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# NANOTUBE SUPERFIBER MATERIALS

Creating Engineering Design

# Nanotube Superfiber Materials Chapter 11 Carbon Nanofiber Multifunctional Mat Micro And Nano Technologies

**Mark J. Schulz, Vesselin N.  
Shanov, Zhangzhang Yin**



## **Nanotube Superfiber Materials Chapter 11 Carbon Nanofiber Multifunctional Mat Micro And Nano Technologies:**

**Nanotube Superfiber Materials** Carla L. Lake, Patrick D. Lake, 2013-09-16 Carbon nanofibers are useful additives for improving the performance of polymer matrix composites but the performance has sometimes been hindered by limits encountered in composite processing. Historically incorporating nanofibers and other nanoparticles into structural composites has required lengthy predispersion steps using specialty dispersion techniques. Also filtration of the nanoparticles by larger reinforcements is a problem in resin transfer molding processes. A way to overcome the problems with nanoparticles is through the use of carbon nanofiber sheets. The sheet material eliminates predispersion and reagglomeration and allows nanoparticle insertion into prepeg materials in the same manner as with traditional reinforcement materials. Composites fabricated with carbon nanofiber sheets demonstrate multifunctional property enhancements without altering traditional composite manufacturing processes. This chapter discusses development of carbon nanofiber continuous sheet goods and their applications.

**Nanotube Superfiber Materials** Stephen C. Hawkins, 2013-09-16 The nature of fiber materials and the differences between conventional fibers and nanoscale fibers are discussed in this chapter. The challenge of carbon nanotube CNT yarn fiber fabrication is provided from the perspective of conventional yarn fiber fabrication. Prospects for large scale manufacturing and the physical properties of yarn are also discussed. This chapter sets the stage for presentation of a compendium of techniques working toward producing superfiber materials.

Nanotube Superfiber Materials Rachit Malik, Noe Alvarez, Mark Haase, Brad Ruff, Yi Song, Bolaji Suberu, Duke Shereen, David Mast, Andrew Gilpin, Mark Schulz, Vesselin Shanov, 2013-09-16 Individual carbon nanotubes CNTs have exceptional mechanical and electrical properties. However the transfer of these extraordinary qualities into CNT products without compromising performance remains a challenge. This chapter presents an overview of the manufacturing of CNT sheets and buckypaper and also describes research performed at the University of Cincinnati in this field. CNT arrays were grown using the chemical vapor deposition method. Sheets were drawn from the spinnable CNT arrays and characterized using scanning electron microscopy to show the highly unidirectional alignment of the nanotubes in the sheet. The anisotropic morphology of the sheet provides superior properties along one material axis as observed by measuring the tensile strength, electrical resistivity, optical transmittance and electromagnetic interference shielding properties of the material. Surface modification of aligned multiwall nanotube sheets was carried out via incorporation of an atmospheric pressure plasma jet in the sheet posttreatment process. Helium oxygen plasma was utilized to produce carboxyl COO functionality on the surface of the nanotubes. X ray photoelectron spectroscopy confirmed the presence of the functional groups on the nanotube surface. The sheet was further characterized using Raman spectroscopy, Fourier transform infrared spectroscopy and contact angle testing. Composite laminates made from functionalized CNT sheets showed higher strength than those made with pristine sheets. The effects of plasma power and oxygen concentration were studied in order to determine the best possible

parameters for functionalization Plasma treatment is a useful tool for fast clean and dry functionalization of CNTs This study demonstrates the ease of incorporating the plasma tool in the manufacturing process of sheets leading to the production of CNT polymer composites Macroscopic structures of nanotubes such as threads and sheets are leading to novel applications

