pinfa
Phosphorus, Inorganic & Nitrogen Flame Retardants Association

Your newsletter for non-halogen fire safety solutions
No. 96 November 2018

Fire safety is a crucial enabling factor for tomorrow's technological innovation and for sustainability. *Energy efficient buildings, electric vehicles, plastics recycling, bio-based materials, greener electronics … You will find all these themes in this Newsletter, because that is where both research and industrial development of PIN flame retardants are in the news today. pinfa believes that fire safety should not be seen as a constraint for innovation in materials, electronics and electrical products and energies or modern buildings, but as a core value, integral to product quality and societal trust. PIN flame retardants can contribute to fire safety in tomorrow's materials, products and buildings, whilst enabling compatibility with recycling obligations and sustainability objectives. Studies summarised in this Newsletter illustrate the range of different PIN FR chemistry solutions, indicate that PIN FRs can reduce smoke toxicity (measured in fire tests) and point to the need to ensure that flame retardants used are compatible with future material recycling. pinfa is working on these questions. We are organising a panel at AMI Fire Resistance in Plastics (Cologne, 11th December, see below). We are currently carrying out testing to compare smoke toxicity from several pure polymers to that from PIN flame retarded polymers. pinfa and pinfa North America are also organising workshops on fire safety in electric vehicles and in green electronics.*

Stakeholder meeting on fire safety in EU Horizon Europe

Brussels 4th December 2018. A wide range of stakeholders will discuss fire safety in the EU's research and technology in Horizon Europe (100 billion €, 2021-2028, see pinfa Newsletter n°93) and the global IAFSS "Agenda 2030 for a Fire Safe World" (see below in this pinfa Newsletter). With support of ISO TC 92, CEN / CENELEC, pinfa, Brandforsk, Kingspan, Modern Building Alliance, NFPA and Rockwool.

Registration https://www.eventbrite.co.uk/e/workshop-to-define-a-fire-safety-mission-for-europe-registration-50848694815

Fire Resistance in Plastics

Flame Resistance in Plastics and the Circular Economy

pinfa and AMI are organising a specialist panel on flame retardants in the plastics circular economy at AMI's Fire Resistance in Plastics Conference, Cologne, Germany, 10-12 December 2018. This is the world's biggest conference on flame retardants, with over 170 delegates from industry (plastics, compounders, additives) and R&D in 2017. The Circular Economy panel will bring together specialists to discuss the EU Plastics Circular Economy strategy, interactions between FR selection and plastics recycling objectives, and fire safety treatment of recycled polymers.

https://www.ami.international/Events/Resources/Programme/Fire_Resistance_in_Plastics_18.pdf

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Workshop on design for fire safety in green electronics

San José, California, 30 April – 1 May 2019. Day 1 will provide an overview of flame retardants, fire testing and formulation for electrical and electronic applications, with presentations by Alex Morgan (UDRI), testing and standards organisations and compounders. Day 2 will discuss emerging flame retardant needs for green materials for electronics applications, resulting from developments in performance and fire testing requirements and sustainability specifications, with OEM and component manufacturer perspectives.

www.pinfa-na.org Abstract submission: rweiler@amfine.com
Further information and registration dwagner@pinfa-na.org

pinfa China: fire safety challenges in electro-mobility

pinfa organised the first workshop on fire safety challenges in electro-mobility with 140 attendees in Shanghai, 22nd November 2018. With its ambitious targets for electric vehicles, China is leading globally in the sales of electric vehicles with almost 600 000 cars sold in 2017, three times the number of the next runner up, the USA. Electric vehicles pose new fire risks coming from the battery and high voltages and currents in charging and operating the cars. Safety standards for batteries, cables, connectors etc. are still under development and not globally harmonized. For polymer materials particular challenges include resistance to arcing (high current tracking index = CTI), colourability and colour stability, especially for the “signal orange” for high voltage parts, where a CTI of 600 V is becoming a regular requirement. To protect against risks from electrical faults, UL 94 V0 is required by most OEMs in China.

pinfa is also planning similar workshops in Japan and in Europe in 2019 – stay tuned for details.

