Darrell H. Reneker

Nanofibers by electrospinning

Thin, long, high surface area fibers

An electrified jet, carrying a solution of dissolved but entangled polymer molecules, emerges from an orifice. The electrical charge distributes itself on the surface of the liquid jet. The self-repulsion of the charge tends: to elongate the jet, to reduce the jet diameter, and to prevent the formation of a capillary instability. The elongation proceeds so rapidly that the jet bends and coils to accommodate the increase in its length without accelerating the liquid jet in the initial direction. Many turns of bending coils form and the perimeter of each turn grows longer. Ultimately, when the solvent evaporates, a nanofiber is formed that is strong enough to prevent further elongation by the remaining electrical force. (see “Fundamentals and applications of micro- and nano- fibers”, Yarin, Pourdeyhimi and Ramakrishna, Cambridge, 2014)

Nanofibers of polyvinylidene fluoride (PVDF) a few nanometers in diameter were observed with an aberration corrected transmission electron microscope. The positions of fluorine atoms in a twisted and bent segment of a PVDF molecule were observed. Segmental motions of the molecules on a time scales of seconds were observed. Measurements of the electron current through the sample showed that atomic resolution images were obtained before the imaging electrons changed the chemical structure of the molecular bonds of the polymer. Many interesting things inside the nanofiber were observed (see DOI: 10.1039/c5nr01619c). Do the motions of PVDF molecules observed in both the electron microscope images and in molecular dynamics calculations play an important role in the separation of sodium and chlorine ions from uncharged but dipolar water molecules?

The use of nanofibers for filtration has grown rapidly during the previous two decades. Nanofiber applications in biology and clinical medicine are developing rapidly. Mats of nanofibers carrying drugs for slow release can be placed at and remain for long times at strategic locations in the body. Limited electrical communication with the nervous system is already achieved for hearing, sight, muscle control, and sense of touch. The development of electrically conducting nanofibers can provide additional signal channels between electronic devices and nerves. Nanofibers, manufactured in the gravity free vacuum of outer space from molten polymer, and positioned by nanofiber handling kinds of additive manufacturing techniques, may form useful structures. Contemplation, of a bag 10 meters in diameter, with ten nanometer thick walls of nanofibers and lithium metal, built with solar generated electrical power and thermal energy, is interesting.

Design skills of synthesis chemistry, computational devices, molecular scale and contemporary chemical, mechanical and electrical engineering are all needed.