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Non-halogenated flame retardants for various applications in advanced materials

ABSTRACT

The growing regulatory pressure on halogenated flame retardants and increasing demand for sustainable advanced materials have intensified research into effective non-halogenated fire protection systems. For several years, research activities at Łukasiewicz ICSO have focused on the development of innovative, efficient flame retardants dedicated to a broad spectrum of advanced material applications, including polyurethane foams, polymer emulsions, adhesives, resins, as well as paper-, plywood-, wood-based materials and textile fabrics.

This contribution presents non-halogenated flame retardant systems whose fire-retarding performance is based on synergistic phosphorus–nitrogen chemistry. Particular attention is given to bio-based flame retardants containing α -amino acids and phosphoric acid, characterized by a high content of phosphorus and nitrogen, while being free from harmful halogens and formaldehyde. These systems act predominantly in the condensed phase, promoting char formation and reducing heat release during combustion. To further enhance fire resistance and functional performance, selected formulations are additionally reinforced with aluminium hydroxide, which contributes to reduced flammability through endothermic decomposition and supports the formation of a stable protective layer. Importantly, the presence of inorganic components also improves the durability and stability of the interaction between the flame retardant and treated substrates, such as textile fibers.

The presented solutions can be synthesized from raw materials of natural origin, recycled feedstocks, or petrochemical sources, offering flexibility in terms of sustainability and application requirements. The results demonstrate that non-halogenated, phosphorus–nitrogen-based flame retardants can meet stringent fire safety criteria while remaining compatible with modern advanced materials and environmentally responsible design principles.

Keywords: Flame retardants, plastic additives, amino acids, organic technology, advanced materials

BIOGRAPHY

Research-driven chemist with a PhD in Chemistry and over 10 years of experience in applied chemical technology, polymer modification, and catalytic process development. Currently, I lead the Chemical Processes and Technologies Research Group at the Łukasiewicz Research Network – ICSO, where I oversee industrial and scientific R&D in the field of organic and bioorganic technologies, obtaining and implement of functional additives for polymers, chemical recycling of materials, and flame-retardant obtaining technologies as well as circular economy issues and waste water treatment.