Online at: https://researchtrendsjournal.com ISSN No: 2584-282X

INTERNATIONAL JOURNAL OF TRENDS IN EMERGING RESEARCH AND DEVELOPMENT

Volume 1; Issue 1; 2023; Page No. 196-200

Received: 02-10-2023
Accepted: 09-12-2023

To study electrical, mechanical, optical & electronic properties of metal carbon nanotubes (CNTs)

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DOI: https://doi.org/10.5281/zenodo.13093871

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Abstract

In the field of Nano Science & Technology, the most unique invention & properties carbon nanotubes (CNTs) have attracted many industries & companies towards itself, and continue to attract, considerable interest in a wide variety of scientific files. CNTs show as a significant material for future because of its huge production & are used in Membranes, Capacitors, Polymers, Metallic Surfaces, Ceramics & Nano medicines etc. A rolled up of graphite sheet non-stop unbreakable hexagonal such as mesh structure depending upon the number of carbon layers, it can be single-walled carbon nanotubes, double-walled carbon nanotubes and multi-walled carbon nanotubes. Carbon nanotubes have a number of extraordinary properties such as high electric conductivity, high thermal conductivity, high mechanical strength, tensile strength and thermal resistivity etc. Due to these & desirable properties, they have extremely wide applications in Commercial and Research industries also. The properties of such types of carbon nanotubes can be further improved by use of metal to add in them. These metallic carbon nanotubes have gained prominence due to specific properties which can be further strengthened.

Manganese carbon nanotubes have proven as good n-type semiconductors with high physical and chemical stability and high refractive index. They are widely used as photo catalysts, solar cells, sensors, self-cleaning and bactericidal actions. The Manganese carbon nanotubes are synthesized after decomposing at higher temperature by a simple process to use Egg albumin (White proteins) which acts as a gelling agent in the presence of manganese metal ion/metal salt solution. The Characterization of these manganese carbon nanotubes is carried out by Thermo Gravimetric Analysis (TGA), X –ray Diffraction Analysis (XRD), Scanning Electron Microscopy (SEM), Tunneling Electron Microscopy (TEM), Infrared Spectroscopy (IR), Nuclear Magnetic Resonance (NMR) and Photo Luminescence (PL) etc.

Keywords: CNTs, PL, TEM, SEM, XRD, IR, UV, NMR, Egg Albumin, Metal Solution & Mn^{++} etc.

Introduction

Nano Science and technology is a highly multidisciplinary field, drawing from fields such as applied physics, Optical Physics, materials science, interface and colloid science, device physics, super molecular chemistry self-replicating machines and robotics, chemical engineering, mechanical engineering, Electronics engineering, biological engineering and electrical engineering etc. Generally two main approaches are used in nanotechnology such as "bottom-up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition or level and another "top-down" approach, Nano-objects, materials and deices are constructed from larger entities without atomic-level control. These above two methods are possible range approaches for a wide range of endevours. Carbon nanotubes (CNTs) have been widely investigated as an essential component for fabricating nanoelectronic devices and its numerous biomedical and biotechnological applications, including bone growth, enzyme encapsulation, biosensors and as vesicles for DNA delivery into living cells.

Molecular electronics seeks to develop molecules with useful electronic properties. These could then be used as single-molecule components in a Nano electronic device. For example rotaxane. Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nanocar.

Metal CNTs can play the major role in information data Storage devices; it is dependent on magnetic and optical properties. Organized two-dimensional or three-dimensional arrays of metal or semiconductor nanoparticles or CNTs exhibit special optical and magnetic properties & on the basis of these properties, chemical & optical computers can be made. The compression of nanoscale improved Ceramics & insulators CNTs particles yields more flexible solid objects apparently because of the multitude of grain boundaries that exists.

Properties of Carbon Nanotubes (CNTs): CNTs have High Electrical Conductivity, Very High Tensile Strength, Highly Flexible- can be bent considerably without damage, Very Elastic ~18% elongation to failure, High Thermal Conductivity, a Low Thermal Expansion Coefficient, Good Electron Field Emitters & a High Aspect Ratio (length = ~1000 x diameter) etc.