**Nanotube Superfiber Materials** Lakshman K. Randeniya,2013-09-16 This chapter discusses fabrication of carbon nanotube yarn and coating of metals and nonmetals onto the yarn to increase electrical conductivity An increase in weight due to the metal particle coating is the trade off for achieving increased electrical conductivity Electrical conductors made from the hybrid alloy yarn may have multiple applications including in electrical conductors and transmission lines Carbon nanotube yarns also show potential as microelectrodes and robust and flexible chemiresistors for molecular detection The decoration of metal nanoclusters on the yarn provides high sensitivity and selectivity to gases that are present in industrial and environmental emissions Overall coating yarn with particles produces a multifunctional material that opens up new design possibilities for applications

**Nanotube Superfiber Materials** Xin Wang,Philip D. Bradford,Qingwen Li,Yuntian Zhu,2013-09-16 Carbon nanotubes CNTs possess the unique combination of extreme mechanical and physical properties at the level of the individual tube They are often considered one of the best candidates for the reinforcement of the next generation of multifunctional composite materials It is essential to assemble the CNTs into macroscopic assemblies resembling traditional fiber reinforced composites to begin to realize their potential and make them a serious candidate for commercial composite structures This chapter presents a general introduction to aligned and high volume fraction CNT composites and then explores two recent promising approaches for fabricating strong stiff and multifunctional aligned CNT polymer composite prepregs at satisfactory processing rates One approach involves incorporating drawable superaligned CNT sheets into high volume fraction composites through spraying or spray stretching and winding The other approach is based on directly shear pressing vertically aligned CNT arrays into horizontally aligned sheets with subsequent polymer infiltration Both approaches produced CNT composite prepregs with desirable structural features and excellent properties Aligned CNT bismaleimide composites produced by stretch winding exhibited a combined tensile strength and elastic modulus exceeding carbon fiber composites The exceptional mechanical performance coupled with unique electrical and thermal properties makes these materials promising for a wide range of applications such as multifunctional composite structures lightweight and flexible conductors thermal interface materials and sensors

**Nanotube Superfiber Materials** Mark J. Schulz,Brad Ruff,Aaron Johnson,Kumar Vemaganti,Weifeng Li,Murali M. Sundaram,Guangfeng Hou,Arvind Krishnaswamy,Ge Li,Svitlana Fialkova,Sergey Yarmolenko,Anli Wang,Yijun Liu,James Sullivan,Noe Alvarez,Vesselin Shanov,Sarah Pixley,2013-09-16 Nanotubes are a unique class of materials because their properties depend not only on their composition but also on their geometry The diameter number of walls length chirality van der Waals forces and quality all affect the properties and performance of nanotubes This dependence on geometry is what makes scaling up nanotubes to

form bulk material so challenging Nanotubes are also unusual because they stick together to form bundles or strands Nanotube superfiber materials are fibrous assemblages of nanotubes and strands The hope and dream of researchers around the world is that nanotube superfiber materials will have broad applications and change engineering design This chapter gives a perspective on nanotube superfiber development This chapter discusses new applications where we think we can go with the material properties and what applications will be enabled and new techniques for developing superfiber material

**Nanotube Superfiber Materials** Rufan Zhang, Yingying Zhang, Fei Wei, 2013-09-16 Ultralong carbon nanotubes CNTs are ideal building blocks for nanodevices and superstrong fibers Due to their high aspect ratio structure formed from sp<sup>2</sup> hybrid C C bonds they have extraordinary mechanical electrical and thermal properties It is of great importance to synthesize ultralong CNTs with controlled structures as well as optimized properties for their applications This chapter discusses the synthesis methods growth mechanisms structures electrical and mechanical properties as well as the applications of ultralong CNTs We show that the controlled synthesis of ultralong CNTs with certain structures and properties is of fundamental importance for their applications Finally we also show that the mechanical properties of ultralong CNTs are near the theoretical value showing great potential for their applications in superstrong fibers

