electricity. He explained how flame retardants can limit these risks by protecting against ignition: start of fire caused by small heat sources or electrical faults. Standard fire test methods are designed to verify this fire prevention (UL 94 small flame, "glow wire" simulating electric overheating). Flame retardants also slow the spread of fires which do start, so increasing escape time. Flame retardants must not only deliver fire safety and be compatible with performance specifications of materials, they must also offer durability (remain present and effective over product lifetimes, including through product reuse or recycling), environmental sustainability and socio-economic value.

Irantzu Garmendia Aguirre, European Commission Joint Research Centre, presented the work of the JRC developing the EC framework for "Safe and Sustainable by Design" (SSbD). The aim is to create a SSbD way of thinking to design, develop, produce and use chemicals and materials that while providing the desirable function are safe and sustainable throughout the entire life cycle. The need for engagement of the entire chemicals – materials value chain, and importance of integrating safety and sustainability in innovation with functionality were emphasised.

Chris Slootweg, University of Amsterdam, also emphasised the challenge of combining durability of flame retardants (needed for recycling) with avoiding environmental persistence. Leaching of FRs out of products must be avoided. SSbD principles and recycling can be combined with Green Chemistry to develop new sustainable flame retardants.

Laurent Tribut, Schneider Electric, emphasised the essential contribution of the company's products to electrical safety (e.g. circuit breakers), and so to reducing fire risks. Schneider Electric is extending this further with development of fire and fault detectors to include into electrical boxes. Flame retardants are used only when needed for fire safety, to prevent ignition and fire spread, and this is around half of the company's materials. Challenges include increasing fire risks with higher voltages in new energy systems, DC power, battery flashover potential at the same time as demanding material requirements for engineering polymers. Flame retardants used must ensure durable protection of product life times of decades, and be recycling-compatible.

Krzysztof Biskup, European Fire Safety Alliance, pointed out that the EU "renovation wave" aimed at achieving higher energy performance and sustainability of buildings, may increase fire risk if not properly addressed. Although fire safety is a competence of Member States, the EU should play an important coordinating role, covering the harmonisation of fire statistics, shared fire safety research, exchange of experiences, and considering fire safety in regulatory documents (e.g. in the Energy Performance of Buildings Directive, Construction Products Regulation). He pointed to the #keepEUfiresafe campaign calling on the EU to develop a Fire Safety Strategy, what was described in the EU Fire Safety Manifesto 2024-2029 (see pinfa Newsletter n°155).

Discussion, moderated by **Régine Roncucci, European Parliament Intergroup on Climate Change, Biodiversity and Sustainable Development**, noted the need for regulation to push towards sustainable flame retardants. Without this, older, less environmentally friendly options be preferred by much of the market because they are cheaper. The need for a global approach was underlined. **Laurent Tribut, Schneider Electric** noted that his company and other responsible manufacturers apply demanding EU chemical safety requirements worldwide, but other companies overseas not. **Christian Panofen, Huber**, and also other participants, underlined that EU manufacturer of cars or electrical equipment will be disadvantaged if cheap imported products contain chemicals which are restricted for use in Europe. Chemicals in imported items need to be regulated and verified.

Adam, Jarubas, Member of the European Parliament, concluded that the meeting had improved understanding of what are flame retardants and how they work. He underlined that there is no safe EU Green Deal without adequate fire safety measures. He supports the European Fire Safety Manifesto and hopes that the EU Parliament elected in June will take this forward. He called the establishment of an EU Fire Safety Strategy.

"Fire safety and Europe's climate ambition: The role of sustainable flame retardants in Europe's energy transition", European Bureau for Conservation & Development, European Parliament, 14th February 2024
https://ebcd.org/events/hybrid-event-fire-safety-and-europes-climate-ambition-the-role-of-sustainable-flame-retardants-in-europes-energy-transition/

pinfa-NA SPE Flame Retardant Week 2024

pinfa-NA's online event for plastics professionals, with the Society of Plastics Engineers, attracted over 100 participants, with eight strongly attended speaker sessions over four days, plus panel sessions. This National Week of Flame Retardants covered regulatory developments impacting flame retardants worldwide, how PIN FRs work in different plastics, fire performance testing and standards and a range of different innovative PIN FRs for different polymers and applications.