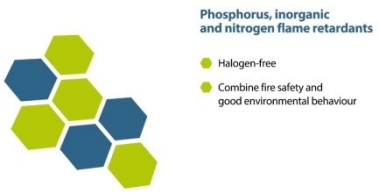
On this occasion, also **pinfa China was officially inaugurated** – the founding members in China are JLS, Budenheim, Clariant, Huber, Nabatec and Presafer. More members are welcome to join us! The first chairman of pinfa China is EngHeng Khoo, Head of the Business Line Flame Retardants, Clariant, who gave a video welcome address at the e-mobility workshop.

Energy efficient buildings and fire

RISE is currently starting, for the Norway Directorate for Civil Protection (DSB) and the Norway Building Authority (DiBK) an assessment of how new materials and technologies in buildings impact fire safety. This will build on several projects and on the 2015 SPFR report on “Energy Efficient Buildings and Fire Safety”. A summary in RISE’ BrandPosten Newsletter identifies as challenges: the use of advanced technologies such as control systems and ventilation, renewable energy installations (solar power, heat pumps, batteries), new construction materials, composite materials and use of timber and wood in buildings.

“Energy Efficient Buildings and Fire Safety”, RISE BrandPosten #58 2018, p12-13 https://www.sp.se/sv/units/risesafe/safety/fire/brandposten/Sidor/default.aspx and P.

Nordlokken et al. SPFR report A15 20129:1 https://dibk.no/globalassets/02.-om-oss/rapporter-og-publikasjoner/energibesparende-bygg-og-brannsikkerhet_sp-fire-research_2016.pdf



New pinfa introduction video

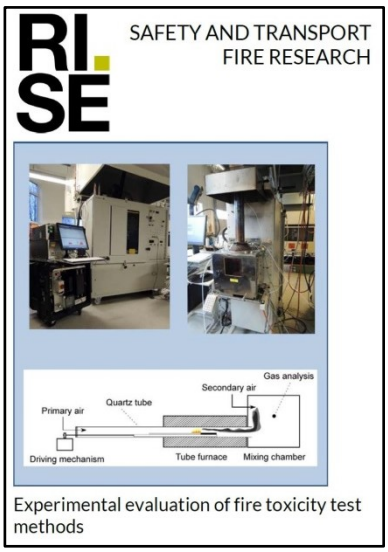
pinfa has published a new two minute video explaining who we are and what we do. Infographics explain how different (phosphorus, inorganic and nitrogen based) PIN flame retardants function to reduce fire in materials and their environmental and health profile advantages. pinfa's positive and transparent advocacy approach is explained, underlining openness to dialogue with stakeholders, NGO's, experts and policy makers, as well as pinfa's objective of wide communication of innovations and new applications of PIN-based fire safety.

https://vimeo.com/comana/review/292685230/30eb727f75

Separating brominated FR contaminated plastics

In EU-funded INSPIRE4LIFE project, SRC Bertin Technologies and Rescoll have developed an automated system to detect plastics containing brominated flame retardants (BFRs) in electrical and electronic waste (WEEE). EU regulation requires that WEEE containing BFRs be separated out of the recycling stream, because of concerns about these chemicals. The Quantom InLine technology uses LIBS (Laser-Induced Breakdown Spectroscopy) to both identify the polymer, enabling sorting of the WEEE plastics, and to detect the presence of BFRs, enabling exclusion of contaminated materials from the recycling streams. The system is fully automated, operates even on coloured or black plastics, achieving 97% accuracy in polymer determination, and can treat 12 items/minute (up to 150x80 cm), that is around 1.3 t/h. The following polymers are identified: ABS, ABS-PC, HIPS, HIPS-PPE, ABS-PMMA, PVC, PA, PP-PE, PPT. Flame retardants (Br, Cl, P) are identified from 1% w/w (of element, e.g. 1% P). Demonstration trials have successfully produced 3D printing filaments from 100% recycled HIPS (sorted, shredded and mechanically re-extruded).

LIFE INSPIRE project – Bertin Technologies http://www.libs-quantom.fr/projet-life/presentation/