*Nanotube Superfiber Materials* Ana Laura Elías, Néstor Perea-López, Lakshmy Pulickal Rajukumar, Amber McCreary, Florentino López-Urías, Humberto Terrones, Mauricio Terrones, 2013-09-16 Carbon nanotubes CNTs are considered one dimensional systems that possess fascinating electronic chemical and mechanical properties They exhibit metallic or semiconducting behavior depending on the nanotube diameter and chirality and they are ultrarobust and lightweight Moreover their surface can be chemically activated thus being able to establish different types of bonds between the carbon nanotube surface and a large number of chemical species for instance they could be introduced into a polymeric matrix improving its mechanical or electronic properties In addition CNTs are able to host different species in their hollow core such as ferromagnetic clusters molecules and gases Nowadays synthesis techniques have achieved control of the length and diameter of CNTs which constitutes a step forward toward applications In this chapter we address the issue of using CNTs as fundamental building blocks for constructing three dimensional 3D networks Here we present a review of the experimental and theoretical investigations on the formation of 3D networks using CNTs as the main component In addition the latest advances on the synthesis and characterization of different carbon nanostructures involving CNTs such as branches junctions and foams are discussed

**Nanotube Superfiber Materials** Janet Hurst, 2013-09-16 This chapter describes the development of noncarbon nanotubes and compares the features of carbon and noncarbon nanotubes Carbon nanotubes are the most widely available nanotube material and are typically used for reinforcement of polymeric and glass materials electronic applications etc Noncarbon nanotubes such as boron nitride and silicon carbide have advantages for use in aggressive environments Possible uses of noncarbon nanotubes include reinforcement of metals polymers and glasses

environmental and thermal barrier coatings electronics and radiation shielding

**Nanotube Superfiber Materials** Mark J. Schulz, Vesselin N. Shanov, Zhangzhang Yin, 2013-06-17 Nanotube Superfiber Materials refers to different forms of macroscale materials with unique properties constructed from carbon nanotubes. These materials include nanotube arrays, ribbons, scrolls, yarn, braid, and sheets. Nanotube materials are in the early stage of development and this is the first dedicated book on the subject. Transitioning from molecules to materials is a breakthrough that will positively impact almost all industries and areas of society. Key properties of superfiber materials are high flexibility and fatigue resistance, high energy absorption, high strength, good electrical conductivity, high maximum current density, reduced skin and proximity effects, high thermal conductivity, lightweight, good field emission, piezoresistive, magnetoresistive, thermoelectric, and other properties. These properties will open up the door to dozens of applications including replacing copper wire for power conduction, EMI shielding, coax cable, carbon biofiber, bullet proof vests, impact resistant glass, wearable antennas, biomedical microdevices, biosensors, self-sensing composites, supercapacitors, superinductors, hybrid superconductor, reinforced elastomers, nerve scaffolding, energy storage, and many others. The scope of the book covers three main areas: Part I Processing, Part II Properties, and Part III Applications. Processing involves nanotube synthesis and macro-scale material formation methods. Properties covers the mechanical, electrical, chemical, and other properties of nanotubes and macroscale materials. Different approaches to growing high quality long nanotubes and spinning the nanotubes into yarn are explained in detail. The best ideas are collected from all around the world including commercial approaches. Applications of nanotube superfiber cover a huge field and provides a broad survey of uses. The book gives a broad overview starting from bioelectronics to carbon industrial machines. First book to explore the production and applications of macro-scale materials made from nano-scale particles. Sets out the processes for producing macro-scale materials from carbon nanotubes and describes the unique properties of these materials. Potential applications for CNT fiber yarn include replacing copper wire for power conduction, EMI shielding, coax cable, carbon biofiber, bullet proof vests, impact resistant glass, wearable antennas, biomedical microdevices, biosensors, self-sensing composites, supercapacitors, superinductors, hybrid superconductor, reinforced elastomers, nerve scaffolding, energy storage, and many others.

