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From Networks to Nematics – Carbon Nanotubes as Soft Matter

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Carbon nanotubes represent just one example of an emerging paradigm in condensed matter physics and materials science: traditionally "hard" materials appearing in new "soft" applications and environments. In part, this trend being is being fueled by the desire to exploit solution and fluid-based approaches, such as self assembly and flow processing, in an effort to streamline the engineering and commercialization of new materials and applications. In this talk I will review our recent work on dispersing, aligning and manipulating carbon nanotubes in complex fluids and polymer melts. Due to the large aspect ratios and strong attractive interaction potentials intrinsic to such materials, a number of scientific and technical challenges become immediately apparent. In particular, I will focus on the subtle interplay of rheological influences, such as externally applied shear and elongation stresses, with the inherent "stickiness" of carbon nanotube suspensions and melts, where the latter typically favors the formation of disordered networks or "gels" over the more desirable liquid-crystalline order. For simple shear, the strength of the applied stress is found to be a critical factor in dictating carbon nanotube morphology, which varies from a quiescent network to macroscopic aggregates to a fully dispersed, flow-aligned (para)nematic state. Although we find remarkably low loading thresholds for elastic percolation, our results highlight a fundamental dilemma for the engineering of conducting carbon nanotube polymer composites; dispersion stability will often be achieved at the expense of electrical conductivity.