Each speaker presentation (20 minutes) was followed by online questions, with active exchanges both with speakers and between participants in the online Chat. A wide range of questions were raised and discussed, with technical questions on specific compounds and applications answered both online or after the event directly to participants.

Roger Avakian, polymer formulation expert, summarised different non-halogenated flame retardant and drip suppressant technologies. He noted that PIN FRs can act by different mechanisms: inhibition of combustion reactions in the gas phase, lease of inorganic gases (diluting oxygen available to fire), heat sink by release of steam or formation of a protective char or ceramic barrier layer ("condensed phase"). Specific fire tests are designed to assess fire performance of plastics in conditions reflecting prevention of real fires.

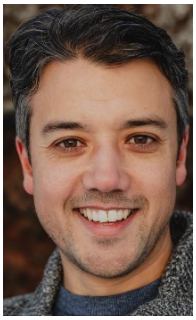
Margaret Baumann, Performance Polymers, updated on regulatory developments impacting flame retardants and synergists worldwide. Investors and customers are also pushing industry to move away from chemicals identified as having environment or health hazards. Most regulations to date and expected target certain problematic halogenated FRs (polybrominated PBDEs, HBCD, TBBPA, TCPP and expected in the future TBNPA) or in some cases all halogenated FRs (e.g. for certain applications: State of New York, EU Ecolabel). However, several non-halogenated phosphorus esters (TPP) are also regulated. A significant question today is that of perfluorinated drip suppressants (e.g. PTFE polytetrafluoroethylene, KPFBS potassium perfluoro butanesulfonate). Apple has announced that it will phase out PTFE. The PIN FR industry today proposes non-halogenated solutions to avoid flaming dripping in PIN FR plastics (see pinfa Newsletters n°s 154, 156).

James Zhou, Avient, explained the distinctions between and roles in fire safety of codes, standards, regulations, specifications and guides. He presented ten aspects of polymer fire behaviour, and how PIN FRs can mitigate or improve these: thermal degradation, ignition, extinction, dripping and flaming droplets, flame spread, heat release rate, fire endurance, smoke evolution, toxic smoke gases, char formation. Non-toxic polymeric phosphorus PIN FRs are available which reduce smoke emission and smoke toxicity, and can achieve UL 94 V-0 (?3.2 mm) in several polymers with PIN flame retardants.

Xiudong Sun, FRX Polymers, presented application of the company's polyphosphonate PIN FR in a range of polymers including: TPUs, polycarbonate (PC), PC/PBT, PC/ABS. The polymeric phosphorus-based PIN FR offers low toxicity, non-migrating and is transparent, with a range of melt-flow characteristics. It is suitable for thermoplastics (including spinning, film extrusion) and for thermoset oligomers and reactive. Examples include polyphosphonate homopolymers and carbonate copolymers used in PFAS free formulations. Phosphorus content rangers from 6.6 to 10.6 %. The product is Greenscreen® Benchmark 3, TCO and Oeko-Tex approved, and a ChemSec Marketplace named alternative to brominated FRs. FRX polymers presented data on PFAS and PTFE free formulations using polyphosphonates with and without synergists.

Maz Bolourchi, Imerys, presented performance benefits of the company's specific mineral PIN FR synergists. The company offers nine different types of mineral as polymer additives, with tailored particle shapes, sizes and chemistries, including for fire performance of engineering plastics, polyolefins, rubbers etc. The mineral additives can improve compound properties, improve melt flow, reduce impact of glass fibres on processing (debundling) and reduce corrosion of processing equipment. Fire resistance is improved by enhancing char integrity. Applications include automobile, electronics, building and construction.

Brian Hanrahan, Lumina / Celestial Materials, presented the company's anorthosite inorganic PIN FR, a natural high-purity, non-alkaline, Feldspar calcium – aluminium - silicate mineral, mined in Greenland. In fire, the mineral reacts in heat to generate a ceramic protective coating on the polymer surface. To date, UL 94 V2 is achieved in high density polyethylene at 30% loading. Work is underway to improve effectiveness by adding an activator and drip suppressants. The anorthosite can be combined with the widely-used inorganic PIN FRs ATH and MDH.