Nanotube Superfiber Materials Michael B. Jakubinek, 2013-09-16 Individual carbon nanotubes (CNTs) have been reported to have the highest thermal conductivities of any known material. However, significant variability exists both for the reported thermal conductivities of individual CNTs and the thermal conductivities measured for macroscopic CNT assemblies, e.g. CNT films, buckypapers, arrays, and fibers, which range from comparable to metals to aerogel-like. This chapter reviews the current status of the field, summarizing a wide selection of experimental results and drawing conclusions regarding present limitations of the thermal conductivity of CNT assemblies and opportunities for improvement of the performance of nanotube superfiber materials.

Nanotube Superfiber Materials Nicola Pugno, 2013-09-16 In this chapter the mechanics of nanotubes, graphene, and related fibers are reviewed.

with an eye to the limiting case of the design of a space elevator megacable The effect on the fracture strength of thermodynamically unavoidable atomistic defects with different sizes and shapes is quantified Brittle fracture is investigated both numerically with ad hoc hierarchical simulations and theoretically with quantized fracture theories for nanotubes graphene and related bundles

**Nanotube Superfiber Materials** T. Filleter, A.M. Beese, M.R. Roenbeck, X. Wei, H.D. Espinosa, 2013-09-16 Performance and efficiency demands in industrial applications are pushing a need for carbon fibers that can outperform existing technologies Fibers that incorporate carbon nanotubes CNTs to enhance specific mechanical properties are a promising route to addressing this need Some of the major roadblocks to unlocking the full potential of macroscopic fibers based on CNTs are controlling and optimizing the shear interactions within and between CNTs geometrical organization of the CNTs and structural properties of the individual CNTs Several approaches have been pursued in order to optimize the mechanical behavior of CNT fibers including irradiation induced covalent cross linking reformable or rehealable bonding and optimized geometrical and structural fiber designs These approaches are inspired by nature which uses hierarchical bonding schemes in optimized orientations to tailor the mechanical properties of its materials to the needs and environment of specific organisms In this chapter these approaches for developing high performance CNT fibers will be reviewed and an outlook of their potential impact will be discussed

**Nanotube Superfiber Materials** Steven D. Keller, Amir I. Zaghoul, 2013-09-16 The application of carbon nanotube CNT materials to produce lightweight flexible and durable RF antenna designs is explored through simulation fabrication and measurement of a variety of CNT thread and sheet antenna designs The conductivity and current distribution for a dipole antenna constructed from CNT thread rope are simulated using Hall n s integral equation for a thin wire applied to the Method of Moments An aperture coupled patch antenna composed of CNT sheet material is fabricated measured and compared with a standard copper patch antenna Finally a meshed patch antenna composed of interwoven CNT threads is developed and simulated as a concept for a multifunctional communications antenna and reactive gas sensor

**Nanotube Superfiber Materials** Miao Zhu, Hongwei Zhu, 2013-09-16 Carbon nanotube CNT yarn represents one of the most remarkable macrostructures of CNT with its excellent performance in terms of mechanical and electrical properties Various synthesis methods have been developed and an increasing number of applications have been reported to date making yarn production one of the most active fields in current research on nanomaterials In this chapter we focus on the direct synthesis of long CNT yarns by chemical vapor deposition including some discussions of the growth parameters and key characteristics of as grown yarns A general introduction to the potential applications of CNT yarns fibers is given to outline its broad prospects in different fields

**Nanotube Superfiber Materials** Xiaogan Liang, 2013-09-16 This chapter provides a systematic comparison of band structures physical properties as well as associated applications between carbon nanotubes and graphene Both these two carbon based nanomaterials are composed of hexagonally arranged carbon atoms based on sp<sup>2</sup> hybridization and thus share some relevant characteristics

However they have significantly different electronic states due to their morphological variation in quantum confinement which is responsible for their different electrical mechanical and optical properties This chapter provides readers some basic knowledge hints and insights for choosing appropriate carbon based nanomaterials for specific applications in electronics machines composites optics optoelectronics and other areas

