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Fluid Phases of Carbon Nanotubes and Graphene

MATTEO PASQUALI, Department of Chemical & Biomolecular Engineering and Chemistry, The Smalley Institute for Nanoscale Science and Technology, Rice University

Nanoscale carbon—including Carbon Nanotubes (CNTs) as well as graphene, i.e., graphite in its single layered form—has remarkable electrical, thermal, and mechanical properties, more so than previously known polymer molecules or colloidal particles. Realizing these properties in applications requires understanding and controlling the behavior of fluid phases of CNTs and graphene. Biological and environmental applications are likely to require dilute phases of CNTs and graphene; material processing, e.g., production of coatings and fibers, will require more concentrated phases. Fluid processing is one of the most important frontiers of applied research in CNTs and graphene. Nano-carbon fluids are almost considered an oxymoron because dispersing or dissolving CNTs and graphene into fluid phases is exceedingly difficult. This talk reviews advances in understanding and controlling fluid phases of CNTs and graphene, with specific focus on single-object properties and true solutions. The dynamics of individual CNTs can be studied by fluorescence microscopy, revealing that their translational and rotational motion and bending stiffness can be described well by the semiflexible chain model. Even at low concentrations (few parts per million), CNTs form complex fluid phases with intriguing properties. In strong acids, CNTs as well as graphene dissolve spontaneously. At low concentration, these fluids can be used for making transparent, conducting films and coatings. In crowded environments, CNTs reptate like stiff polymers. At sufficiently high concentrations, CNTs and graphene form liquid crystals that can be spun into well-aligned, macroscopic fibers. Like in polymeric systems, the properties of macroscopic CNT materials depend on the length (molecular weight) of the constituent CNT macromolecules.