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NANOTUBE SUPERFIBER MATERIALS

Changing Engineering Design

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Nanotube Superfiber Materials Changing Engineering Design Micro And Nano Technologies

Xiaogan Liang

Nanotube Superfiber Materials Changing Engineering Design Micro And Nano Technologies:

Nanotube Superfiber Materials Mark Schulz,Vesselin Shanov,Zhangzhang Yin,2013-09-16 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* Adam Hehr,Yi Song,Bolaji Suberu,Joe Sullivan,Vesselin Shanov,Mark Schulz,2013-09-16 This chapter investigates the use of carbon nanotube CNT sensor thread in distributed structural health monitoring SHM systems specifically as embedded damage and strain sensors The CNT sensor thread has shown potential to be integrated into onto composite materials to provide confident damage detection localization and characterization in complex geometries without complicated detection algorithms and minimal sensing channels This chapter articulates current work done with CNT thread in Nanoworld Laboratories specifically CNT thread performance as a sensor past current and future embedded sensing work and potential SHM design architectures for aircraft along with a description of a few potential multifunctional aspects of the material

Multifunctional here implies improving the composite material besides self sensing of damage and strain Some of these multifunctional characteristics include self sensing of moisture oxidation and temperature improved mechanical properties of damping toughness stiffness and strength and improved thermal and electrical transport among many other potential areas Besides these multifunctional characteristics CNT thread is low in weight and small in size and the material is modest in cost As a consequence of these strong sensor and material characteristics the authors believe that this could be a game changing material for high cost composite commercial and defense vehicles Future military and commercial composite vehicles will have nano inside to provide safety reliability durability condition based maintenance and multifunctionality *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** 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* 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 sp2 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** 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* 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. Zaghloul,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 Brad Ruff,Weifeng Li,Rajiv Venkatasubramanian,David Mast,Anshuman Sowani,Mark Schulz,Timothy J. Harned,2013-09-16 There are two ways to manufacture components and devices the top down and bottom up processes Each process has its advantages and disadvantages In our group the bottom up process was selected to build up electromagnetic devices using nanoscale materials in a series of steps The design of a lightweight electric motor is described based on using nanoscale materials Development of the motor is work in progress and various processes and results are described There are several potential applications for lightweight sustainable electric motors One billion electric motors are produced in the world each year **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** Y.J. Liu,D. Qian,P. He,N. Nishimura,2013-09-16 In this chapter a hierarchical multiscale approach for modeling carbon nanotube CNT composites using molecular dynamics MD at the nanoscale and the boundary element method BEM at the microscale is presented First the current status in modeling and simulations of CNT composites is reviewed Then the basics of MD are introduced and the modeling techniques using MD at the nanoscale to extract the CNT properties and a cohesive interface model for CNT polymer composites are discussed Next the boundary integral equations BIEs governing the displacement and stress fields in fiber reinforced composite models at the microscale are presented The BEM applied to solve the BIEs numerically is discussed and the fast multipole BEM techniques that are suitable for solving large scale models are presented In the numerical studies parameters in the cohesive interface model are obtained by conducting CNT pull out simulations with MD and these parameters are subsequently used in the BEM models of the CNT polymer composites Marked decreases of the estimated effective Young s moduli are observed using the new BEM models with the cohesive interface conditions as compared with earlier models with perfect bonding interface conditions The developed BEM models combined with the MD can be a very useful tool for studying interface effects in CNT composites and for large scale characterizations of such nanocomposites Future efforts and directions in the research on modeling nanocomposites are offered to conclude this chapter **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 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 Yoku Inoue,2013-09-16 Ultralong multiwalled carbon nanotube arrays forests were grown by chloride mediated chemical vapor deposition in which iron chloride was used as a catalyst precursor Highly spinnable millimeter long arrays were grown with a very rapid growth rate of 100 m min By stacking long lasting carbon nanotube CNT webs unidirectionally aligned CNT sheets were fabricated The sheet was highly anisotropic in electrical and thermal properties and due to high alignment of the CNTs in the sheets CNT yarns were fabricated using the millimeter long CNTs and a detailed analysis of various postspin processes including postspin twisting and multiply twisting and their effect on CNT yarns were studied Mechanical properties clearly depended on the dimensions of CNTs where thinner and longer CNTs led to strong and stiff yarns Large contacting surface areas in the yarns brought by closer packing with high aspect ratio CNTs were effective for higher van der Waals interaction leading to higher tensile properties Growth of millimeter long highly spinnable CNT arrays and the material properties of tailored large scale CNT structures including unidirectionally aligned sheets and spun yarns are described **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 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** Yi Song,Bolaji Suberu,Vesselin Shanov,Mark Schulz,2013-09-16 Multiscale laminated composite materials are formed by adding carbon nanotube CNT materials to microfiber laminated composites CNTs reinforce the weak failure modes of laminated composites Laminated composite materials provide high specific strength and high performance but have low interlaminar shear modulus and shear strength due to the lack of fiber in the transverse or out of plane direction The weak interlaminar property may lead to premature failure of composite structures Therefore it is necessary to reinforce polymeric laminated composites in the transverse direction CNT materials have excellent mechanical thermal and electrical properties and are integrated into polymeric composites as reinforcement These composite laminates using CNT materials are called multiscale composites In this research multiwalled carbon nanotube MWCNT arrays are integrated between the carbon fabric plies of laminated composites and work as a bridge to interlock adjacent carbon fabric plies together The MWCNT arrays are arranged within the laminated composite so that the laminate interfaces have higher interlaminar properties The mechanical response of these composite materials under quasi static loading including interlaminar shear is described in this chapter *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 Noe T. Alvarez,Vesselin N. Shanov,Tim Ochmann,Brad Ruff,2013-09-16 Carbon nanotubes CNTs have been at the frontier of nanotechnology research for the past two decades The interest in CNTs is due to their unique physical and chemical properties which surpass those of most other materials To put CNTs into macroscale applications the nanotubes can be spun to form continuous fiber materials Thus far the properties of the fibers are far below the properties of the individual nanotubes If the electrical and mechanical properties of the fibers could be improved the resulting superfiber materials would change the industry and society For example CNT materials might replace copper wires providing lighter stronger cables for aerospace applications The small size of individual nanotubes and the mixture of different diameters and chiralities limits the electrical conductivity of CNT fiber A simple way to improve the electrical conductivity of CNT fibers is chemically doping the CNTs within the fibers This chapter attempts to summarize classify and provide a basic understanding of doping at the atomic and molecular levels Characterization of doping and current results of our doping efforts are discussed **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 102W 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 electrodynamical 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

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