**Nanotube Superfiber Materials** Canh-Dung Tran,2013-09-16 Carbon nanotube CNT yarn a macroscopic structure of CNTs with many potential applications has attracted increased attention around the world and across many research areas and industrial fields including materials science electronics medical biology and ecology Spinning CNTs into yarn based on traditional textile spinning principles has demonstrated the potential in many important applications by producing weavable multifunctionalized yarns Between 1991 and 2010 new manufacturing methods have enabled the production of pure CNT yarns and CNT based composite yarns called superfiber suitable for weaving knitting and braiding with continuous improvements Especially various novel technologies are used to recently produce yarns for electrochemical devices and medical bioengineering Thus the studies on assembling individual CNTs into macrostructures of controlled and oriented configurations continue to play an important role in exploiting CNT potential applications

*Nanotube Superfiber Materials* Fabrizio Pinto,2013-09-16 A novel approach leading to potentially extremely high density energy and power storage is proposed based upon the energy exchange between the dispersion force field in an assembly of aligned telescoping nanotubes and the electrostatic field produced by an external voltage source biasing such nanostructures with respect to a facing electrode We show that the retraction of a telescoping core into the outer nanotube shell in quasi equilibrium results in the conversion of energy stored in the van der Waals field of the system into an electric current along with heat dissipated into the environment On a macroscopic scale the combined effect of the large effective areas and dominant dispersion force magnitudes typical of nanotubes makes such an implementation quite competitive as a storage system conservatively capable of energy densities  $1.3 \times 10^2 \text{ W h kg}$  depending on the particular class of nanotube employed and with power densities in principle limited only by the dynamical response of the driving electronics Additionally since the mechanism of energy storage and release is ultimately related to quantum electrodynamic dispersion interactions the system charge and discharge time profiles can be directly addressed by the user on the nanoscale and are not limited by the electrochemical processes

**Nanotube Superfiber Materials** Simon Jestin,Philippe Poulin,2013-09-16 Recent developments in the field of carbon nanotube CNT based wet spun fibers are described in this chapter Wet spinning essentially enables a wide variety of polymers to be spun into fibers It has been used to produce composite fibers composed of polymers loaded with CNTs and even fibers solely composed of CNTs Fibers obtained by wet spinning approaches contain highly aligned CNTs making the fibers suitable for use in a variety of textile cable and composite applications Exciting results have been achieved at the laboratory scale Today it is critical to consider scale up of production of such superfibers so that applications can be fully validated

Nanotube Superfiber Materials

Kazuhiro Yanagi, 2013-09-16 The electronic transport properties of networks of single walled carbon nanotubes are investigated in this chapter The ratio of semiconducting to metallic single walled carbon nanotubes called the MS ratio affects the conduction mechanisms in nanotube networks Several theories about the conduction mechanisms are discussed The results presented are useful in the design of nanotube networks that are expected to be used in a wide range of applications such as field effect transistors and conducting films

The Top Books of the Year Nanotube Superfiber Materials Chapter 11 Carbon Nanofiber Multifunctional Mat Micro And Nano Technologies The year 2023 has witnessed a noteworthy surge in literary brilliance, with numerous compelling novels captivating the hearts of readers worldwide. Lets delve into the realm of popular books, exploring the captivating narratives that have captivated audiences this year. The Must-Read : Colleen Hoover's "It Ends with Us" This touching tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover masterfully weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can prevail. Uncover the Best : Taylor Jenkins Reid's "The Seven Husbands of Evelyn Hugo" This intriguing historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reid's absorbing storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Discover the Magic : Delia Owens' "Where the Crawdads Sing" This mesmerizing coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens weaves a tale of resilience, survival, and the transformative power of nature, entrancing readers with its evocative prose and mesmerizing setting. These top-selling novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of compelling stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is an exceptional and gripping novel that will keep you guessing until the very end. The novel is a cautionary tale about the dangers of obsession and the power of evil.

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