Research Experience
Dr. Alisyn J. Nedoma

1 Overview

My expertise is controlling the structure and properties of polymer nanocomposites using thermodynamic and kinetic controls. Working extensively with block copolymers, I have developed nanostructure characterization skills ranging from microscopy to small angle scattering. I apply first principles modelling to experimental work in order to guide systematic studies and quantify observations. My work demonstrates the manipulation of interactions in complex systems to control nanostructure and has delivered the fundamental understanding needed to optimize composites for commercial applications. My research combines modelling, synthesis, characterization, and optimization to generate novel multifunctional materials.

Teambuilding has been the greatest asset that I have brought to my collaborations. My interactions with colleagues are driven by respect for the work that we do together, and an ability to structure projects that build on members' strengths. I am a thoughtful manager, responding to researchers' differing needs for interaction by tailoring my delivery mode, whilst building a strong team ethos of shared discoveries. In both teaching and mentoring, I foster casual, two way communication. My enthusiasm enables me to effectively engage and interact with students and colleagues.

2 Improving plastic solar cells

As a Junior Research Fellow at Imperial College London, I independently built a research program that improved the stability and efficiency of plastic solar cells. My idea was to use a block copolymer to modulate the active nanostructures in solar cells. Pitching my idea to several funding agencies, I was awarded research grants from Imperial College (£30,000) and the Royal Society (£15,000). Joining the Centre for Plastic Electronics, I engaged collaborators, propelling my research program by building a team of faculty and students with complementary talents. Synthesis, characterization, and device testing, were each carried out in a different department by a member of my collaboration. Communicating regularly with each member, I streamlined the discovery and publication of novel methods for improving the stability and efficiency of plastic solar cells.

My work generated active nanostructures that were thermally stable up to 200°C, exceeding the benchmark for stability at 80°C, by using a diblock copolymer. Working within the specifications set by my synthetic collaborator, I designed the diblock copolymer with one semicrystalline block and one amorphous block. At equilibrium, the blocks phase separated to form alternating lamellar stacks of crystalline and amorphous regions with a repeat spacing of 14 nm (see Fig. 1). The light absorption spectrum of the diblock copolymer combined the absorption spectra of the two constituent polymer species, enhancing the light harvesting efficiency of the material. A fullerene was blended into the diblock copolymer, and preferentially segregated into the amorphous block. Using competitively awarded time at neutron and x-ray scattering facilities, I parsed out the interplay of thermodynamics and kinetic trapping in the self-assembly of nanostructures, and published my results as the corresponding author[1].

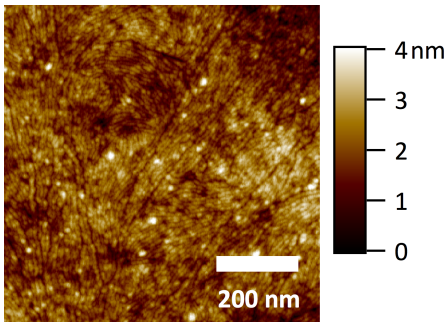

Figure 1. Atomic force micrograph of a block copolymer/fullerene thin film with crystalline polymer lamellae. Bright spots are fullerene crystals.

One of my main findings, in agreement with similar studies that use a homopolymer[2], is that kinetically induced structures form during the fabrication of a thin film, and vestiges of these kinetic effects remain even after thermal treatment. My work identifies an ongoing challenge in the field: nucleating a large number of fullerene crystals during the fabrication of the thin film. My findings have generated continued interest in the use of diblock copolymers for solar applications, and have resulted in efforts to simplify the synthesis of conjugated block copolymers.

Addressing the challenge of nucleating fullerene crystals, I published (corresponding author) a study comparing the nanostructures for two distinct methods of fabricating films: printing and rapid precipitation[3]. Rapid precipitation, quenching a solution of the polymer and fullerene into a nonsolvent, produces finer phase separation and higher crystallinity than printing a film. Using small angle neutron scattering, I determined that rapid precipitation nucleates both polymer and fullerene pure phases, whilst printing only nucleates polymer crystals because the solvent has a greater affinity for the fullerene whilst drying (see Fig. 2). Already a mature technology for producing commercial membranes, rapid precipitation promises scalability and finer nanostructures for plastic solar cells. Upscaling rapid precipitation for thin films is a nontrivial endeavor, but the challenges are offset by the potential in cost savings, decreased exposure to toxic solvents, and quality added device performance.

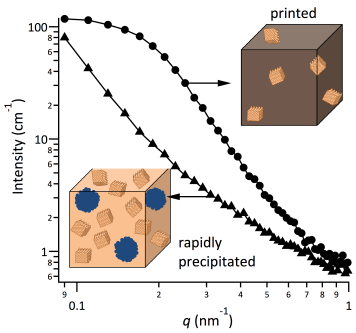

Figure 2. Small angle neutron scattering spectra. The printed sample comprises polymer crystals in a homogeneous polymer/fullerene phase. The rapidly precipitated sample comprises polymer crystals, fullerene aggregates, and a polymer-rich mixed phase.

3 Developing ultrainsulator thermal foams

During my doctoral research at the University of California, Berkeley, I engineered the materials and methods for Dow Chemical Company to produce nanostructured thermal foams. My research tailored the interactions of a block copolymer to stabilize the interface between two immiscible polymers: one a thermal insulator, the other a mechanical support. Combining neutron scattering measurements with thermodynamic modelling enabled me to quantitatively predict the phase behaviour and size of nanostructures formed. Lamellar structures were obtained from polymers with molecular weights varying across two orders of magnitude and binary feedstocks ranging from 10 - 90 vol%. The low cost and robust predictability of self assembly met Dow's expectations for flexibility between polymer batches. My doctoral research demonstrated predictable, tuneable nanophases in polymer-polymer composites.

References

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[2] B. Schmidt-Hansberg, M. Sanyal, M. F. G. Klein, M. Pfaff, N. Schnabel, S. Jaiser, A. Vorobiev, E. Muller, A. Colsmann, P. Scharfer, D. Gerthsen, U. Lemmer, E. Barrena and W. Schnabel, *ACS Nano*, 2011, **5**, 8579–8590.

[3] R. Dattani, M. T. F. Telling, C. G. Lopez, S. H. Krishnadasan, J. H. Bannock, A. E. Terry, J. C. de Mello, J. T. Cabral and A. J. Nedoma, *ChemPhysChem*, 2015, **16**, 1231–1238.