Nanocomposite Thin Films for Reduced Flammability Foam and Fabric

Jaime C. Grunlan
Assistant Professor
Department of Mechanical Engineering
Texas A&M University
College Station, TX 77843-3123
(979) 845-3027 office; jgrunlan@tamu.edu

The number of fire-related fatalities and amount of property damage has significantly declined worldwide in recent decades as legislation has forced a variety of polymeric materials to be rendered flame retardant. Brominated compounds are among the most popular retardants, but environmental concerns have led to significant research into the use of more benign nanoparticles such as clays and carbon nanotubes. These nanocomposites typically exhibit reduced mass loss and heat release rates, which is believed to be due to the formation of a barrier surface layer in the case of clay and a gel-like network in the case of nanotubes. Despite this improved thermal behavior, adding these particles is known to increase processing viscosity and modulus of the final polymeric material. These adverse side effects for flexible foams and fabrics make the need for an alternative technology of vital importance. In the present work, thin nanocomposite coatings (less than one micron thick) made with clay and polymer, uniformly applied to the three-dimensional surface of foams and fabrics, are shown to impart benefits similar to those seen for bulk nanocomposites. This novel coating system is made possible using the layer-by-layer assembly deposition technique. These films, typically < 1μm thick, are created by alternately exposing a substrate to positively- and negatively-charged molecules or particles in water until the desired number of "bilayers" (or cationic-anionic pairs of layers) is achieved. Individual layers may be 1 – 100+ nm thick depending on chemistry, molecular weight, charge density, temperature, deposition time, counterion, and pH of species being deposited. These films are also optically transparent, so they will not alter the aesthetics of a given subtrate. These features allow complex substrates (e.g., foam and fabric) to be fully covered without changing their intrinsic properties. Using traditional coating techniques on foam would lead to pore blockage, but an LbL coating simply covers the internal walls of each pore. In fabric, each thread can be individually coated with a flame retardant clay-filled thin film and still remain soft and flexible. These qualities should result in a highly effective, environmentally friendly coating for fire suppression. Here we show the result of applying this technology to polyurethane foam and cotton fabric. The application of 10 - 30 bilayers (BL) of clay and polycation to cotton fabric enhances char yield by an order of magnitude and cuts the peak heat release rate of open-cell polyurethane foam in half.