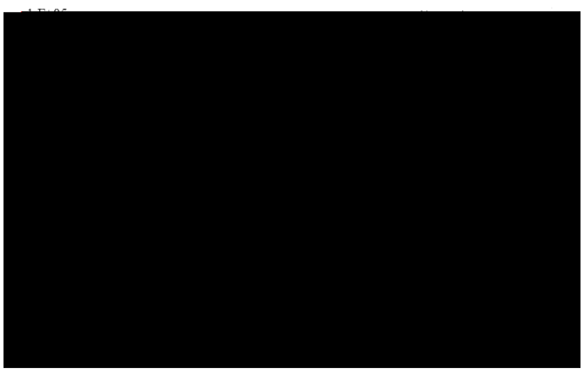
Novel polymer nanocomposite materials

We develop new materials for structural, electronic, electrical, and shape memory applications by combining nanoscopic metallic, semi-conducting, and non-metallic inorganic particles with high performance engineering thermoplastics, thermoplastic elastomers, and thermosetting polymers. The focus of this research is to develop fundamental understanding on nanofiller dispersion in thermosets (epoxies and PMR polyimides), polyolefins, thermoplastic polyurethane elastomers and foams, shape memory polymers, and polymer blends.

Our study revealed that low molecular weight thermosetting resins can be used as dispersing agents of nanoparticulate fillers, such as fumed silica and layered silicates in thermoplastic polymers, such as polyethersulphone, polyphenyleneether, polypehnylene sulphide, etc.

(a) **Epoxies**: We also found that in epoxy-nanoclay systems, the ratio $G'/|\eta^*|$ plays an important role in determining whether exfoliation, partial exfoliation, and intercalation occurs; G' is the storage modulus of intra-gallery epoxy and $|\eta^*|$ is the complex viscosity of extra-gallery epoxy at an instant of time. Complete exfoliation is obtained for values of $G'/|\eta^*|$ greater than ~4 1/s. Similar observations were made in the case of thermoset polyimides. A list of peer-reviewed publications is presented at the end of this document.



(b) **PMR resins:** We developed a novel method of nanoclay exfoliation in synthesis of nanocomposites of PMR-type thermoset resins. The method involves nanoclay intercalation by lower molecular weight PMR monomer prior to dispersion in primary, higher molecular weight PMR resin and resin curing to obtain the final composites. It was found that sonication of clay at the time of intercalation by lower molecular weight PMR resin helps achieve higher degree of exfoliation. In addition, clays obtained from ion exchange with a 50:50 mixture of N-[4(4-aminobenzyl)phenyl]-5 norborene-2,3-dicarboximide (APND), and dodecylamine (C12) showed better exfoliation than Cloisite® 30B clay and resultant nanocomposites show higher thermal stability and higher tensile modulus. A list of peer-reviewed publications is presented at the end of this document.

(c) **TPU:** Our group has developed a bulk polymerization method for efficient exfoliation of reactive layered silicate nanoparticles in thermoplastic polyurethane

Publications:

1. Roy, S., Lee, B.J., Kakish, Z.M., Jana, S.C. 2012 Exploiting sorbitol-POSS interactions: Issues of reinforcement of isotactic polypropylene spun fibers. *Macromolecules*, 45(5), 2420-2433.
2. Roy, S., Feng, J., Scionti, V., Jana, S.C., Wesdemiotis, C. 2012 Self-assembled structure formation from interactions between polyhedral oligomeric silsesquioxane and sorbitol in preparation of polymer compounds. *Polymer*, 53, 1711-1724.
3. Roy, S., Scionti, V., Jana, S. C*., Wesdemiotis, C., Pischera, A.M., Espe, M. P. 2011 Sorbitol–POSS interactions on development of isotactic polypropylene composites. *Macromolecules*, 44, 8064–8079.
4. Gunes, I.S., Pérez-Bolívar, C., Jimenez, G. A., Celikbicak, O., Li, F., Anzenbacher, P., Wesdemiotis, C., Jana, S.C.* 2011 Analysis of energy transfer and ternary non-covalent

17. Dharaiya, D., Jana, S.C., 2005 Thermal decomposition of alkyl ammonium ions and its effects on surface polarity of organically treated nanoclay. *Polymer*, 46(23), 10139-10147.
18. Dharaiya, D., Jana, S.C., 2005 Nanoclay-induced morphology development in chaotic mixing of immiscible polymers. *J. Polym. Sci., Part B: Physics*, 43(24), 3638-3651.
19. Pattanayak, A., Jana, S.C., 2005 Thermoplastic polyurethane nanocomposites of reactive silicate clays: Effects of soft segments on properties. *Polymer*, 46(14), 5183-5193.
20. Pattanayak, A., Jana, S.C., 2005 High strength and low stiffness composites of nanoclay-filled thermoplastic polyurethanes. *Polym. Eng. Sci.*, 45(11), 1532-1539.
21. Pattanayak, A., Jana, S.C., 2005 Properties of bulk-polymerized thermoplastic polyurethane nanocomposites. *Polymer,* 46(10), 3394-3406.
22. Pattanayak, A., Jana, S.C., 2005 Synthesis of thermoplastic polyurethane nanocomposites of reactive clay by bulk polymerization methods. *Polymer*, 46(10), 3275-3288.
23. Park, J.H., Jana, S.C., 2004 Adverse effects of thermal dissociation of quaternary ammonium ions on nanoclay exfoliation in epoxy-clay systems. *Polymer*, 45(22), 7673-7679.
24. Park, J.H., Jana, S.C. 2003 A case study on the effects of plasticization of epoxy networks by organic treatment on exfoliation of nanoclay. *Macromolecules*, **36**, 8391-8397.
25. Park, J.H., Jana, S.C., 2003 Mechanism of exfoliation of nanoclay particles in epoxy-clay nanocomposites. *Macromolecules,* **36**(8), 2758-2768.
26. Park, J.H., Jana, S.C., 2003 The relationship between nano- and micro-structures and mechanical properties in PMMA-epoxy-nanoclay composites. *Polymer*, 44(7), 2091-2100.
27. Jana, S.C., Jain, S. 2001 Dispersion of nanofillers in high performance polymers using reactive solvents as processing aids. *Polymer*, **42**(16), 6897-6905.