Amit Paul, Paxymer, presented the company's carboxylic and acrylate copolymers (see pinfa Newsletter n° 88), which are a PIN FR synergist effective with phosphorus, inorganic and nitrogen flame retardants in a number of different polymers. Use of the synergists at 1 – 5 % loading increases the protective char layer in fire and makes the char layer less brittle, accentuates gas phase fire inhibition, reducing dripping, smoke emission and smoke toxicity. The synergist can also improve compound processing and mechanical performance for a given fire performance. Paxymer sees a trend towards acceptance of more complex compound formulations, necessary to achieve demanding fire standards and performance specifications with safe and sustainable additives.

Gary Wnek, Case Western Reserve University, discussed non-halogenated PIN intumescent coatings to reduce flammability and smoke emission of HDPE (high density polyethylene) and other highly flammable thermoplastics. PIN components tested include poly acrylic acid, tannic acid (bio-based), ammonium polyphosphate, sodium silicate, with an epoxy binder to generate a coating. Resistance of up to one hour to a direct flame was achieved. In addition, intumescence was rapid enough to quickly cover a hole through the coating and HDPE (up to an 18 mm diameter), and so prevent burning.






A final discussion panel session brought together the above speakers with **Qingliang He (Lanxess), Paul Hardy (Amfine), Emmanuel Laval (RioTinto), Tobias Moss (Budenheim), Subra Narayan (Clariant), Rainer Sauerwein (Nabaltec)**.

The discussion noted that the market for PIN flame retardants is growing faster than the overall flame retardant market (c. +8% versus +6% per year) – see also pinfa Newsletter n°156. Investments are being made by industry to ensure supply in response to this growing demand.

Formulation with PIN FRs to achieve demanding fire testing specifications can be discussed with suppliers and experts, because there is no one solution to work with all polymers, and combinations of PIN FRs and PIN synergists can be identified to provide solutions and to reduce FR loadings.

Questions raised included development of bio-based PIN FRs, data on life cycle analysis, compounding to achieve fire performance requirements with glass fibres and PIN FRs, questions about regulatory perspectives for melamine and boron compounds, PIN smoke suppressants and PIN solutions to replace antimony and perfluorinated anti-drip additives.

National Week of Flame Retardants 2024, SPE (Society of Plastics Engineers) and pinfa North America, online, 22-25 January 2024, register here to watch recordings of all sessions
https://www.4spe.org/i4a/pages/index.cfm?pageid=8457

RESEARCH AND INNOVATION

Transparent, adhesive PIN FR solution

Evonik's new phosphorus monomer offers a safe fire safety solution (no leaching risk) for the popular material PMMA. Polymethyl methacrylate is a transparent, high-performance, thermoplastic widely used as a lightweight alternative to glass. Evonik's new phosphorus-methacrylate monomer can be used as co-monomer in the polymerization process of PMMA. Bonding to the acrylic polymer by polymerisation, it provides flame-retardancy without compromising the transparency or mechanical properties. The new monomer can also be used in other resin formulations, e.g. vinyl esters, polyesters or acrylic adhesives. It

provides flame-retardancy, improves adhesion and reduces corrosion. Applications include PMMA-sheets in construction, acrylic waterproofing roof systems, metal coatings, and wood coatings. Improved performance enables less material use and lightweighting, contributing to design flexibility and sustainability.

"Evonik launches high-performance phosphate methacrylate VISIOMER® HEMA-P 100", 17th January 2024 https://methyl-methacrylate-monomers.evonik.com/en/evonik-launches-high-performance-phosphate-methacrylate-visiomer-hema-p-100-232339.html

Stress crack proof LSF0H cable compound

Avient have launched a PIN flame retardant formulation resistant to stress cracking in armoured electrical cables. Cable sheath materials can crack when subject to tensile stress (curved installation) or pressure (underground), leading to loss installation and possible electrical misfunction. The risk is accentuated in armoured cables because metal sheath elements dilate with temperature changes. Avient's new LSF0H formulation (Low Smoke and Fume Zero Halogen) can achieve 55-61-1997 LTS1 classification for low and medium voltage cables, including in complex and armoured cable designs.

