



Fire-Retardant Polymeric Additives

Mechanical properties are retained or even enhanced.

John F. Kennedy Space Center, Florida

Polyhydroxyamide (PHA) and polymethoxyamide (PMeOA) are fire-retardant (FR) thermoplastic polymers and have been found to be useful as an additive for imparting fire retardant properties to other compatible, thermoplastic polymers (including some elastomers). Examples of compatible flammable polymers include nylons, polyesters, and acrylics. Unlike most prior additives, PHA and PMeOA do not appreciably degrade the mechanical properties of the matrix polymer; indeed, in some cases, mechanical properties are enhanced. Also, unlike some prior additives, PHA and PMeOA do not decompose into large amounts of corrosive or toxic compounds during combustion and can be processed at elevated temperatures.

PMeOA derivative formulations were synthesized and used as an FR additive in the fabrication of polyamide (PA) and

polystyrene (PS) composites with notable reduction (>30 percent for PS) in peak heat release rates compared to the neat polymer as measured by a Cone Calorimeter (ASTM E1354). Synergistic effects were noted with nanosilica composites. These nanosilica composites had more than 50-percent reduction in peak heat release rates.

In a typical application, a flammable thermoplastic, thermoplastic blend, or elastomer that one seeks to render flame-retardant is first dry-mixed with PHA or PMeOA or derivative thereof. The proportion of PHA or PMeOA or derivative in the mixture is typically chosen to lie between 1 and 20 weight percent. The dry blend can then be melt-extruded. The extruded polymer blend can further be extruded and/or molded into fibers, pipes, or any other of a variety of objects that may be required to be fire-retardant.

The physical and chemical mechanisms which impart flame retardancy of the additive include inhibiting free-radical oxidation in the vapor phase, preventing vaporization of fuel (the polymer), and cooling through the formation of chemical bonds in either the vapor or the condensed phase. Under thermal stress, the cyclic hydroxyl/methoxy component forms polybenzoxazole (PBO) in a reaction that absorbs heat from its surroundings. PBO under thermal stress cross-links, forming a protective char layer, which thermally insulates the polymer. Thus, the formation of the char layer further assists to extinguish the fire by preventing vaporization of the polymeric fuel.

This work was done by Martha K. Williams and Trent M. Smith of Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Office at (321) 861-7158. KSC-12697

Catalytic Generation of Lift Gases for Balloons

Relatively lightweight, low-power gas generators are based on methanol reforming.

Goddard Space Flight Center, Greenbelt, Maryland

A lift-gas cracker (LGC) is an apparatus that generates a low-molecular-weight gas (mostly hydrogen with smaller amounts of carbon monoxide and/or carbon dioxide) at low gauge pressure by methanol reforming. LGCs are undergoing development for use as sources of buoyant gases for filling zero-gauge-pressure meteorological and scientific balloons in remote locations where heavy, high-pressure helium cylinders are not readily available. LGCs could also be used aboard large, zero-gauge-pressure, stratospheric research balloons to extend the duration of flight.

Methanol reforming has been investigated as a means of generating hydrogen for fuel cells. Although the product-gas specifications, process-stream, and control requirements for fuel-cell applications differ from those of lift-gas applications, the underlying methanol-re-

forming principle is the same for both classes of applications, and some of the heat-exchange and catalyst design requirements from fuel-cell applications are adaptable to lift-gas applications.

In the methanol reforming reactor that lies at the heart of an LGC, methanol is catalytically cracked to carbon monoxide and hydrogen in an endothermic reaction, typically at a temperature in the approximate range of 250 to 350 °C and at a pressure that can lie in a range from somewhat below to somewhat above standard sea-level atmospheric pressure. A small portion of the methanol feed is diverted to a low-pressure combustor to provide the heat for the endothermic reforming reaction and maintain the reactor at the reaction temperature.

When the feedstock is pure methanol, the overall chemical reaction is $\text{CH}_3\text{OH} \rightarrow \text{CO} + 2\text{H}_2$. In a steam-reforming vari-

ant, the feedstock is a mixture of methanol and steam, typically comprising equal numbers of methanol and water molecules, in which case the overall chemical reaction is $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 3\text{H}_2$. The optimum choice of temperature, pressure, and catalyst depends on details of the specific application. The exact formulations of methanol-reforming catalysts are proprietary; what is known is that most of them include copper oxide and zinc oxide on alumina supports.

The only consumables needed for the methanol-reforming process in an LGC, other than methanol, are air and a small amount of electrical power for an air blower and for instrumentation. In principle, an apparatus that generates hydrogen by electrolysis of water could be used as an alternative to an LGC, but an electrolytic apparatus would be less ad-