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Original Research Article

Role of Carbon Nanotubes as Energy Storage Materials

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ABSTRACT

Graphene and carbon nanotubes (CNTs) have gotten a lot of attention because of their varied nanostructures, making it a very intriguing and comprehensive topic in nanotechnology. Graphene and carbon nanotubes (CNTs) both have unique electrical, mechanical, thermal, catalytic, and electrochemical features because they are made up of sp^2 hybridized carbon atoms. Carbon nanotube hybrid nanostructured materials (CNT hybrid nanocomposites), Carbon nanotubes (CNTs), and nanotechnology have the potential to improve energy conversion and storage device applications. Carbon nanotubes are being evaluated for application in renewable energy sources, including solar cells and hydrogen storage. Carbon nanotubes (CNTs) are utilized in storage technologies such as Li-ion batteries, supercapacitors, and thermal energy harvesting. We describe the functions of carbon nanotubes (CNTs) in new energy storage technologies, particularly electrochemical supercapacitors and Lithium-ion batteries, in this study. The use of carbon nanotubes in binder-free electrodes, microscaled current collectors, and adaptable and stretchy energy storage systems is also explored.

Keywords: Carbon nanotube, Energy, Renewable Energy Sources, Li-Ion Batteries, Supercapacitors.

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Introduction

The carbon nanotube was first invented by Sumio Iijima[1], who used an arc-discharge evaporation approach to make graphitic carbon helical microtubules. CNT has good electrical properties, a large surface area, and is a good conductor and absorber. CNTs are formed up of single or multiple graphene sheets with open or closed ends with elongated, gossipy barrels shaped tubules constituted of graphite coatings with sizes varying from a few nanometers to 100 nanometers with approximately to 132,000,000:1 circumference ratios [2].The fullerene structural family includes nanotubes [3]. The term originates from graphene, a lengthy, hollow structure with one-atom-dense carbon sheets as walls.Fullerenes and carbon nanotubes are the type of sp2 hybridized in a hexagonal honeycomb lattice in an array of atoms, similar to graphite[4]. Three of the valence shell atoms are chemically bonded in sp2 hybridization, leaving one free electron, known as the electron. Carbon nanotubes, for example, have extended -electron clouds and exhibit a large swath of remarkable electrical and thermal conductivity features[5]. Carbon nanotubes are tube-shaped substances consisting entirely of carbon. Nanoscale measures its diameter, which is far too small[6]. Carbon nanotubes are produced by rolling graphene sheets into cylinders [7]. Here, CNTs are one of the allotropes of carbon that fall between fullerene cages and flat graphene.

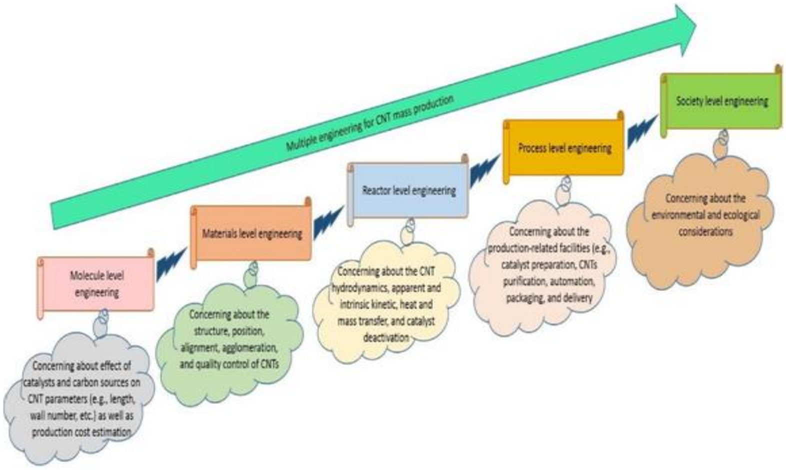

Figure 1. Multi-levelengineeringrangingfrombasicresearchtonanoengineeringis requiredforthe massproduction ofCNTs.

