Conductive coatings and fibers from nanoscale carbon

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Certain materials properties are viewed as contradictory. For example, high electrical and thermal conductivity are associated to hard, crystalline materials such as metals or graphite. Conversely, softness is associated with biological materials, polymers, colloids, and disordered structures, which are also thermally and electrically insulating. We have essentially accepted that certain ostensible contradictions cannot be resolved. For example, we have no material that is electrically conductive and can be sutured or sewn, despite the obvious need in medical devices and wearable electronics.

Nanoscale carbon—including Carbon Nanotubes (CNTs) and graphene—has remarkable electrical, thermal, and mechanical properties; thus, it is uniquely suited as building block for novel conductors. Yet, broad applications of nanoscale carbon to real-world problems have largely gone unfulfilled because of difficult material synthesis and laborious processing. In this talk, I will discuss how CNTs and graphene can and should be viewed as hybrids between polymer molecules and colloidal particles, and how this approach can be used to manufacture for soft conducting coatings and fibers.

Even at minute concentrations, CNTs form complex fluid phases with intriguing properties. In crowded environments (e.g., gels), CNTs reptate like stiff polymers; surprisingly, the small bending flexibility of CNTs strongly enhances their motion. CNTs and graphene can be solution-processed in strong acids, their sole true solvents. At low concentration, these fluids can be used for making transparent, conducting, flexible films and coatings, as well as highly porous, soft three-dimensional structures. At higher concentration, these fluids can be wire-coated to make shielding in coaxial cables. At even higher concentration, CNTs and graphene form liquid crystals that can be scalably spun into high-performance multi-functional fibers. These CNT fibers combine the high conductivity, strength, and the emergent property of softness; they are already finding high-value applications in aerospace electronics, Hi-Fi cables, and field emission. As soft conductors, CNT fibers provide a natural interface to the electrical function of the body as restorative patches for electrically damaged heart tissue as well as electrodes for stimulating and sensing the activity of the brain.