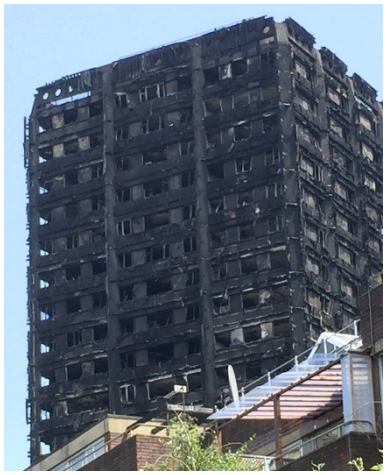


Experimental evaluation of fire toxicity test methods

Comparison of smoke toxicity test methods

RISE Fire Research has published a comparison of four different smoke toxicity test methods. The report compares results for four commercially-available insulation materials: black methyl methacrylate, five polymeric foams, two organic fibres and four mineral fibres. It is not specified what were the polymers or fibres but elemental analysis is provided. The mineral fibres contained 1.5-3.2% carbon, possibly bonding or covering materials. Four smoke test methods were used: ISO/TS 19700 Steady State Tube Furnace (SSTF), Controlled Atmosphere Cone Calorimeter (CACC), EN 4554-2 Smoke chamber Test and gas production by FTIR. Tests included flaming and non-flaming (pyrolysis) conditions. It is noted that different smoke gases are detected in different tests, for example HBr only in SSTF tests despite significant presence in one of the polymeric foams. The report concludes that, for flammable materials, the combustion behaviour is greatly influenced by the test conditions.

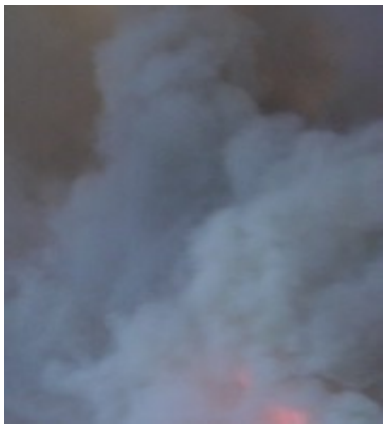
"Experimental evaluation of fire toxicity test methods", P. Blomqvist & A. Sandinge, RISE Report 2018:40 http://www.diva-portal.org/smash/get/diva2:1219112/FULLTEXT01.pdf



Grenfell Tower fire fallout concerns

UK media (The Guardian) have reported analysis of dust and soil around Grenfell Tower showing elevated levels of PAH (polycyclic aromatic hydrocarbons) and hydrogen cyanide. The analysis is being carried out in study by Anna Stec, University of Central Lancashire, independently of the official investigations. A number of samples of soils and dusts were collected at 8 sites, both close to and up to a mile from the site of the fire which killed 72 people on 14th June 2017. The Guardian reported that contaminated soil was found up to 2/3 mile from the fire site. Dr. Stec is reported to have communicated preliminary results to Public Health England (PHE) indicating "huge concentrations" of potential carcinogens in dust and soil and in burned debris from the fire, including asbestos. She suggests that other toxicants have been found, which are not currently being measured by PHE. Her full report is expected to be submitted to PHE in Spring 2019. PHE have responded by noting that contaminants in soil can come from many sources, including past industrial emissions or coal fires. In a contradictory statement, they suggest that the plume of smoke rose vertically from the Grenfell Tower Fire but that debris which did deposit locally was cleared up in the days after the fire. The Coronor for Grenfell has called for long-term health screening for all persons exposed to smoke from the fire and the England National Health Service (NHS) has announced that survivors of the fire will be screened for effects of smoke inhalation.

The Guardian, 12 October 2018 https://www.theguardian.com/uk-news/2018/oct/12/toxins-found-in-grenfell-tower-soil-study-finds



Study says PIN FRs reduce smoke toxicity of TPU

Thirteen different combinations of thermoplastic polyurethane (TPU) with and without PIN flame retardants were tested for emission of toxic gases during thermal degradation / combustion in nitrogen and in air (TG-FTIR, static tube furnace and steady-state tube furnace). The PIN flame retardants tested were ammonium polyphosphate (APP), aluminium hydroxide (ATH) and nano-montmorillonite (MMT) in varying combinations and loadings up to 12% total. Smoke toxicity estimated by FED (fractional effective dose) was calculated based on concentrations of CO, CO_2 and HCN. Over 50% of toxicity was due to HCN. Smoke toxicity, as calculated by this method, was reduced in TPU containing APP-ATH and APP-ATH-MMT.