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Because of its outstanding electrical and mechanical characteristics, carbon nanotubes are utilized as electrode material.The relatively inexpensive price of the carbon source materials consumed in making CNTs, gadget manufacture is gaugeable and feasible from a financial standpoint [8].The electrochemical behavior of CNTs is influenced by two distinct regions: the CNT sidewall and the tube ends. The electrochemical characteristics of the CNT walls are analogous to that of highly oriented pyrolytic graphite's basal plane, while The cylinder endings' chemicalelectroactivity is equivalent to the border plane of distinctly crystalline

pyrolyzed graphite[9].

❖ Literature Review:

Type of CNTs:

Single-Walled Carbon Nanotubes (SWCNTs)

Single-walled carbon nanotubes are a type of nanotube with only one wall (SWCNTs).

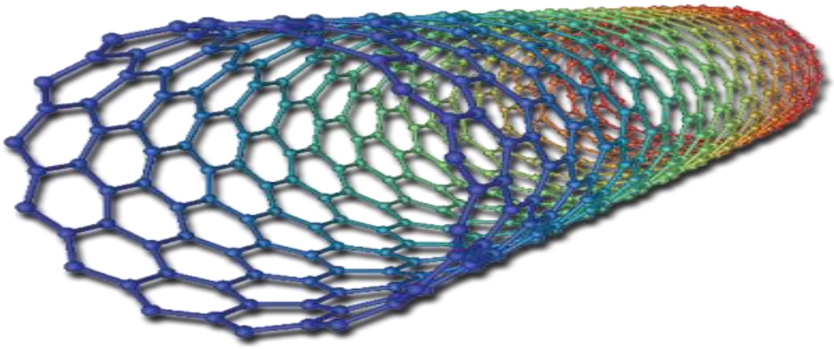

Figure 2. Single-walled carbon nanotubes structure[10].

A graphene sheet coiled into a cylinder or tubular with a diameter ranging from 0.4 to 2 nanometers is a single-walled carbon nanotube. Obesity of the stem wall is assessed graphene sheets with a thickness of 0.34 nm were used [11, 12]. The quantity of unit vectors in deuce ways in the graphene beehive crystal grid is determined by a pair of parameters (m, n) in the enclosed graphene sheet. They are known as twisty nanotubes if m = 0, and recliner nanotubes if n = m, otherwise, they're referred to as chiral [2].

Multiple Walled Carbon Nanotubes (MWCN)

Carbon nanotubes with multiple walls are mainly composed of several rolled graphene layers (MWCNTs).AnMWCNTis made up of two or more coaxial carbon nanotubes as well as a 0.34

nm inner-cover range. MWCNTs have a diameter ranging from 3 to 30 nm [40]. Multi-walled nanotubes have a stronger tensile strength than single-walled nanotubes because the interlayer spacing between graphene sheets is around 3.3Å [14].

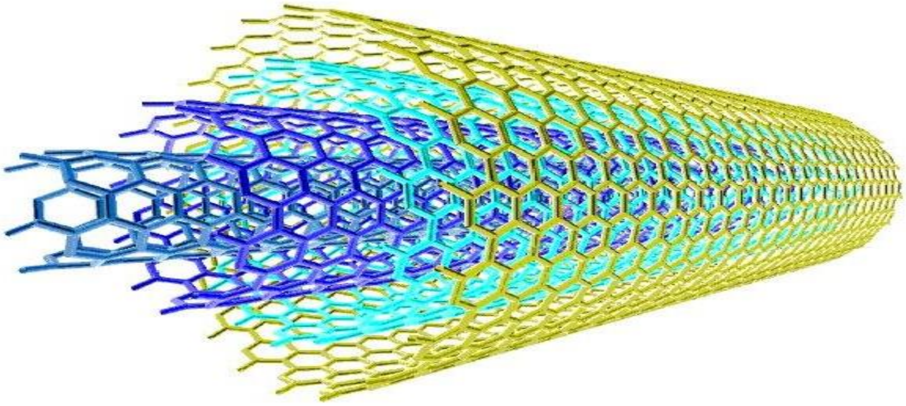

Figure 3. Multiple Walled Carbon Nanotubes shape [13].

