Chapter 5

Fire-Resistant Polymeric Foams and Their Applications

Mohammad Harun-Ur-Rashid,[1] Abu Bin Imran,[2] and Md. Abu Bin Hasan Susan[3,*]

[1]Department of Chemistry, International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh

[2]Department of Chemistry, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

[3]Department of Chemistry, University of Dhaka, Dhaka 1000, Bangladesh

*Email: susan@du.ac.bd.

Every year, a large number of fire incidents occur all over the world. Fires initiated from soft furnishings at residences, in particular, mattresses and furniture; cause a large fraction of casualties. To minimize causalities of this kind, it is essential to avoid the use of common polymeric foams participating in the fire. Conventional fire-resistant technologies suffer from their ineffectiveness and are not viable options for operation. Therefore, high-performance fire-resistant polymeric foams have received great attention in the last few decades. From that perspective, it is essential to compile information related to thermally insulated and fire-resistant polymeric foams, foam coatings, and foam additives for the interested communities in the respective sectors. Thermally insulated and fire-resistant polymeric foams and the associated materials can be prepared from non-renewable resources such as petrochemicals and renewable resources like natural biopolymers. However, biopolymers are associated with certain limitations, and the incorporation of fillers or nanofillers through the implementation of nanotechnology can resolve this. Most polymers are susceptible to high-temperature conditions and flames due to the presence of a higher amount of organic matter. The combustion of polymers generates different types of toxic gases, liquids, and solids that are hazardous to the environment and health. Developing polymers capable of exhibiting fire-resistant properties without compromising the other desirable features for multipurpose industrial and consumer applications to control fire damage has been a very demanding task. It is thus crucial to discuss and summarize the design, fabrication, characterization, mechanism of fire-resistance, present, and future trends, and prospective applications of fire-resistant polymeric foams collectively in a single platform. This chapter on fire-resistant polymeric foams and their applications is expected to serve the interested community with the aforementioned information.

Introduction

Fire-resistant materials are essential for preventing and mitigating occurrences of accidents caused by fire. Conventional brominated and inorganic fire-resistant materials are usually inefficient, mechanically weak, and toxic to the environment (*1–3*). Due to the inherent drawbacks of conventional fire-resistant materials, there is an increasing need to design and develop high-performance materials. The mechanical strength and the density of fire-resistant materials play decisive roles in assessing the suitability and utility for many consumer and industrial applications. The last few decades experienced the successful incorporation of different types of fire-resistant agents such as phosphorus and halogen-containing substances (*4, 5*), intumescent agents that swell up when heated and thus protect the coated material in case of fire (*6–8*), layered materials of inorganic origin (*9–11*), and other materials capable of resisting fire (*12–15*) into various polymeric foams to achieve fire-resistant property.

Conventional polymer foams, such as polyurethane (PU) and polystyrene (EPS), are especially attractive for the thermal insulation of buildings since they are low cost, highly thermally conductive, and possess superior compressive strength (*16, 17*). But, the higher amount of organic substances and greater surface areas have made polymer foams extremely flammable. Once ignited, they burn very quickly, releasing a huge amount of thermal energy and toxic fume (*18*). Their traditional use in structures has led to a significant risk of fire for occupants (*19*) and has already resulted in a significant loss of life and property. Therefore, it is crucial to develop a polymeric foam that is fire-resistant without considerably reducing its thermal insulation. As a result, it is essential to develop fire-resistant polymeric foam without compromising its thermal insulation significantly. Numerous attempts have already been undertaken to develop rigid PU foam that is fire-resistant by the use of (i) reactive flame-retardants (FRs), (ii) additive FRs, or (iii) surface FR treatments. Commonly used additive FRs such as phosphorus-containing compounds and expandable graphite (EG) have proven relatively high effectiveness in rigid PU foam (*20, 21*). The greater loading content of FRs necessary to achieve adequate fire safety may adversely affect the synthesis of fire-resistant polymeric foam. Reactive FRs, on the other hand, can offer long-lasting fire-retardancy while maintaining the mechanical properties of the bulk polymeric foam (*22*). Ultimately, the produced PU foam exhibits poor flame usually due to low FR contents, as high contents can adversely alter the physical properties such as the structural stability and density of the foam. However, a huge challenge is coming up with a scalable and economical route for producing polymeric foam with improved flame-retardancy without sacrificing other desirable properties (*23–30*), including high mechanical strength, low densities, and advantageous thermal features. The chapter summarizes the introduction, synthesis, processing, characteristics, and applications of fire-resistant polymeric foams.

Combustion of Polymer

Polymers decompose and produce flammable gases that react with oxygen to form an ignitable source when exposed to sufficient heat. Autoignition occurs either at the flash point or impulsively when the temperature is high enough for autoignition. Heat is generated during polymer combustion, some of which is passed to the substrate and promotes further degradation. If the heat is sufficient to maintain the polymer decomposition rate and keep the volatile matter concentration within the flammability limit, a self-sustaining combustion cycle begins. A typical combustion cycle with a complex coupling of energy feedback from a flame to the combustible breakdown products is shown in Figure 1 (*31*). Fuel, heat, and oxygen are three essential elements to sustain a fire (*32*).