Flame Retardant Polymers from LANXESS – Durethan® and Pocan®

1 Flame Retardancy and Fire Safety

Every year, fires cause considerable damage to people, property and the environment. Thus the use of fire-protected materials is essential in different areas of the electrical engineering and electronics sectors. These materials are being recommended for a growing number of applications within the transportation, construction, textile and furniture industries. In electrical engineering, for example, live parts such as switching devices, housings, cable sheathing and cable shafts, must be insulated by use of flame retardant plastics. Stringent fire safety requirements also have to be satisfied in the transportation sector depending on the particular area in which the materials are to be used (road and rail vehicles, aircraft). A large number of plastics fulfill these requirements and also offer additional advantages through their ease of processing, their mechanical property profile over a broad range of temperatures, their flexibility in use and their low density.

In many cases, the selection of appropriate materials for specific applications is explained in standards and national regulations. These national regulations are continually being revised and put on an international footing. At the same time, precise analysis of the cause of fires is also leading to a further tightening of the standards. This means that the producers of household appliances, office and industrial electronics, construction elements or components for use in the transportation sector, must select different materials which will comply with newer standards. Meanwhile, the plastics manufacturers are called upon to further develop their products to support this need.

The key component of flame retardant polymers is the flame retardant system employed. The appropriate flame retardant system will depend on the properties the material is required to display in service. Almost all applications require the eco-toxicological properties to be considered. For example, the use of a number of defined brominated flame retardants is prohibited by the RoHS Directive[1]. In addition, the flame retardant systems affect the electrical, chemical, mechanical and rheological properties of the compound, and therefore affect the properties of the final product.

2 Flame Retardants

The term “flame retardant” covers a wide range of different chemical substances that serve to reduce the flammability of materials and the rate of flame spread. The individual flame retardant’s behavior can be very unique and is a function of its chemical composition. The most common flame retardants are based on compounds containing the elements bromine, chlorine, phosphorus, nitrogen, aluminum or magnesium.

The way in which these main types of flame retardants act is explained below:

2.1 Halogenated flame retardants (bromine, chlorine)

Bromine and chlorine are available in the form of organic halogen compounds that are compounded

[1] EU Directive 2002/95/EC: Restriction of the use of certain hazardous substances in electrical and electronic equipment and Decision 2005/618/EC.

with the polymer matrix. In the event of a fire, the halogen radicals are released from these organic halogen compounds and react with the energy-rich hydrogen and hydroxy radicals inside the flame. This process removes energy from the flame. In many cases, compounds containing antimony are used as a synergist, thus, giving rise to a closed loop with recovery of the halogen radicals.

2.2 Flame retardants containing phosphorus

Phosphorus is compounded with the polymer matrix in the form of either organic phosphorus compound[2] or inorganic "red phosphorus". Inorganic phosphorus is particularly effective when used in polymer matrices containing oxygen, such as in polyamides and polyesters. In the event of a fire, phosphorus oxides form which remove water from the substrate and thus lead to the carbonization of the polymer matrix. This layer of carbon separates the polymer from the flame. The polyphosphoric acid similarly forms a layer that impedes further combustion.

Organic phosphorus systems all work according to the same principle and are sometimes used in combination with compounds containing nitrogen. Additionally, these act through intumescence, a topic which is dealt with in the next section.

More recent findings show that the phosphorus similarly acts as a radical catcher in the gas phase.

Flame retardants containing nitrogen

Flame retardants containing nitrogen work on the basis of various mechanisms acting simultaneously. When they are subject to heat, the compounds disintegrate and, in the process, remove energy from the heat source. Depending on the system and the degree of decomposition, gases such as nitrogen or ammonia are released. This causes the matrix to foam and "swell up" (intumescence). If the flame retardant also contains phosphorus (polyammonium phosphates), the mechanisms of flame retardants containing phosphorus will also come into play, and a layer of carbon (carbon foam) will form in addition to the intumescence. With flame retardants containing nitrogen, the mechanism of matrix depolymerization occurs in a similar way - the matrix decomposing and retracting from the heat source.

2.3 Inorganic flame retardants

Inorganic flame retardants, such as aluminum hydroxide (ATH) or magnesium hydroxide (MDH), split off water while consuming energy. This cools the matrix, and the fumes are diluted by the water. It is not possible to use ATH with polymers such as polyamides or polyesters due to their high processing temperatures.

[2] The misleading chemical term "white phosphorus" is sometimes used to achieve a distinction in color terms from "red phosphorus".

The following diagram shows in summary form, how and where flame retardants act.