Synthesis of Carbon Nanotubes

There are various types of synthesis methods available for carbon nanotubes. laser ablation method,Arc discharge (AD), chemical vapor deposition method (CVD) are generally considered:

Arc Discharge Method

CNTs are made from carbon waste from graphite electrodes using the arc-discharge method [1]. CNTs were synthesized using the arc discharge process at high temperatures (above 1800°C). A stream of 50 amps is transferred between two graphite electrodes with various potentials in the arc discharge method.The electrodes are maintained at 1mm throughout, and the anode is moved nearer to the cathode until an arc appears. Chamber nanotubes, as well as by-products, can be recovered after cooling and depressurization, and are typically put on the cathode [15].

Laser Ablation Method

An inert gas forinstanceN_2,Ar, He, etc.,appears a laser beam vaporizes a huge graphite sheet. The powerful laser pulses melted a carbon target that was put in a tube Incinerator and warmed to roughly 1200 C [16,17].MWCNTs with an interior dimension of 0.01 to 0.02 mm as well as a circumference of around 0.1 mm are formed when one and the other electrodes are constructed of unmixed graphite [18]. The nanotubes are transported to the copper collector by argon flowing through the chamber. Nanotubes and byproducts as an example of fullerenes and amorphous carbon are overcoated on a chamber's sidewalls after it has been cooled. Van der Walls made it possible for the newly formed SWNT to come together.

Chemical Vapour Deposition Method (CVD)

Because metal instigators are used in the combustion of hydrocarbon vapors, chemical vapor deposition (CVD) is also known as catalytic chemical vapor deposition (c-CVD) [19]. The CVD approach entails the breakdown of a gaseous or volatile carbon molecule catalyzed by metallic nanoparticles in the appearance of a catalyst at temperatures around 700–1100 °C. For large-scale manufacturing, this method is favored.

Renewable Energy Sources

Hydrogen Storage

CNTs are good hydrogen adsorbents because of their elevated surface area and aperture segments percentage.The incorporation of hydrogen is proportionate to one and the other factors, along with an adsorbent material's gas adsorption is known to be affected by pressure and temperature [20]. CNTs with hollow structures are lightweight and can hold hydrogen at a higher density than liquid or solid hydrogen. The hydrogen inside can be gradually released and used as an energy source via thermal control [21].At pressures as high as 112.169 kg/cm^2 and temperatures fluctuate via 250 to 1400 _C, researchers tested hydrogen adsorption on different CNTs[22]. In their tests, they discovered all of the CNTs looked at had superior hydrogen desiccations. The excessive rate of absorption was about 0.1 weight percent. The US Department of Energy's expectations for CNT-based hydrogen storage has not been reached. [23].

Solar Cells

Solar cells have a lot of potential as a renewable and alternative source of electricity As a result So long as the sun appears to be an abundant source of energy, Photons absorbed the sun's energy is turned into electrical power in a photovoltaic appliance. When a photon is ejecting, its power is approximately identical to that of an electron. As a result, the remaining energy is transformed into heat and dissipated. Organic solar cells have poor total efficacy of energy transformation, which is only of their key advantages. [24]. The most reasonable method for embedding CNTs into solar cells is to combine them with a related polymer that donates electrons as a solution. A narrow translucent particulate grid (59-121 nm) is then twisted with the slurry [25]. Glass or plastic electrodes with indium tin oxide and a poly (3,4ethylenedioxythiophene): poly (styrenesulfonate) coating are widely used [26]. Furthermore,the physical and electrical characteristics of CNTs couldbe improved bycross-linking, such as utilizing nucleic acids, to increase their solubility in liquids for integration in a matrix. Due to their strong electron affinity, polymers combined with CNTs are a cost-effective and speedy method toward the ionization of excitation energy. With an excessive yield, Free electrons are isolated from the excitation energy. Makes it possible to achieve better energy conversion efficiency [27].

