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BPI
Bavarian Polymer Institute

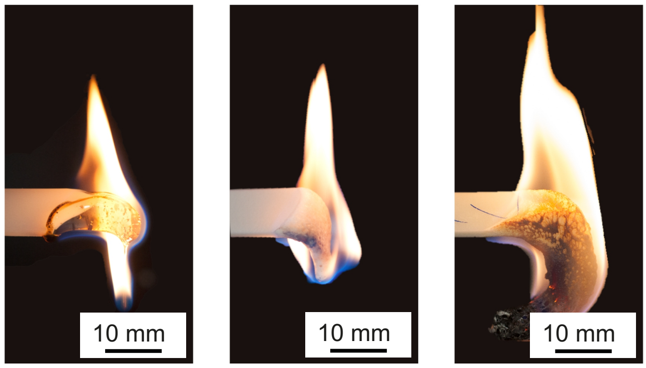
Flame Retardant Polymers

Material Characterization and Fire Testing

Barcode zu Ansprech-partner und Infomaterialien

Motivation

The mostly organic structure of polymeric materials causes an early thermal degradation of molecular chains when exposed to heat, promoting the release of easily flamable and toxic gases, Fig. 1. In order to reduce the fire hazard especially in fire-critical applications with direct risk of personal injury and property damage, advanced material modifications are necessary to achieve high fire safety standards. New research opportunities support the ongoing development of efficient and ecologically compatible flame retardants to achieve safe products with high engineering requirements.



Polyethylen (PE) *Polylactid (PLA)* *Polyamid 6 (PA6) & Glassfibres*

Fig. 1: Burning behavior of various Polymers

Flame Retardant Additives & Synergists

To achieve high fire saftey classifications, thermoplastic polymers can be modified with flame retardant additives, Fig. 2. Flame retardants are typically classified according to their main active ingredient and can be listed in descending order of efficiency as follows: halogen, phosphorus, nitrogen and inorganic. Due to health and environmental concerns, halogen-containing flame retardant additives are more and more replaced by phosphorus-based agents. These provide good flame retardant efficiency at reasonable low loading levels.
Flame retardant additives can be used individually or in combination with so called synergistic agents. Typically, synergistic agents show only minor flame retardant effects when used alone, but significantly improve or sustain the overall flame retardant efficiency when used in combination with other agents. This allows to reduce the overall additive loading level while sustaining flame retardant properties. Concurrently, lower loading levels can be used to improve certain material properties or material cost ratios.

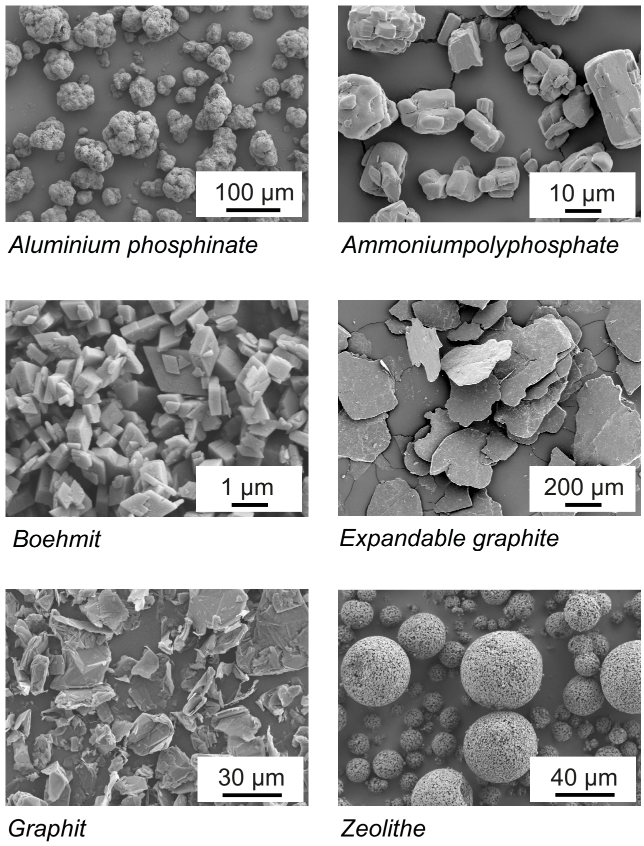


Fig. 2: Scanning electron micrographs (SEM) of different flame retardant additives

Processing and Challenges

In order to chieve a specific fire protection effect, a defined quantity of flame retardant additves are added into a matrix polymer and dispersed homogeneously by extrusion processing. The mostly chemical reactive additives require specific processing temperatures to prevent early degregation and therefore negative effects on component properties. High filler contents and non-circular particle shapes lead to an increased material viscosity, which complicates processing and reduces the throughput speed. Therefore, a systematic material selection of functional flame-retardant types and synergistic combinations offer the possibility to achieve highly efficient flame-retardant compounds without the loss of essential aterial .