"Comparative study of toxicity for thermoplastic polyurethane and its flame retardant composites", C. Liu et al., J. Thermoplastic Materials 1-15, 2018 https://doi.org/10.1177/0892705718798409

PIN FR synergy reduces smoke from epoxy

The mineral and phosphorus PIN FRs hexaphenoxycyclotriphosphazene (HPCTP) and aluminium trihydroxide (ATH) were tested separately and in combination in epoxy resin, at loadings of 15% total PIN FR. ATH decreases the tensile strength of the resin, whereas HPCTP increases it, so that combinations can be used without deterioration of mechanical properties. Combinations of the two PIN FRs enabled increase in LOI from 21.5 (pure resin) to 27 – 28, decrease of up to 31% in total and

peak heat release, and decrease in horizontal burning length of up to 30%. A combination of the two PIN FRs is effective in reducing total smoke release by around 10% and reduces release of toxic carbon monoxide (COP = CO production rate). The authors conclude that these effects are due to a combination of release of water vapour from the mineral PIN FR and formation of a char residue (solid phase action) by the phosphorus PIN FR.

"Synergistic Effect of Hexaphenoxycyclotriphosphazene and Aluminium Tri-Hydroxide on Flame Retardancy and Smoke Suppression of Epoxy Resin", M. Dong, Aust. J. Chem. (CSIRO) 2018 https://doi.org/10.1071/CH17594

POP PBDEs found in recycled plastics in toys

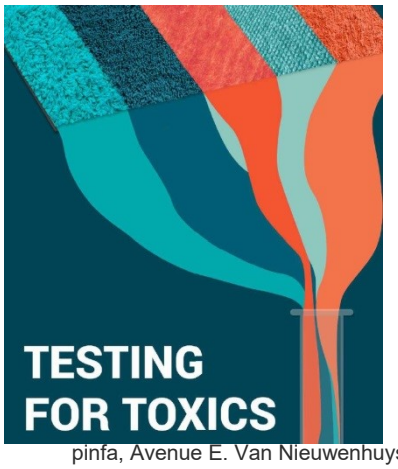
A study published by three NGOs (Arnika, HEAL, IPEN) found the brominated flame retardants PBDE in nearly a quarter (109 out of 403) of plastic consumer products, including toys, purchased in shops in 21 EU and nearby central-eastern European countries. Of the 109 items identified as containing brominated flame retardants, over 90% contained OctaBDE and over 90% contained DecaBDE. A toy guitar from Portugal showed the highest level of PBDEs at over 3300 ppm. 50 items (that is over 10% of the total purchased) exceeded the limit for OctaBDE in products made of virgin plastics (10 ppm under EU POP's regulations – Persistent Organic Pollutants). No items exceeded the limit for OctaBDE in recycled plastics (1000 ppm), but a few items did exceed this level for DecaBDE or total PBDEs (no EU limits are today fixed for these under EU POP's regulations). The study has been publicised by the European Environmental Bureau (EEB) within a wider campaign to reduce WEEE and increase recycling, and by HEAL (Health and Environment Alliance), who particularly attack brominated flame retardants, claiming that they are "toxic …disrupt hormone function and cause neurological and attention deficits in children". The European Parliament Environment Committee voted on 10th October for stricter controls of POPs on 10th October but not addressing the question of POPs in recycled plastics. The NGOs are calling on the EU to restrict all halogenated flame retardants under REACH, and to apply the same POP limits in recycled plastics as for virgin plastics.

"Toxic loophole: Recycling Hazardous Waste into New Products", Arnika, HEAL, IPEN, J. Straková et al., ISBN 978-80-87651-45-2
http://www.sverigeskonsumenter.se/Documents/Rapporter/Toxic_Loophole_report.pdf

HEAL (Health and Environment Alliance), 16 October 2018 https://www.env-health.org/european-study-exposing-toxic-e-waste-chemicals-in-childrensproducts-spurs-calls-for-policy-to-end-recycling-exemptions-for-hazardous-waste-2/

EEB (European Environment Bureau) "Electronic waste is an environmental time bomb" 19 October 2018 https://eeb.org/electronic-waste-is-an-environmental-time-bomb-ngos-warn-in-new-video/

NGO letter to European Parliament 4th October 2018 https://www.env-health.org/wp-content/uploads/2018/10/Letter-on-the-EU-POPs-reg-Recast.pdf



NGOs target chemicals in carpets and recycling

A report published by five NGOs states that "toxics" were found in analysis of carpets from leading European manufacturers, pointing at (amongst other chemicals cited) presence of the chlorinated flame retardants TCPP and TDCPP and of fluorinated stain repellents. A total of 15 carpets were analysed, a leading brand and a brand

presented as environmentally friendly from the seven largest European manufacturers, plus one 100% recycled carpet. The report notes that none of the chemicals tested were found in three carpets from the major manufacturers, and that two of these included recycled content, showing that recycling can be compatible with absence of the chemicals tested.