CNTs for Energy Storage Devices

Li-Ion Batteries

Plug-in hybrid electric vehicles (PHEVs),Hybrid electric vehicles (HEVs),and electric vehicles (EVs) can all be used in ordinary routines to diminish our reliance on fossil fuels. For ongoing development in these applications, advanced energy transformation technologies with elevated-density of power, rising energy extended period of existence, moreover, excessive-power resistance are required. [28]. Because of their magnificent electrical conductivity, a broad region of a particular surface, and stability of the structure, carbon nanocomposites, Graphene, and carbon nanotubes, in particular, are being widely investigated for potential battery applications.These nanostructured materials have the potential to give: (1) high especial surface area; (2)enhanced ionic and electronic conductivity; (3)quick movement of mobile species; (4) mechanical resilience; and (5)improved surface reactivity when utilized as electrodes in lithium batteries [29]. The energy density, charge/discharge cycle rate, and self-discharge current of LIBs are all high. With a lower working strong volumetric/gravimetric power output and potential Li–S battery is less harmful to the environment and less expensive, while Li–O2 batteries have a very elevated energy density(Figure 4).

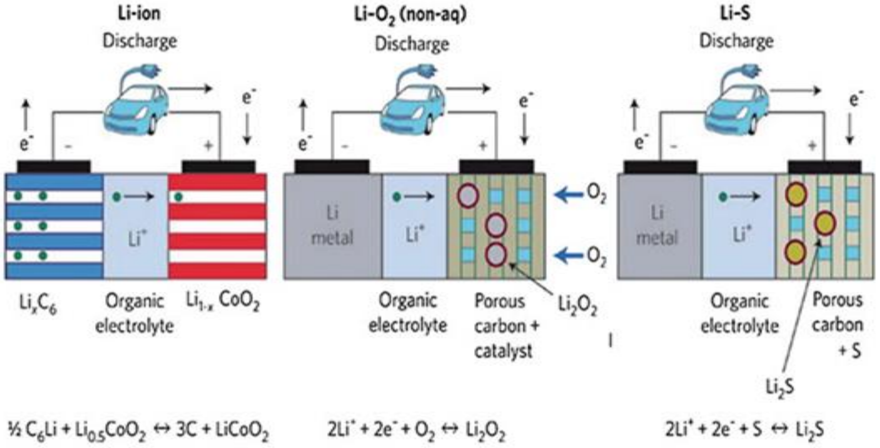

Figure 4. Schematic representation of Li-ion, non-aqueous Li–O2, and Li–S batteries.[29] Copyright 2016 Royal Society of Chemistry

Because graphite is the most widely utilized anode, to improve Li-ion electrodes, carbon nanotubes should be used in general (with some homogeneous characteristics to CNTs). Graphite has a capability specific to 350 (mAh)/g (gravimetric) and 770 (mAh)/cm3 in most commercial batteries (volumetric). Graphite is a long-lasting material with negligible capacity fading even after When compared to Li+/Li, it has a number or more of charge/discharge cycles and steers at a current of 0.1 V.Now attempts at hybrid electric vehicle applications, however, have attentiveto novel anode substances with somewhat higher positive insertion voltages concerning Li+/Li to While charging at high rates, decrease the risk of large-surface-area Li plating.At 50% capacity, batteries in hybrid electric vehicles are charged at a rate of 10% of the overall charge/discharge capability.As a consequence, when fully charged, the optimum negative electrode for future vehicle networks could have a 0.5 V charge/discharge potential versus Li+/Li. As a result, higher-potential transition metal oxides are being considered for next-generation anode technologies [30].

