Stimulus-Responsive Polymer/Nanoparticle Composites

Nearingburg Ben, Nguyen Linda, Elias Anastasia L

Stimulus-responsive or “smart” materials are able to sense a change in their environment and react by altering their physical or chemical properties. Polymer/nanoparticle composites consisting of ferromagnetic nanoparticles embedded in a polymer matrix are an emerging example of a stimulus-responsive material. In these materials, the nanoparticles couple energy from an electromagnetic field into heat, causing the polymer matrix to deform in a reversible and repeatable manner. A variety of interesting devices based on these systems including sensors, actuators, and microvalves have been demonstrated in the literature. The purpose of our work is to investigate the physical properties of composite films which contain iron oxide nanoparticles, and optimize the responsivity of these materials. Both paraffin and polyethylene glycol (with a range of molecular weights) have been employed as host materials in these systems. Composite samples containing between 1-12 wt% nanoparticles were prepared by dispersing nanoparticles in a liquid matrix using a combination of mechanical and ultrasonic mixing. In the case of polyethylene glycol, the resulting mixtures were photopolymerized in the presence of an appropriate initiator. Scanning electron microscopy was used to verify the uniformity of the resulting mixtures. Heating experiments were undertaking using an Ameritherm Novastar 10kW inductive heater operating at a frequency of 151 kHz. Heating rates between 0.4°C/s and 13.5°C/s were observed, depending on the particle concentrations and matrix materials employed. Large temperature differences (> 60°C) were achieved, with sufficient heat flow to surmount thermal transitions (glass transition, or melting) and vastly alter the mechanical properties of the composites. The temperature profile of the system has been correlated to the heat capacity of the polymer matrix, suggesting that copolymers or other mixed composite systems may be combined to yield functional devices.