ILFLAME

Synergistic interaction of phosphorus, silicon, and nitrogen in the flame retardancy of epoxy composites using ionic liquids and SILP materials with additional activity as a curing agent

The main objective of the **ILFLAME** project is to develop composite systems (based on epoxy resins and reinforcing fiber) with high flammability resistance, cured and modified using ionic liquids (ILs). The goal will be achieved by: (i) the use of new ionic liquids containing in their structure a large number of phosphorus and silicon bearing groups combined with a nitrogen atom in one molecule, (ii) the implementation of a model of multidirectional flame retardancy (in both the epoxy resin and the reinforcing fiber), (iii) the use of ionic liquids designed in a way, that phosphorus and silicon atoms will exhibit different chemical nature and different intramolecular connections with other atoms in the molecule, and (iv) the use of silica-embedded ionic liquids material, *Supported Ionic Liquids Phase (SILP),* in the composite system as a new approach to not only flame retardancy, but also curing of epoxy resin.

Composite materials based on epoxy resins and reinforcing fibers are the backbone of polymer materials used widely around the world. It is a valuable construction material in areas such as electronics (equipment housings, electronic components), paints and coatings, construction (construction material used both indoors and outdoors) or transportation (construction materials in aviation, automotive, marine or railroad industries). It owes its popularity due to its high tensile strength, high adhesion to substrates, good corrosion resistance, chemical resistance, and moisture resistance.

The biggest disadvantage of this group of materials is their flammability, resulting in the generation of large amounts of heat and the formation of a number of combustion products that are harmful to human health, such as: (i) toxic gases (HBr, HCl), (ii) benzene derivatives and higher aromatic hydrocarbons (PAHs), (iii) non-flammable vapors (CO_2, NOx, SOx), (iv) flammable VOCs (methane, ethane) or (v) organic irritants, the composition of which is determined by the components of the resin and the overall composite.

Research on flame retardants in recent years has focused on the search for new compounds with effective action and has largely consisted of organic synthesis of substances based on previously known flame retardants (structural improvements of substances, new derivatives) or synthesis of completely new molecules. The greatest scientific interest in the context of flame retardants is focused on phosphorus-containing compounds (both organic and inorganic) as well as compounds containing silicon or nitrogen.

Ionic liquids are chemical compounds with an ionic structure, consisting of a cation and an anion and having several specific properties. The cation of the IL is usually of organic origin and has a varied structure. In addition, the positive charge of the cation can be located on various atoms, which most often include nitrogen, phosphorus and sulfur, and various functional groups can be present in the cation structure. The anions of ILs can be both organic and inorganic, and their nature significantly affects the properties of the entire compound.

Recent studies show the potential of ILs to impart fire-resistant material characteristics to composites. However, basic ILs from the group of mainly phosphonium ionic liquids are being studied, which have numerous functionalities and one of them is to affect composite materials by reducing flammability. These compounds were not designed precisely for flame retardancy of composites which limits the possibility to learn more about the performance of ILs as flame retardants. In addition, the use of ionic liquids as initiators of epoxy resin curing is also known in the literature. ILs can be designed to predict their performance as curing initiators in a selected range of temperatures and intensities. The curing process can be either cationic or anionic, and the amount of ionic liquid required for the curing process is much smaller than for classical amine curing agents.

The hypothesis formulated in the IFLAME project is: **The proposed ionic liquids, and SILP materials based on them, will possess double functionality, being effective flame retardants using the synergistic effect of the interaction of phosphorus, silicon, and nitrogen in carbon/flax-fiber-reinforced epoxy composite systems than the solutions known so far in the literature and having the ability of initiating the resin curing process.**