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Carbon Nanotube Spun Threads: Current Status and Prospects

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ABSTRACT

Carbon Nanotubes (CNTs) have excellent properties along the tube axis. Although the material has fantastic properties at nanoscale, it has proven difficult to assemble CNTs into macroscale products that retain these properties. Macroscopic assemble can be achieved by method of spinning. During this talk I will discuss different methods for spinning CNTs into continuous fibers viz. dry spinning and wet spinning. CNT fibers can be produced from spinnable arrays. It is found that CNT length plays an important role in the strength of CNT fibers. Several ways of spinning CNTs includes dispersing in liquid and by binding the ends of CNT bundles in the array. The obtained fiber has high electrical conductivity by using annealed CNTs but low strength. Besides dry spinning, wet spinning methods were also applied to spin CNT fibers. One way of wet spinning to produce CNT fibers is through coagulation of CNT dispersions in a polymer bath. Process of another method is to add CNTs in a polymer solution and wet spin the polymer. Polyvinyl Alcohol (PVA) is used as the matrix polymer. Addition of CNTs in PVA solution improves strength of the fiber when CNT are well dispersed. Properties of these fibers were dominated by the polymer. Spinnable Carbon Nanotubes (CNTs) are useful formats for studying physical properties of CNT fiber assemblies in their pristine states. They are free of catalyst, uniform in length, with a comparatively narrow diameter distribution and their assembly into thread does not require additional chemicals or solvents. Good quality drawable CNT arrays can be readily assembled into uniform diameter threads with great control over the number of CNTs incorporated into the thread assembly. This uniformity allows study the physical properties that result from changes that occur during thread formation. The properties like electrical resistivity and mechanical strength can be correlated as a function of diameter, density and turns/meter. Understanding the effects of dry-spinning parameters will allow a better design of the physical properties of CNT threads for specific applications, such as strain or electrochemical sensors. Direct spinning from CVD chamber is another method of spinning. The alignment and compaction of Carbon Nanotube (CNT) bundles greatly affects the time-dependent behaviors and relaxation process of the CNT fibers spun from floating catalyst chemical vapor deposition method. The long-term mechanical behavior of the CNT fibers shows a strong time-dependency in relaxation process that evidences a noticeable viscose force due to weak interfaces between their CNT bundles. The CNT fibers with higher alignment and compaction exhibit stronger CNT-CNT interfaces, resulting in better inter-tube load transfer efficiency, more difficult CNT bundles slippage and higher elastic behavior. The direct spun mat comprises an interlinked random network of nanotube bundles. The bundles occasionally branch and the mesh topology resembles a 2D lattice of some nodal connectivity. The macroscopic in-plane tensile response is elasto-plastic in nature, with significant orientation hardening. *In situ* microscopy reveals that the nanotube bundles do not slide past each other at their junctions under macroscopic strain. A micromechanical model can be developed to relate the macroscopic modulus and flow strength to the longitudinal shear response of the nanotube bundles. CNT spun thread has got tremendous attention in several applications. In one such application CNT spun thread can be used to predict damage in laminated composite materials.

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