POLYMER-INORGANIC NANOCOMPOSITES: INVESTIGATION OF THERMAL DEGRADATION AND FLAME RETARDANT MECHANISMS

Gordon L. Nelson, Irina Bogdanova, and Feng Yang

Florida Institute of Technology , Department of Chemistry, 150 West University Blvd., Melbourne, Florida 32901-6975 (nelson@fit.edu)

Preparation of polymer/alumina and polymer/silica nanocomposites were accomplished using a single-screw extrusion technique (European Patent 1401924, Issued 20080709). The single screw extrusion technique creates a better interface than solution blending, an interface which is perfected on multiple extrusions. Less damage to particles is done versus twin screw extrusion. A systematic investigation of interfacial interactions, mechanisms of reinforcement, and the thermal degradation and flame retardant mechanisms was undertaken. Silica spheres of various dimensions, and alumina or alumina hydrate nanoparticles of various shapes (100/10 nm rods, 40-80 irregular, 15 nm spherical, and 2800/2-4 whiskers) were used. Several surface treatments were examined.

It was found that the stereochemistry of the polymer chains versus the shapes of the nanoparticles were extremely important. PMMA, polystyrene (PS), and polycarbonate (PC) were studied. It was found that aromatic polymers such as PC and PS have stronger interfacial interactions with needle or whisker-shaped nanoparticles than with spherical-shaped nanoparticles, while linear aliphatic polymers such as PMMA showed stronger interactions with spherical nanoparticles. It was found that the chemical nature of nanoparticles also plays a role in the thermal degradation of polymer nanocomposites. SEM studies of chars revealed that alumina nanoparticles moved to the surface of the nanocomposites, while silica nanoparticles stayed in the body of the material, which enhanced char formation.

While a 29% increase in tensile strength, a 34% increase in modulus, and a 60% increase in elongation at break was achieved for alumina whiskers at a 1% loading level in PC, lesser effect on mechanical properties was found for alumina in spherical shape (15 nm). In PC a 100/10 nm rod gave a 54% increase in tensile strength, a 97% increase in modulus, but a reduction in elongation at break. For PS, a 37 %

improvement in tensile strength, a 51% increase in modulus and no change in elongation at break was seen for whiskers at 1 % loading. But for 100/10 nm rods PS showed minimal increase in tensile strength, an under 29% change in modulus and no change in elongation at break. For 20 nm silica spheres PS showed a decline in tensile strength, a 50 % increase in modulus and no change or a decrease in elongation at break. For PMMA an up to 29% decline in tensile strength was seen for rods and whiskers. However, the 15 nm alumina spheres showed a 12% increase in PMMA at 1% loading, with a 9 % increase in modulus and a 40 % increase in elongation at break. Silica spheres (20 nm) showed a 3 fold increase in tensile strength, 2.8 fold increase in modulus, and 2.6 fold increase in elongation at break at high filler loadings (13%). The difference between alumina and silica spheres is the catalytic impact of alumina on the degradation of oxygen containing polymers.

For thermal degradation in TGA a 10 to 20 degree increase at 10% weight loss and 5 to 10 degree increase at 50% weight loss was generally seen regardless of resin, particle loading or shape. However, for Cone Calorimetry the 40 nm irregular particles for PC yielded a 33% reduction in peak rates of heat release at a 2% loading, while the 100/10 nm rods yielded a 45% reduction in peak rates of heat release. Silica (16 nm spheres) yielded only a 15% reduction in peak rates of heat release at a 3% loading. The highest increase in oxygen index (OI) was to 27.1 (versus 23.3 for neat resin)(3.8 units) for 100/10 rods at 2% loading. PC with 16 nm silica spheres showed no change in OI at particle concentrations from 1 to 5 percent. A 0.3 to 0.6 increase in OI was seen for PS/alumina nanocomposites, versus up to 1.2 units for 20 nm silica. For PMMA an oxygen index improvement of 0.3 to 0.6 units was seen for alumina nanocomposites, and a 3.7 unit increase for silica (20 nm) at 5% loading. PMMA nanocomposites showed a 22 to 27% reduction of peak rates of heat release with silica spheres. Clearly, different additives showed different impacts.