Press release October 2018 "Carpets in circular economy" https://changingmarkets.org/portfolio/carpet-recycling/ and full report "Testing for toxics. How chemicals in European carpets are harming health and hindering circular economy" (Changing Markets, HEAL, Recycling Netwerk, WECF France, Deutsche Umwelthilfe) http://changingmarkets.org/wp-content/uploads/2018/10/SMALL-changing-markets-layout-EN.pdf

Hazardous substances and plastics recycling

A report for the Nordic Council of Ministers assesses what actions are needed to ensure that hazardous substances in plastics do not obstruct safe recycling. The report identifies "Flame retardants" as one of ten groups of "hazardous" substances, and includes in annex a list of over 40 flame retardants, some which are clearly not hazardous (for example, amongst others, aluminium hydroxide, magnesium hydroxide or poly[phosphonate-co-carbonate]). The report is based on a literature search, stakeholder interviews and workshop. It concludes that new legislation is not needed, but harmonisation and guidance for existing legislation, and recommends: avoidance of use of "hazardous" additives in plastics, better information and training of recyclers, traceability and labelling of plastics additives content, improving analysis of plastics going to recycling and a systematic approach to risk assessment of recycling.

"Hazardous substances in plastics – ways to increase recycling", A. Stenmarck et al., IVL, IVL Svenska Miljöinstitutet AB, CRI, SINTEF, VTT, Funded by the Nordic Council of Ministers, report n° C233, ISBN 978-91-88319-51-7, April 2017 https://www.ivl.se/download/18.3016a17415acdd0b1f47cf/1491996565657/C233.pdf

BfR
Risiken erkennen - Gesundheit schützen
Bundesinstitut für Risikobewertung

Report criticises quality of REACH dossiers

A large-scale assessment of more than 3 800 REACH* dossiers (100-1000 and > 1000 tonnes) by the German Environment Agency (UBA) and Federal Institute for Risk Assessment (BfR) concludes that, for each different endpoint, 2 – 61% on average of responses in dossiers are non-compliant, and that overall (total in all dossiers) 32% of endpoint responses in > 1000 t dossiers and 19% in 100 – 1000 t dossiers are non-compliant. Non-compliance was often identified because of use of unsuitable test methods, inappropriate assessment factors for PNEC*, missing environmental exposure assessment, not all hazard information taken into account, inadequately justified QSAR* or QSAR not corresponding to ECHA* Guidance, insufficiently justified data waiving or use of waivers / adaptation for UVCBs. The difficulty of any such assessment is shown by the conclusion for 37% of endpoint responses overall as "complex" (not identified whether compliant or not). It is noted that the assessment does not include scientific evaluation of studies nor of read-across and does not represent the ECHA Compliance Check. UBA and BfR conclude that there is a strong need to improve quality of REACH dossiers. ECHA has itself repeatedly warned of missing data after its own compliance checks and has welcomed the report. ECHA has published a communication emphasising the legal

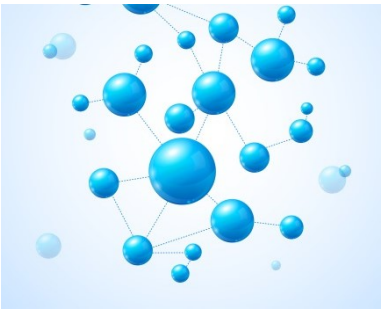
obligation to update REACH dossiers whenever any new information becomes available, concerning the chemical, its production or uses, in particular through new co-registrants. ECHA has also announced a "major enforcement project" for 2019, covering both registration obligations and control of imported substances by customs authorities.

