Shape Memory Polymer Nanocomposite Materials

This research program was initiated after a gap was identified between shape memory polymer research activities in US and existing demands for smart materials in industry. The objective is to develop fundamental understanding of shape memory properties of polymer and polymer nanocomposite materials in efforts to obtain a factor of 2-3 increases in shape recovery stress. Such increases in shape recovery stress will qualify polyurethane based shape memory polymers as implants (against ~5 MPa compressive stress of body tissues) and in smart fabrics. Two approaches are followed in our research – (1) introduction of functionalized nanoparticles in rod, disc, and spherical shapes and (2) formation of phase-separated domains of much stiffer polybenzoxazine. Fundamental quantities such as non-covalent filler-polymer interactions, crystallinity, domain orientation function, time constants for stress relaxation, and thermal expansion coefficients are studied to quantify the optimum formulation and optimum properties. We are able to increase the recovery stress by almost 100% with the introduction of ~3 vol% carbon nanofibers and by almost 200% with the introduction ~10 wt% polybenzoxazine. Currently we are investigating factors affecting the actuation times. Figure 1 presents typical shape recovery experiment of a stretched polymer specimen.

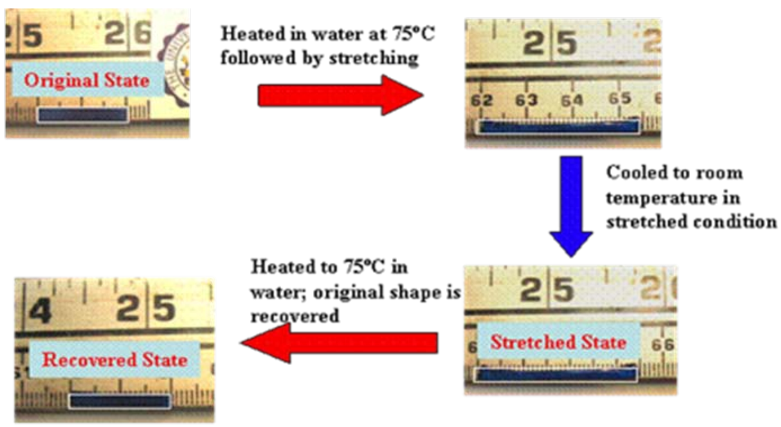

Figure 1 Typical steps in shape recovery experiments involving thermoplastic polyurethanes and its nanocomposites of layered silicate clay.

More information on our work can be obtained from the following articles:

1. Gunes, I. S., Perez-Bolivar, C. A., Cao, F., Jimenez, G. A., Anzenbacher, P., Jana, S.C., 2010 Analysis of non-covalent interactions between the nanoparticulate fillers and the matrix polymer as applied to shape memory performance. *J. Mater. Chem.*, 2010, 20, 3467 - 3474
2. Jimenez, G., Jana, S.C. 2009 Composites of carbon nanofibers and thermoplastic polyurethanes with shape memory properties prepared by chaotic mixing. *Polym. Eng. Sci.* 49(10), 2020-2030.
3. Gunes, I.S., Jimenez, G., 2009 Carbonaceous fillers for shape memory actuation of polyurethane composites by resistive heating. *Carbon*, 47, 981-997.
4. Gunes, I.S., Cao, F., Jana, S.C. 2008 Effect of thermal expansion on shape memory behavior of polyurethane and its nanocomposites. *J. Polym. Sci., Part B: Physics*, 46, 1437–1449.

5. Gunes, I.S., Cao, F., Jimenez, G., Jana, S.C. 2008 Evaluation of nanoparticulate fillers for development of shape memory polymer nanocomposites. *Polymer*, 49, 2223–2234.
6. Gunes, S., Jana, S.C., 2008 Shape memory polymers and their nanocomposites: A review of science and technology of new multifunctional materials. *J. Nanosci. Nanotech.* 8, 1616-1637.
7. Cao, F., Jana, S.C., 2007 Nanoclay-tethered shape memory polyurethane nanocomposites. *Polymer*, 48(13), 3790-3800.