SAXS characterization of single component nanocomposites and polymer matrix composites

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The presentation will give an overview of some recent X-ray characterization work carried out at the Materials and Manufacturing Directorate at the Air Force Research Laboratory and highlight two examples in which scattering data is used to interpret critical parameters for understanding polymer dynamics in the glassy state or shape changes of a nanoparticle within thermosetting resins.

Single component nanocomposites made of polymer-grafted nanoparticles exhibit unique physical aging behavior (structural relaxation) compared to conventional nanocomposites. It is critical to understand the morphology and structure of these hybrid systems and couple their glassy dynamics with confinement geometry and distribution. SAXS in combination with TEM is used to probe the morphology of these systems as a function of polymer molecular weight of grafted chains, the graft density and the core particle size. This data is compared to conventional blends at similar nanoparticle loadings. Structural relaxation is critical in thin film and emerging applications such as additive manufacturing. It is shown that confinement environment and distribution dictates or even suppresses structural relaxation.

Shape change in gold nanoparticles as a function of temperature within thermosetting resins at very low volume fractions (< 1%) allows the reporting of temperatures that a composite has seen in service and therefore allows assessment of potential damage to a thermoset composite. UV spectroscopy of the plasmon resonance peak provides an aspect ratio as function of temperature. However, the dielectric constant of the matrix changes under environmental changes and leads to a convolution of property changes in UV-Vis. SAXS was carried out to follow the shape change in real-time while doing simultaneous UV-Vis spectroscopy to decouple shape change from dielectric constant changes of the matrix. The data is used to map a temperature gradient within a carbon fiber/epoxy composite that underwent heat treatment through the fiber.

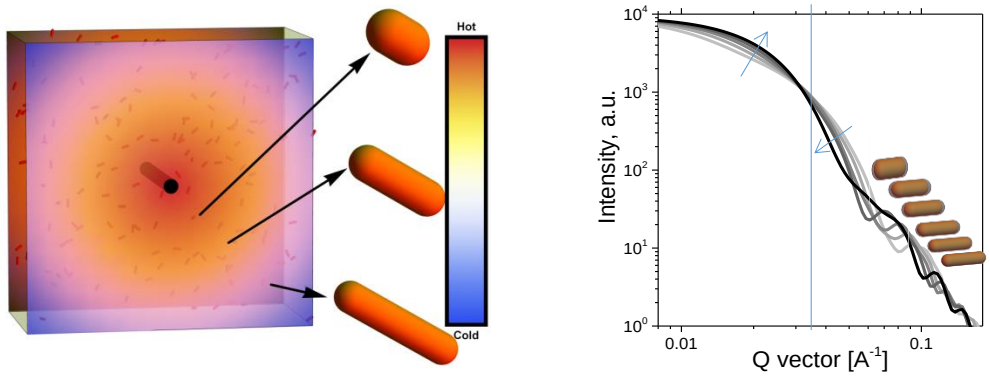

Figure: Gold nanoparticles as temperature sensor. Left: Schematic of shape change of gold nanoparticles triggered by a heat radiating carbon fiber within a thermoset composite. Right: SAXS pattern evolution as the shape of gold nanoparticles changes.