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Introductory Chapter: Carbon Nanotubes and Their Applications

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1. Introduction

Carbon nanotubes (CNTs) is smart carbon materials which significantly utilized for the potential applications, large-scale synthesis, structural evaluation, and physical as well as chemical properties of carbon nanotubes and/or related conjugated carbon materials. Here, the various areas of carbon nanotubes (CNT) related topics including carbon materials for their various synthesis methodologies, total morphological, orientational, elemental, structural evaluations and characterizations as well as potential applications in different fields including bio-materials as well as nanomaterials for scaffolds as promising cell carrier for tissue engineering, designing antimicrobial polymeric bio-composite mats and natural medicinal plant polymer for cosmeceutical applications, carbon nanotubes/silicon composites to materials of Li secondary batteries, CNT composites with metal oxides as well as hierarchical crystalline nanotube on the cooperative Phenomena of Functional Molecular Group as the Target of Expression of New Physical and chemical Properties were discussed in this chapter.

2. Literature review

Substantial nanotube discovery which originated to existent in 1991 was CNTs. That buckyballs are spherical and round, nanotubes are tubic cylinders which are not folded round to generate to sphere [1]. CNTs are confined of C-atom connected in hexagonal shapes, with every C-atom covalently-bonded to three other C-atoms. CNTs have average dia. as lower as <1.0 nm and sizes up to several centimeters. A carbon nanotube is a long-tube-shaped carbon-material, made of only carbon, having a diameter measuring in nanometer scale. A nanometer is one/billionth of a meter, or about 10,000 times smaller than a normal human hair. CNTs are exceptional and unique because the bonding between the carbon-atoms is very strong and the tubes can have extreme characteristic aspect ratios. Generally CNTs are allotropes of carbon with a cylindrical tubic nanostructure. These tubic-cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, nano-electronics, optics-electronics and other fields of nanomaterials science and technology. Due to the nanomaterial's extraordinary strength and stiffness, nanotubes have been created with L-to-D (Length-to-diameter) ratio [2] considerably bigger than for any other modified material. Additionally, due to CNTs exceptional characteristic property such as thermal conductivity, mechanical, and electrical, CNTs find potential applications as additives to different structural nanomaterials [3, 4]. For large number of potential applications with CNTs, the challenge lies in the alignment and ordering of CNTs to take advantages of their highly anisotropic thermal, electrical, physical characteristics. CNTs have emerged as a new category of nano-sized particles for incorporation into various liquid crystal systems, attracting favorable interest from both basic level science research and as well as industrial applications [1]. As a result of the exceptional properties of CNTs, the novel materials can be envisioned that exhibit property enhancements at lower concentration than in conventional composite technology [5]. CNTs also represent a promising material due to their unique physicochemical properties: their nanoscale needle shape, high chemical stability, thermal conductivity, and mechanical strength, which confer an advantage in the fabrication of field emitters. The utilization of CNTs relies on their electronic properties since they can be either metallic or semi-conductive, depending on the geometric configuration of a graphene sheet rolled up as a tube (i.e., diameter and chiral angle) [6–9]. Global attention on CNTs also attracted by many researchers have evaluated the extraordinary properties of CNTs toward development of nanocomposites and sheets holding highly oriented CNTs with enhanced electrical and mechanical properties. Exert of electrical field to a matrix containing CNTs can also lead to expansion of a highly oriented network from the negative electrode toward the positive electrode, which acting as a pathway for transferring current from the negative electrode toward the positive electrode [10–14]. The CNT arrays or vertically aligned CNTs itself is an extensive area of research apart from its originator CNT. As one can expect the complexity to grown long continuous CNTs [15, 16], scientist and researchers have derived out a brilliantly new idea of CNT yarn. The idea of aligning carbon nanotubes into arrays was perceived in 1994 by Ajayan et al. [17] by cutting thin slices of the nanotube-polymer composites. One of the most promising CNT applications of the field emission is an electron source. Lots of electronic devices are based on electron sources which are the most crucial component served as state-of-art vacuum nano-electronics and emerging novel devices in nowadays, such as field emission displays, emerging sensor, energy storage equipment, scanning ultrafast electron microscopes, X-ray generators, free electron lasers, Terra Hartz sources and so on [18–20]. Recently, such electron sources have intrigued a strong interest and encouraged the further studies of pulsed electron emission, opening the door to high-tech novel devices. For example, pulsed electron emission opens a way toward the time resolved electron microscopy, because electrical gating and source control enable time resolution down to picoseconds, while using optical control enables creation of electron pulses with duration down to tens of femtoseconds. Such dense and short electron bunches can become a popular platform for material and device imaging, inspection, and failure analysis. They would enable exciting technological developments like four-dimensional time resolved electron microscopy, spectroscopy, holography, single-electron sources, and carrier envelope phase detection [21, 22]. Many other investigations in terms of electrode materials are focused on CNTs and their modified or hybrid materials. Compared with aluminum foil or copper foil, metal-free current collector is a research hotspot, CNT film or cellulose papers used as negative electrode or anode current collector was applied in flexible lithium ion battery in many researches [23, 24]. Different modern and advanced techniques have been developed for exploring the mechanical properties of individual carbon materials or CNTs. One method for measuring the Young's modulus of a CNT is to fabricate a nanotube beam that is clamped at each end to a ceramic membrane (or otherwise supported) and to measure its vertical deflection versus the force applied at a point midway along its length [25]. The atomic force microscope is a natural and convenient means for studying the Young's modulus of CNTs, because it allows measurement of the deflection of a sample as a function of applied force when used in contact mode [26].