ECHA "Evaluation under REACH: Progress Report 2017"
https://echa.europa.eu/documents/10162/13628/evaluation_under_reach_progress_en.pdf/24c24728-2543-640c-204e-c61c36401048

BfR statement "BfR Communication No 030/2018 of 25 September 201"
https://www.bfr.bund.de/cm/349/data-quality-of-environmental-endpoints-in-registrations.pdf and presentation of results by Angelika Oertel, BfR, "Data quality of environmental endpoints in registrations" https://www.bfr.bund.de/cm/349/reach-compliance-workshop-at-the-bfr.pdf at workshop "REACH Compliance - A workshop on data quality in registration dossiers", Berlin, 23-24 August 2018
https://www.bfr.bund.de/en/event/reach_compliance___a_workshop_on_data_quality_in_registration_dossiers-205356.html

ECHA "Keep your registration up to date" ECHA/NR/18/62 https://echa.europa.eu/-/keep-your-registration-up-to-date

Abbreviations: REACH = European chemical regulation (European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals EC 1907/2006). PNEC = Predicted No Effect Concentration. QSAR = Quantitative Structure-Activity Relationship modelling of chemical properties. ECHA = European Chemical Agency

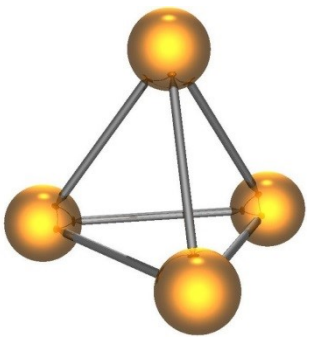


DOPO phosphonamidate PIN FRs for epoxies

Two DOPO-based phosphonamidates were synthesised (by Atherton-Todd reaction) and tested as PIN flame retardants in epoxy resin (80% DGEBA – 20% DDM). Loadings of 2.5% DDM-DOPO (total loading 0.25% phosphorus) or 5% MPL-DOPO (0.52%P) increased LOI from 26 (pure epoxy) to 30 – 31 and achieved UL94-V0 (3mm) compared to no rating for pure epoxy. Cone calorimeter tests show that lower emissions of hydrocarbons, aromatic compounds and ethers from the phosphorus PIN FR epoxy and significantly lower smoke production (TSP), up to 16.5% lower than pure epoxy. Analysis data leads to conclude that these DOPO-based phosphonamidates show a significant gas-phase flame retardant effect.

DOPO = 9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide. The two phoshonamidate derivates studied: 4,4'-diamino-diphenyl methane (DDM)-DOPO and morpholine (MPL)-DOPO

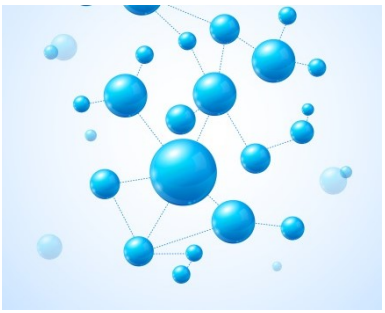
"Two high-efficient DOPO-based phosphonamidate flame retardants for transparent epoxy resin", P. Wang et al., High Performance Polymers 1–12, DOI: https://doi.org/10.1177/0954008318762037



Chemistry of organophosphorus PIN FRs

A detailed (32 page) review of chemical synthesis of organophosphorus PIN flame retardants outlines different types of chemical structure developed, different chemical reaction pathways for synthesis and their likely industrial / economic feasibility and available information on the fire performance and material characteristics of different molecules generated. The review highlights recently developed aromatic DOPO-based phosphinate compounds which offer thermal stability >250°C and so potential applications in polymers such as polyesters and polyamides. The authors note the need to consider both complexity of synthesis (economic feasibility), durability and toxicity/environmental impact in research into new molecules.

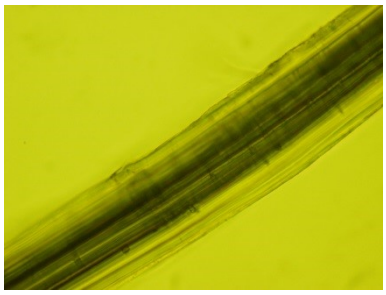
"Recent Developments in Organophosphorus Flame Retardants Containing P-C Bond and Their Applications", S. Wendels et al., MDPI Materials 2017, 10, 784; https://doi.org/10.3390/ma10070784



Colemanite mineral as flame retardant in EVA/EMA

The natural mineral colemanite (hydrated calcium borate), quarried in Turkey, was tested in EVA and EMA (ethylene vinyl acetate and ethylene methyl acrylate, polymers used in particular in wires and cables), including in combination with the PIN flame retardants magnesium hydroxide (MDH) and aluminium trihydroxide (ATH). Various combinations of colemanite, MDH and ATH were tested at total 60% additive / 40% polymer, in 4 mm sheets, and compared to neat polymers EVA and EMA for heat release rate, peak heat release (pHRR), total heat release and time to ignition / self-extinguishment. Optimum reduction in peak heat release (pHRR) for EVA was achieved with 60% colemanite (-82%) and with 30%-MDH / 30%-colemanite in EMA (-69%). Analysis suggests that the colemanite is contributing to a surface barrier effect on polymer. The colemanite also improves ignition resistance and self-extinguishment properties and acts as a smoke suppressor, reducing total smoke release (TSR). The authors note that colemanite seems to act in synergy with MDH but not with ATH in these polymers.