Characterization of Fire Behavior

Numerous fire protection tests are available to identify important burning characteristics of polymer materials, assemblies or end applications (e.g. household devices, cars). Fire testing procedures are generally differentiated into laboratory scale and large scale burning tests. Laboratory scale tests (e.g. Limiting Oxygen Index (LOI), UL-94, Cone Calorimeter) can be used to determine general material characteristics like the ease of ignition, the burning behavior and self extinguishing properties. These provide indicative values in early product development stages for specific applications and are part of common material databases.

Large-scale fire tests (e.g. Single Burning Item) on the other hand are used to conduct fire tests on larger product assemblies or end products. Such tests are often time-consuming and expensive, but are required in particular for the approval of new launched products. Large scale tests provide information about the course of heat development of an assembly in the event of a fire and thus conclusions to be drawn about the flame spread. In addition, some available laboratory scale tests provide the possibility to analyze fire gases and draw conclusions about their toxicity. Compliance with strict limit values is required, particularly in application areas with an immediate risk of personal injury and a limited number of escape routes.

UL-94

A classic example for bench scale fire tests is the UL-94 test , Fig. 3, which allows the characterization of fire propagation (HB test) and self-extinguishing (V test) properties. Current research topics at the Bavarian Polymer Institute focus on the investigation of flame retardant additive combinations providing synergistic effects. This allows an efficient and resoure optimized use of flame retardant additives, without the loss of essential fire protection properties.

Limiting Oxygen Index (LOI)

Another widely used laboratory scale test to analyze the fire behavior is the LOI test, Fig. 4. The test provides a comparative value (OI) based on the atmospheric oxygen saturation needed to sustain a visible burning process. At the Bavarian Polymer Institute, the LOI test supports multiple projects by characterizing material compositions in order to optimize fire protection as well as mechanical properties.

Cone Calorimeter

Cone calorimeter tests allows the investigation of fire behavior under radiation comparable to real fires, Fig. 5. During a test sequence, a flat polymer sample with an edge length of 100 x 100 mm² is heated by an IR heater and ignited by an ignition spark. The heat development, CO/CO_2 generation and smoke gas density of the specimen are recorded over time, giving critical information about fire protection measures in case of fire. Advanced cone calorimeter test setups, as used at the Bavarian Polymer Institute (BPI), are additionally equipped with a comprehensive gas analysis system, Fig. 5. This allows the quantitative and qualitative identification of solid, liquid and gaseous flue gas components (e.g. aerosols, polycyclic aromatic hydrocarbons). Inline measurement furthermore enables a time-resolved allocation of gas evolution, allowing tangible conclusions regarding the relationship of chemical processes and the fire behavior.

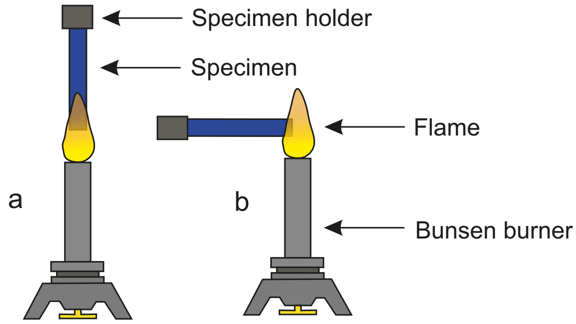


*Fig. 3: a) UL-94 V
b) HB burning Test*

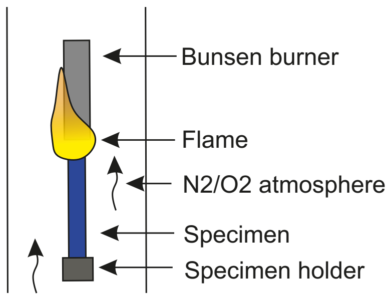


Fig. 4: Test setup for measuring the Limiting Oxygen Index (LOI)

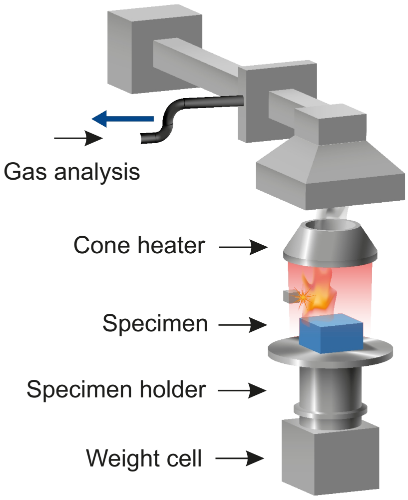


Fig. 5: Cone Calorimeter setup with attached gas analysis

Research Objects and Service for Industry

- Injection molding and specimen preparation
- Development of flame retardant compounds
- Flamability testing
- Thermal analysis
- Gas analysis

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