Shape Memory Polymers and Polymer Nanocomposites

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.

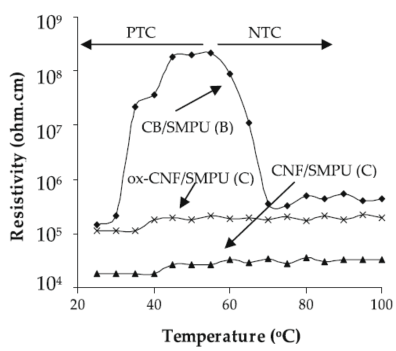

Fig. 12 – Temperature dependent volume resistivity of SMPU/3 wt% CNF, SMPU/3 wt% CB, and SMPU/ox-CNF 5 wt% composites. The composites prepared in Brabender internal mixer and in chaotic mixer are represented, respectively, by (B) and (C).

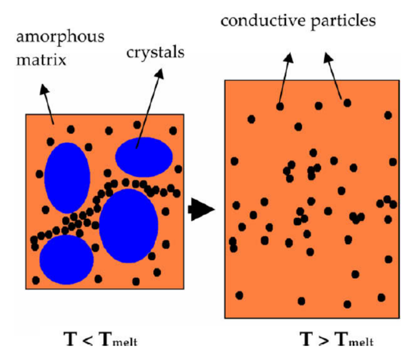

Fig. 14 – Schematic of crystal melting and the origin of the PTC effect in the composites of semi-crystalline polymers. T_{melt} represents the melting temperature of the crystals. Melting of large amounts of crystals augments the volume and disturbs the connectivity of the conductive particles.

Publications:

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2. Gunes, I.S., Jimenez, G., Jana, S.C. 2009 Carbonaceous fillers for shape memory actuation of polyurethane composites by resistive heating. *Carbon*, 47, 981-997.
3. 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.
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.
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8. Gunes, I.S., Cao, F., Jiménez, G.A., Jana, S.C., 2007 Evaluation of nanoparticulate fillers for shape memory polyurethane nanocomposites, SPE ANTEC 65, 1362-1366.
9. Cao, F., Jana, S.C., 2007 Shape memory polyurethane-clay nanocomposites. SPE ANTEC 65, 1367-1371.
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12. Cao, F., Jana, S.C., Shape memory polyurethane-clay nanocomposites. SPE ANTEC 65, 1367-1371.
13. Cao, F., Jana, S.C., 2006, Nanoclay-tethered shape memory polyurethane nanocomposites, SPE ANTEC 64, 646-649.