"Influence of colemanite on the fire retardancy of ethylene-vinyl acetate and ethylene-methyl acrylate copolymers", F. Cavodeau et al., Polymer Degradation and Stability, vol. 144, Oct. 2017, pp. 401-410 http://dx.doi.org/10.1016/j.polymdegradstab.2017.08.016



PIN FR solutions for natural fibre polymer composites

Several recent papers and review assess fire safety solutions for composites using natural fibres in polymers. Such innovative new material solutions are developing in a range of applications, as industries look to include bio-based materials whilst achieving mechanical performance and low weight. Elsabbagh et al. compared different FRs in several natural fibre / polypropylene (thermoplastic) composites, showing that UL94-V0 can be achieved (30% flax fibres) with 28% total DECA (brominated FR) plus antimony or 26% ammonium polyphosphate (PIN FR), but with around 30% loss in tensile strength. Overall, the authors aim to develop an FR selection tool enabling to target objective fire performance, mechanical characteristics and regulatory requirements. Kim et al. review over one hundred studies on natural fibre reinforced composites, covering different fibres, additive and reactive flame retardants, fire modelling and transport and construction applications. They conclude that naturally fire resistant fibres, such as wool, combined with intumescent PIN flame retardants can offer effective fire performance, but that mechanical performance effects of the flame retardants and possible water uptake by and variability of the natural fibres are challenges. Marosi et al. review somewhat more widely flame retardancy of all bio-based polymer composites, including "self-reinforced" composites (where the fibres are made of the same polymer as the matrix). These have advantages for recycling (same polymer type) and can show good fire and mechanical performance with intumescent PIN FRs for bio-based polymers, including polylactic acid (PLA). PIN FRs are identified as preferable fire safety solutions because consistent with environmental objectives of selection of bio-based materials. Compatibility with recycling or biodegradability are key objectives.

"Towards selection chart of flame retardants for natural fibre reinforced polypropylene composites, A. Elsabbagh et al., Composites Part B 141 (2018) 1–8 https://doi.org/10.1016/j.compositesb.2017.12.020

"A review of flammability of natural fibre reinforced polymeric composites", N. Kim et al., Composites Science and Technology 162 (2018) 64–78 https://doi.org/10.1016/j.compscitech.2018.04.016

"Fire-retardant recyclable and biobased polymer composites", G. Marosi et al., in "Novel Fire Retardant Polymers and Composite Materials", 2017. http://dx.doi.org/10.1016/B978-0-08-100136-3.00005-4

PIN flame retardant market growth

A study by Researchandmarkets estimates that global demand for non-halogenated flame retardants will grow by 6.2% per year (CAGR) from 2018 to 2023, with growth particularly strong in consumer electronics production. In this E&E sector, growth is particularly expected in the Asia-Pacific region, with phosphorus-based PIN FRs the leading fire safety solution. The construction sector will also show growing demand for PIN FRs. A second study by Marketresearchfuture estimates the global growth for non-halogenated flame retardants for the same period (2018-2013) at 5.8% CAGR. This study indicates as US$ 2 190 billion the PIN flame retardant market in 2017. Drivers for growth of PIN FRs are indicated in this study as regulatory constraints on halogenated FRs and ecological sustainability of PINs, and growth for PIN FRs in the building and construction sector.

"Global Non-Halogenated Flame Retardants Market - Segmented by Type, Industry Application, and Geography - Growth, Trends and Forecasts (2018 - 2023)", Research and Markets, Feb. 2018 https://www.researchandmarkets.com/research/qsl575/global?w=4

"Halogen-free flame retardants market trend 2018, global share, world key manufacturers, industry major regions, growth opportunities and forecast to 2023", Market-Research-Future, August 2018 https://www.marketresearchfuture.com/reports/halogen-free-flameretardant-market-6062

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For abbreviations see: www.pinfa.org