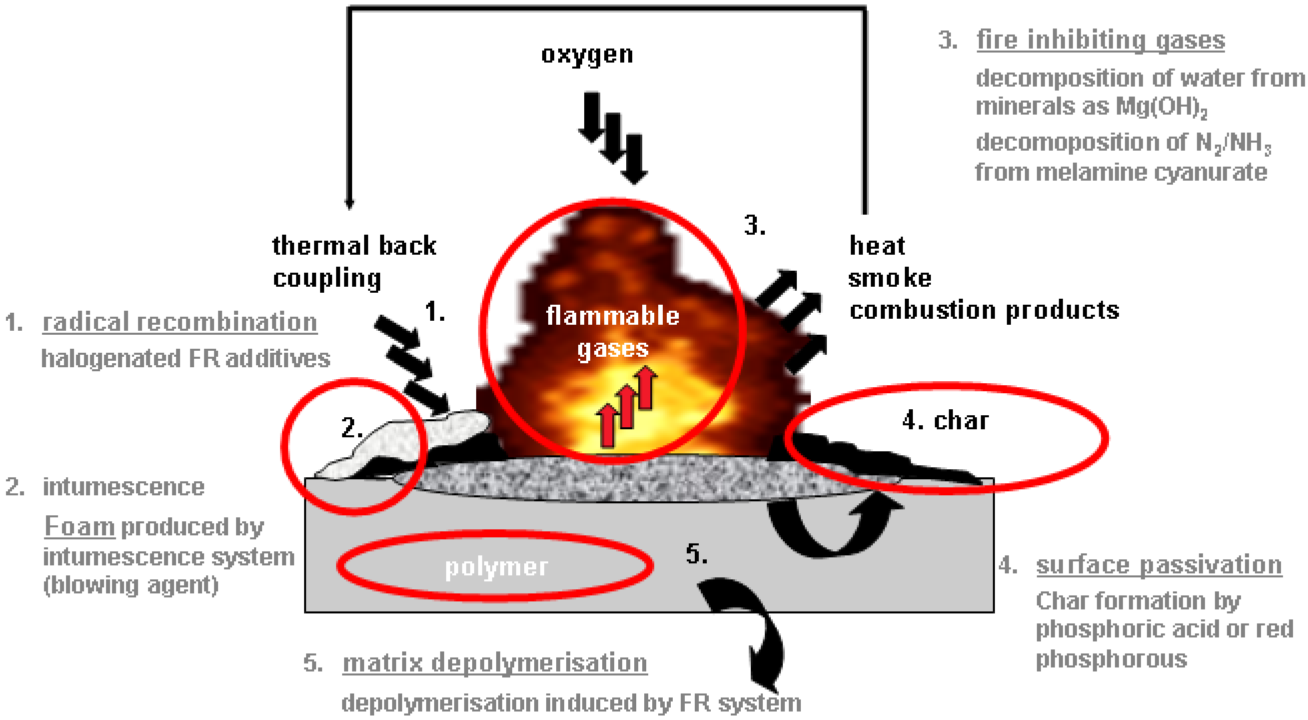

Fig. 1 Mode of action of flame retardants

3 Selecting the Right Flame Retardant

In view of their different modes of action and various chemical compositions, flame retardants must be selected very carefully. The combination of flame retardants and optimum action of the flame retardant system is also conditioned by the base resin system, fillers and processing materials employed. It is thus very difficult to make general statements. A number of examples of the strengths and weaknesses of different flame retardants are nevertheless given below:

- Halogen-containing flame retardants are highly effective. However toxic gases (such as HBr) develop as they burn which usually makes it impossible to use these flame retardants in applications that require very low levels of smoke toxicity.
- Red phosphorus is an efficient flame retardant. The compound's inherent color, however, means that it can only be used in dark-colored (preferably black) applications.
- Inorganic flame retardants have an excellent price-to-performance ratio and only a few undesirable side-effects in the event of a fire. They do, however, influence the mechanical and rheological properties of the compounds.
- Flame retardants containing nitrogen act by preventing ignition when subject to only a low level of heat. This gives rise to high glow-wire ignition temperatures, for example. These systems are, however, generally less efficient than other systems.

Each individual flame retardant has its advantages and disadvantages. One way of offsetting or alleviating the specific drawbacks of an individual flame retardant, is to use flame-retardant systems (i.e. a combination of flame retardants).

	Flame retardant				
	Containing halogen	**Red phosphorus**	**Organic phosphorus**	**Nitrogen**	**Inorganic**
Site of action (as per Fig. 1)	1	4	4	2 ;3; 5	3
Efficiency[3]	+	+	+	o	o
Matrix compatibility	+	+	+	+	-
Environmental assessment[4]	-	+	+	o	+
Migration	+	-	+	+	o
Toxicity of fire gasses	-	+	+	o	+
GWIT	+ (PA)	-	o	o	+
CTI	-	+	+	+	+
Rheology	+	o	o	o	-
Mechanics	+	+	o	o	-
Inherent color	+	-	+	+	+
Processing	+	-	o	+	-

Table 1 Overview of the properties of flame retardants

4 Assignment of products to different flame retardancy systems

The assignment of LANXESS products to particular flame retardancy systems is explained in the currently valid data sheets, where the flame retardant chemicals are classified in accordance with ISO 1043-4. The most important categories are:

Category	Description
(17)	Aromatic bromine compounds (except brominated diphenyl ethers and biphenyls) combined with antimony compounds
(30)	Nitrogen compounds (melamine, melamine cyanurate, urethane)
(40)	Halogen-free organic phosphorus compounds
(52)	Red phosphorus
(61)	Magnesium hydroxide
(72)	Zinc borate

Table 1 Classification of flame retardancy systems

3 Efficiency is calculated as the average ratio of the quantity used to the cost of the raw material.

4 Assessment on the basis of Research Report 29744542: Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals, commissioned by the Federal German Environmental Agency, December 2000

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