Supercapacitors

Supercapacitors manifest elevated energy arcadecoherenceconsiderable 93% for up to 102–103 cycles, they are reasonably constant[31]. Pseudocapacitors and electric double-layer capacitors

(EDLCs) are two distinct kinds of electrochemical capacitors. The electrodes for these technologies are composed of porous carbon materials such as activated carbon, carbon nanotubes (CNTs), graphene, conducting polymers, templated carbons, and metal oxides. [32].In the year 2000, a study looked at the electrochemical impedance performance of MWNT plates and discovered that it was related to the materials' studies and chemical content. Because of the central canal, macropores existand were shown to allow for facile ion access to the electrode/electrolyte functionality and charging of the electrical double layer. When the MWNTs were oxidized and the surface functionality was varied, pseudofaradaic reactions were identified. Specific capacitance values ranged upto 3 to 134 F/g, turn MWNT agglutination settings and aftercare, only with a higher priorityobtained Once it was discovered that Faradaic reactions existed [33].The highest specific capacitance of arc-generated SWNTs was determined to be 170 F/g, with a high energy volume of 20 kW/kg a high power density of 6.4 (W h)/ kg.A warm-up at 1000 °C is required to increase overall inductance and reduce the SWNT-electrode resistivity. The increased resistance is due to the SWNTs' particular level of volume increasing [34].

CNTs for Thermal Energy Harvesting

Thermogalvanic Cells:A term galvanic cell, sometimes called a thermowell, seems to be a thermal power exchanger which converts poor-quality temperatures into electric power through an electrochemical process.So, because two half cells inside the setup are kept in various warm conditions, the moderators' redox potential outcomes at the cathode as well as the anode differ[35].An external circuit can be used to accelerate electrons, allowing current and power to be generated.Thermocell with a Ferro-/ferricyanide redox couple a show in figure 4 [36]. The electrons created by the oxidation of ferrocyanide at the warm anode pass through an external circuit before being spent in a reduction of ferricyanide at the cooled cathode [37]. The natural diffusion and convection of the electrolyte prevent the accretion of reaction result in either half-cell, making it mandatory for moving mechanical components [38].

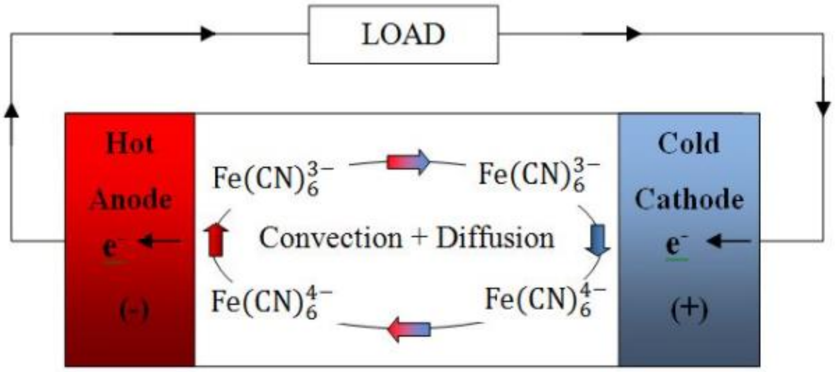

Figure 5. Ferro-/ferricyanide redox thermogalvanic cell [36] Copyright by 2012 Springer.

CNTs for Energy Conversion

Electric power can be stored in two ways, the greatest examples of which are a capacitor and a battery. In a battery, when two electroactive entities undertake oxidation and reduction, the available chemical energy is converted into work by the release of charges [39].

Conclusions and Future Outlook

Carbon nanotubes' very distinctive physical features have been demonstrated for photovoltaic appliances, enhanced, electrochemical capacitors, hydrogen as well as solar cell conversion. Whenever storage is a concern, hydrogen could be maintained like a cosolvent. Unless the stability of the hydrogen deposit is an issue, an alternative method of releasing the imbibed hydrogen for use during storage is required. It doesn't appear likely that carbon nanotubes might be used to store hydrogen. CNTs are utilized in solar collectors because they have stronger thermal and electrical conductivities. Organic solar cells have a short lifespan because they degrade in light. Organic solar cells that are long-lasting and affordable are a major research topic. In the future, supercapacitors and thermocells will undoubtedly play a vital role in power delivery systems and hybrid energy storage for both enormous and residential schemes. The converted waste heat can be retained and then release as needed because these two systems are merged into one gadget. These will not only technological trends improve cars and portable electronics, but they will also transform medical, military, and consumer products, due to the substantial leap forward in the field of energy collection.

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