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Case ID:M21-212P^
Published: 3/30/2022

Structured Composite Fibers Via Forced Assembly Dry-Jet-Wet Spinning of Carbon Nanotubes and Polyacrylonitrile

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-Background Nanoparticle-filled polymer composites have been extensively researched in the past few decades due to their unique functional properties, durability, and chemical stability. Among these, carbon nanotubes (CNTs) have garnered attention for their high flexibility, large aspect ratio, high intrinsic elastic modulus and strength, and high electrical and thermal conductivities. The performance of functional CNT composite materials is heavily dependent on the control of the CNT microstructure, including location deposition, dispersion quality, and nanoparticle alignment at the nanoscale. The precise alignment of individual nanotubes or their bundles remains a challenge within current mainstream strategies of simple blending or mixing for nanoparticle dispersion. Polyacrylonitrile (PAN) is the most frequently used precursor to carbon fibers and has been used in many applications related to CNT-reinforced fibers. However, the high loading of CNTs often results in defects due to limited orientation and nanoparticle aggregation, making it necessary to develop a better method to control CNT conformations. Invention Description Researchers at Arizona State University have developed a method to produce a CNT/PAN-based fiber through a process that combines the dry-jet wet spinning and forced assembly techniques, enabling structural control of multilayered fiber morphology. The mechanical properties of the fiber become more pronounced with increasing layer numbers—at 512 layers (layer thickness of approximately 170 nm), the fibers showed a 27.4% increase in Young's modulus and 22.2% increase in ultimate tensile strength compared to the traditionally dispersed D-Phase fiber (i.e., PAN/0.5 wt% CNTs). The stiffening and strengthening were mainly due to (i) improved quality of nanoparticle dispersion, (ii) increased long-range crystallinity of the polymer chains, and (iii) enhanced nanoparticle orientations degree. The optimum dispersion contained nanotubes that were closely packed and continuously aligned. This higher nanoparticle reinforcement efficiency demonstrated the potential to enhance carbon fibers for diverse mechanical applications. Furthermore, the scalable fabrication of such a hierarchical structure has application potential in thermal management, energy storage devices, wearable electronics, and electromagnetic shielding. Potential Applications • Mechanically reinforced fibers and films • Sensors, actuators, and electronics • Additive manufacturing • Energy storage devices Related Publication: Hierarchically Structured Composite Fibers for Real Nanoscale Manipulation of Carbon NanotubesResearch Homepage of Professor Kenan Song