

Carbon Hybrid Materials - by Design

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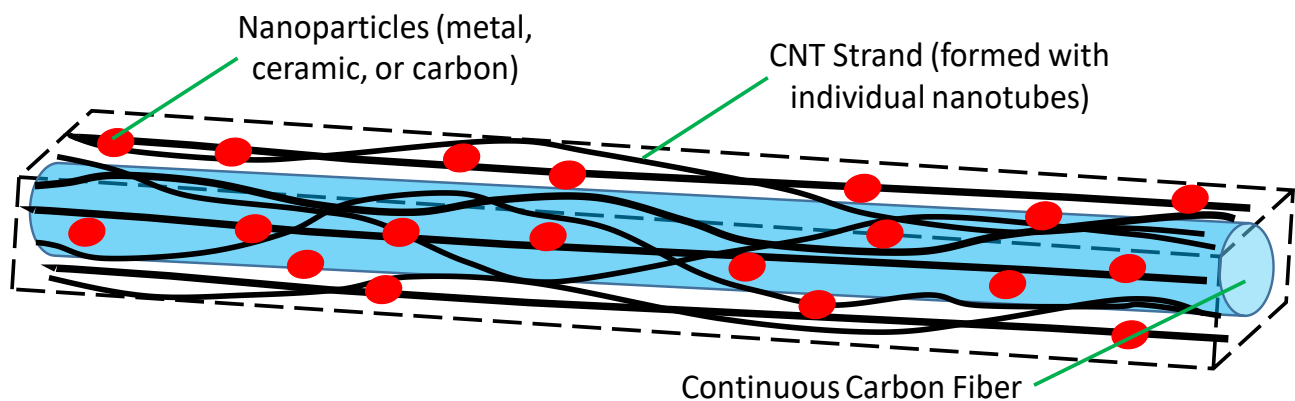
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Graphical Abstract



The scale of Carbon Hybrid Materials components spans three orders of magnitude. The unit cell of CHM incorporates CNT (7 nm) within the strands, the CNT strands (70 nm), Nanoparticles (700 nm), and a Micro-fiber (7,000 nm).

Abstract

The purpose of Carbon Hybrid Materials (CHM) research is to design and synthesize new materials for critical applications. This lecture gives an overview of the development of CHM which is performed by a large team. The experimental procedure used is to combine different Additive Materials (AM) with Carbon Nanotube (CNT) nonwoven matrix material to form custom hybrid materials. A CNT sock which is web-like assembly of strands composed of individual CNTs is produced in the floating catalyst method. The sock is deposited onto a drum and acts as a fabric matrix material. Key findings are that it is possible to use the matrix material to form CHM in different practical ways. Nanoparticles (NPs) are integrated within the matrix. The strands and encapsulate the micro-fibers which are in the form of short fibers, continuous fibers. other types of AM can also be used. However, the AM should be small to best integrate with the CNT fabric matrix which is non-woven. Adding NPs into the inlet of the synthesis process is done using a custom designed particle injector that can inject different types of nano and micro particles into the high

temperature nanotube synthesis process. NPs and short and continuous fibers can also be incorporated into the CNT sock matrix as it is being wound onto a take-up drum in the harvesting box. Solvent which can contain embedded particles or fibers is used to densify the CNT sock. Properties of the CHM produced depend on the AM used. A conclusion is that CHM can be designed to be lightweight and strong in tension, and can form polymer-free composites, electrical conductors and shields, radiation shields, and many other types of customized materials. Composite materials formed using the CNT sock as a matrix material and adding particles or fibers, or both, to the matrix can be an important new material. The CNT sock must completely encapsulate the particle or fiber to have the effect of a matrix material that holds and protects the fiber. Van der Waals forces and entanglement forces are most effective at the nanoscale, thus the AMs must be separated and dispersed when integrated into the CNT sock. Continuous carbon fibers are integrated by winding onto the drum but a flat tow of carbon fibers is needed so that the CNT sock can individually encapsulate the CF. The CHM formed are composite fabrics with no conventional binder or polymer matrix material. Potentially, these polymer-free composites can have modest and tailorable stiffness in bending and would be useful for applications where a polymer matrix is unsuitable. Molecular nanocarbon science has been focused on new forms of carbon and hydrocarbons using organic synthesis. In [1], it is stated that a mixture problem and an unsynthesized problem are holding back the field and “the establishment of new methodologies and techniques for molecular synthesis and structural analysis will remain of vital importance.” Also, “modification of nano-carbons will lead to new fields and applications associated with their unforeseen properties and functions.” This lecture also discusses combining chemically and physically CNT with metals and other carbon and ceramic materials. Adding metals to the nanotube synthesis process has created sheets, spirals and cone shaped carbon forms, and CNT bundles have been “glued” together at their ends with Ag-Cu spheres [2-5]. The CHM method is new and it is unknown what new materials may have properties by design. CHM technology is bringing out new carbon-metal hybrids.

Keywords: Carbon nanotube; fabric matrix; additive materials; nanoparticles; continuous fiber.

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Biography of Presenting Author



Mark J. Schulz is Professor of Mechanical and Materials Engineering at the University of Cincinnati and is Co-director with Dr. Vesselin Shanov of the Nanoworld Laboratories at the University (<https://ceas.uc.edu/research/centers-labs/nanoworld.html>). Nanoworld is a large academic laboratory for carbon nanoscale materials research. The strategic goal of the Nanoworld laboratory is to integrate nanotech into university-wide curricula, to interest students to go to graduate school, and to develop new engineering and medical devices based on carbon materials and biodegradable metals. The Nanoworld Lab focuses on societally important and complex problems, and teaching innovation to students. Nanoworld is trailblazing and road mapping innovation, translating the discoveries to industry, and training a next generation workforce that will be in high demand. Mark teaches the *Introduction to Smart Structures* course. He co-founded the “Nanotechnology Materials and Devices (NMD) Workshop.” The NMD Workshop is organized by the University of Cincinnati, the Air Force Research Laboratory and the University of Dayton Research Institute. Nanotube experts from around the world attend. Mark advised over 70 graduate students. He and his students produced many publications and patents, and conducted many research projects. Mark co-edited four books on nanotechnology. He has a PhD degree in Mechanical Engineering from the State University of New York at Buffalo. Mark collaborates with researchers at other universities (North Carolina A&T SU, the University of Pittsburgh) and industries. He is a fellow of the American Institute for Medical and Biological Engineering and has been a Distinguished Engineering Researcher in the College of Engineering and Applied Sciences.

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