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Self-Assembly of Soft Matter/Nanoparticle Hybrids

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Abstract – The structure, dispersion, and chemical functionality of particles in a material are critical to the material's properties. We are working to build the scientific and technological foundations of using advanced particles, i.e. C_{60} and POSS, to develop new, highly functional materials through self-assembly. These efforts have involved developing new synthetic techniques to efficiently and precisely manipulate particles to control their dispersion and structure within a material. Polymer and porphyrin hybrids have been synthesized using C_{60} and POSS nanoparticles. The polymer materials are capable of assembling into polymer single crystals or micelles in solution. The porphyrin hybrids self-assemble into discotic columnar structures. Finally, C_{60}-POSS conjugate molecules have been synthesized that crystallize into alternating conducting and insulating layers. From these investigations, we will understand how best to chemically incorporate particles into materials for significant technological advancements.

The assembly of nanoparticles within different soft matter domains is robust, both technologically and from a fundamental science perspective. In our group, we have developed a precise, efficient way of attaching nanoparticles, specifically [60]fullerene (C_{60}) and polyhedral oligomeric silsesquioxanes (POSS), to polymers, discotic porphyrins, and to each other (C_{60}-POSS).[1] Figure 1 shows a schematic of each of these molecules. From these unique molecules, we have begun to study their self-assembly in bulk and solution under varying conditions.

The polymer-particle hybrids have been utilized in two capacities. First, a crystallizable polymeric moiety was synthesized to create polymer single crystals grown in solution. From previous studies of diblock copolymers with a crystallizable block, we know that the nanoparticles will be segregated to the basal surface of the polymer single crystal, forming monolayer sheets.[2] We have also used amorphous blocks that are attached to the nanoparticles to study their formation of micelles in solution. Each of these studies provides a promising route to synthesize monolayer conducting or insulating sheets and to analyze the structure of these assembled spherical (C_{60}) or cubic (POSS) particles.

The porphyrin hybrid materials have applications in photovoltaics. We have synthesized molecules with mono-, di-, and tri-substituted C_{60}-porphyrins. The addition of the C_{60} provides a method of charge-separation and conduction for the excitons created in photovoltaic cells. The porhpyrin molecule harvests photons through columnar mesophases. C_{60} is known for its efficiency as an electron-transporting material. We are currently studying the phase structures for these materials that promise to provide good efficiency for photovoltaic devices.

Finally, we have also synthesized dumbbell-like molecules with covalently attached C_{60} and POSS. These nanoparticles have been attached using a short acetate spacer group. We have found that these molecules crystallize under certain solution conditions to form a double-layered structure. This double layer structure consists of alternating conductive C_{60} and insulating POSS molecules. This material has been analyzed for its capacitance capabilities and has shown values better than traditional capacitors. Though it is currently less than inorganic supercapacitors, the formation of these nanoscale layers is much simpler.

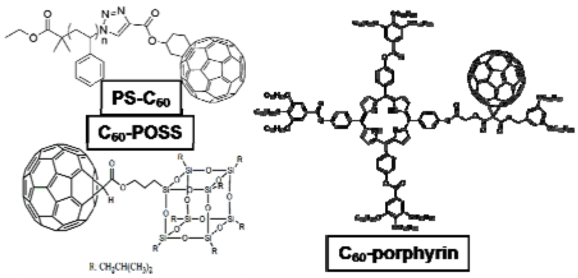

Figure 1: Schematic of polymer-C_{60}, porphyrin-C_{60}, and C_{60}-POSS hybrid molecules. Other materials with POSS instead of C_{60} have also been synthesized.

References

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