"New LSFOH Formulation from Avient Helps Prevent Environmental Stress Cracking in Armored Cables", Avient ECCOH™5983, 11 December 2023 https://www.avient.com/news/new-lsfoh-formulation-avient-helps-prevent-environmental-stress-cracking-armored-cables

Phosphite PIN FR for epoxy

Research proposes maleimide phosphite PIN FR, achieving UL 94 V-1 (3 mm) at 2.5% loading in epoxy (0.12% phosphorus). The phosphorus and nitrogen containing molecule was synthesised by reacting phosphorus with N-(4-hydroxyphenyl)maleimide (ref. 2 below) to generate the maleimide phosphite TDPPI (tris[4-(2,5-dioxopyrrol-1-yl)phenyl] phosphite). This was reacted into curing of an epoxy resin, diglycidyl ether of bisphenol-A. Inclusion of TDPPI into the epoxy resulted in moderate transparency, improved thermal stability and improved mechanical parameters (tensile strength, Young's modulus, flexural strength, Izod strength), increased LOI from 25% to 31% and UL 94 V-1 rating (3 mm, no dripping). The authors consider the fire protective effect to result from charring and synergy between the phosphorus and maleimide.

"Novel self curable phosphorus- and spiro phosphorus-based maleimides: synthesis, characterization, cure behavior and thermal properties", A. Ranjith et al., Phosphorus Sulfur Silicon Relat Elem. 2023;198(7):583-590, https://doi.org/10.1080/10426507.2023.2176499

"Revolutionizing epoxy performance: A new flame retardant with phosphorus and maleimide for enhanced cure behavior, thermal stability, flame retardancy, and mechanical properties", A. Ranjith et al., Polym Eng Sci. 2023;63:3963–3974, https://doi.org/10.1002/pen.26497

Flame retardant anti-corrosion coating

Axalta non-halogenated flame retardant protective and decorative coating for metals in buildings, mobility, offshore. The treatment is an all-in-one (no primer) spray-on thermosetting and protects from sunlight, water and salt and abrasion and provides electrical and sound insulation, as well as being durable and easy to clean. It offers UL 94 V-0 and European railway standard EN 45545-2 fire safety. The coating does not contain halogens (bromine, chlorine), BPA nor heavy metals, and can have drinking water and food contact approvals. A range of finishes and colours are available. Applications include construction, transport systems, outside furniture and fencing, civil engineering.

"Do you need a coating that minimises the spread of fire?", October 2023
https://www.linkedin.com/posts/axaltaindustrialcoatings_axalta-thermoplastics-flameretardant-activity-7122869612286750720-m-Ko

Axalta, "Axalta Develops Halogen-free Flame Retardant Thermoplastic Anti-corrosion Solution",
https://www.coatingsworld.com/contents/view_breaking-news/2022-06-21/axalta-develops-halogen-free-flame-retardant-thermoplastic-anti-corrosion-solution/

Axalta Thermoplastic Power Coatings
https://www.axalta.com/thermoplasticcoatings_global/en_GB/products/plascoat/ppa-571-range.html

Hydrogels as novel PIN FRs

Review suggests highly porous gels, which release water to prevent and slow fire, offer an innovative new PIN FR concept. Hydrogels are 3D crosslinked polymeric materials, based on natural or synthetic polymers, which can be prepared as coatings, films, additive particles or slabs, or built into cavities of 3D-printed structures. They are highly porous, so can fix water in their structure. This is released and vaporised in fire, absorbing heat and diluting fire gases. LOI of up to 60% can be achieved. The polymers of hydrogels are generally flammable, but can be modified using silica materials or other PIN FRs to make them into a fire-protective layer. Aerogels are similar polymer structures but without the water (empty pores) and are highly insulating, and can provide a fire protection barrier if flame retarded. This twenty-page review summarises synthesis, applications and flame retardancy of hydrogels and aerogels, based on over 120 studies, concludes that such gels offer a promising new approach to PIN fire safety. Challenges are to avoid too-early water release, to reduce costs and to further research integration of PIN FRs in to the gel structures.

"Next-Gen Flame Retardants: hydrogels & aerogels", Plastics Engineering", 1st February 2024,
https://www.plasticsengineering.org/2024/02/next-gen-flame-retardants-hydrogels-aerogels-003269/

Hydrogel and aerogel-based flame-retardant polymeric materials: A review", H. Vahabi et al., J Vinyl Addit Technol. 2024;30:5–25,
https://dx.doi.org/10.1002/vnl.22041

PUBLISHER INFORMATION

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