Furthermore, CNTs, which have potential in chemical stability, thermal and electrical conductivity, mechanical strength, and flexibility, may be the best alternative materials for application in flexible transparent conductive electrodes. Actually, CNTs in some applications, which have low conductivity regardless of transmittance, are being commercialized. The rough surface of CNT films due to their tubular structures brings about a serious problem in the application of organic light-emitting diodes [27]. In CNTs, a relatively high contact resistance of the tube-tube junction may lead to insufficient sheet resistance [28]. Regarding this issue, the separation method of metallic and semiconducting components in CNTs by controlling the diameter and chirality of CNTs has been introduced in this book. CNTs have an affinity to also aggregate owing to the van der Waals attractive interaction between their sidewalls [29]. This tube-to-tube contacts results hydrophobic nature of CNTs which is responsible for their poor solubility in water, and also incompatible with a majority of solvents [30]. As a result, CNTs are precipitated in solvent, which the lack of solubility and the difficulty of manipulating them in solvents limit the development of CNT-based devices or composites of interest for new applications. In order to obtain fine dispersion in the selected solutions specially water, it is important to break the cohesion of aggregated CNTs. Development of efficient processes and chemical treatments that are able to control the quality of the CNT samples and to induce both their dispersion and partial or complete de-bundling remains highly challenging.

3. Conclusion

Finally, the growth of dense and long CNT arrays and their application in spinning threads or CNT yarns, non-homogeneous electron emitter plane with large FE current fluctuations and a short emission life-time, LC-CNT surface interaction lead to pinning orientational order uniformly along the CNT, aligned-CNT network within the matrix via electric fields, tensile strength and strength distribution of CNTs, hybrid-types of CNTs-based electronic devices, polymer wrapping methods by disperse CNT using gelatin for making decomposable biopolymer, electrochemical capacitors based on CNTs, hydrogenation and dehydrogenation studies of CNTs functionalized with BH_3, etc. are discussed. Here, we believe that it offers a broad field of existing developments in recent development of carbon nanotube technology research and an excellent introduction to preparation, synthesis, potential characteristic properties in field of materials and composites for their potential applications. This work aims to bridge the gap between undergraduate, graduate, and researches in carbon materials, nanomaterials, polymers, biomaterials, nanocomposites, catalysis as well as bio-medical sciences, in order to initiate scientist/researchers into different carbon nanotubes study in as straight-forward way as conceivable and also introduce the researcher to the opportunities offered by the science and technological fields. We hope, it will offer the evaluation of the state-of-the-art methods and advances of carbon researches and bio-science and nanotechnologies. Distinguished scientist were significantly contributed to present their novel ideas and recent advanced development in the field of carbon materials, carbon nanotubes, or carbon nanotube conjugated related materials in various research and practical fields. The prime goal is to introduce audience about CNTs for the students, researchers, technologists, physicists, chemists, biologists, engineers and professionals who are interested in carbon nanotubes and associated carbon related materials.

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