CNTs with particular combinations of N and M (structural parameters indicating how much the nanotube is twisted) can be highly conducting, and hence can be said to be metallic. Their conductivity is a function of their chirality (degree of twist), as well as their diameter. CNTs can be either metallic or semi-conducting in their electrical behavior. Conductivity in MWNTs is quite complex. Some types of “armchair”-structured CNTs appear to conduct better than other metallic CNTs. The conductivity and resistivity of ropes of SWNTs has been measured by placing electrodes at different parts of the CNTs. The resistivity of the SWNT ropes was in the order of 10^{-4} ohm-cm at 27 °C.

Strength and Elasticity: The carbon atoms of a single (Graphene) sheet of graphite form a planar honeycomb lattice, in which each atom is connected via a strong chemical bond to three neighboring atoms. Because of these strong bonds, the basal-plane elastic modulus of graphite is one of the largest of any known material. For this reason, CNTs are expected to be the ultimate high-strength fibers. SWNTs are stiffer than steel, and are very resistant to damage from physical forces. Pressing on the tip of a nanotube will cause it to bend, but without damage to the tip. When the force is removed, the tip returns to its original state. This property makes CNTs very useful as probe tips for very high-resolution scanning probe microscopy. The current Young’s modulus value of SWNTs is about 1 Tera Pascal.

Thermal conductivity and expansion: CNTs are the best heat-conducting material & Ultra-small SWNTs give the tremendous result & to exhibit superconductivity below 20ºK. The strong in-plane graphitic C-C bonds make them exceptionally strong and stiff against axial strains. The almost zero in-plane thermal expansion but large inter-plane expansion of SWNTs implies strong in-plane coupling and high flexibility against nonaxial strains. Many applications of CNTs, such as in nanoscale molecular electronics, sensing and actuating devices, or as reinforcing additive fibers in functional composite materials, have been proposed. Preliminary experiments and simulation studies on the thermal properties of CNTs show very high thermal conductivity. It is expected, therefore, that nanotube reinforcements in polymeric materials may also significantly improve the thermal and thermo-mechanical properties of the composites.

Field Emission: Field emission results from the tunneling of electrons from a metal tip into vacuum, under application of a strong electric field. The small diameter and high aspect ratio of CNTs is very favorable for field emission. Even for moderate voltages, a strong electric field develops at the free end of supported CNTs because of their sharpness. Due to their high electrical conductivity, and the incredible sharpness of their tip (because the smaller the tip’s radius of curvature, the more concentrated will be an electric field, leading to increased field emission; this is the same reason lightning rods are sharp). The sharpness of the tip also means that they emit at especially low voltage, an important fact for building low-power electrical devices that utilize this feature. CNTs can carry an astonishingly high current density, possibly as high as 10^{13} A/cm^2.

High aspect ratio: CNTs represent a very small, high aspect ratio conductive additive for plastics of all types. Their high aspect ratio means that a lower loading (concentration) of CNTs is needed compared to other conductive additives to achieve the same electrical conductivity. This low loading preserves more of the polymer resins’ toughness, especially at low temperatures, as well as maintaining other key performance properties of the matrix resin. CNTs have proven to be an excellent additive to impart electrical conductivity in plastics. Their high aspect ratio (about 1000:1) imparts electrical conductivity at lower loadings, compared to conventional additive materials such as carbon black, chopped carbon fiber, or stainless steel fiber.

Energy Storage: CNTs have the intrinsic characteristics desired in material used as electrodes in batteries and capacitors, two technologies of rapidly increasing importance. CNTs have a tremendously high surface area (~1000 m^2/g!!), good electrical conductivity, and very importantly, their linear geometry makes their surface highly accessible to the electrolyte.

Molecular Electronics: The idea of building electronic circuits out of the essential building blocks of materials - molecules - has seen a revival the past five years, and is a key component of nanotechnology. In any electronic circuit, but particularly as dimensions shrink to the nanoscale, the interconnections between switches and other active devices become increasingly important. Their geometry, electrical conductivity, and ability to be precisely derived, make CNTs the ideal candidates for the connections in molecular electronics. In addition, they have been demonstrated as switches themselves.

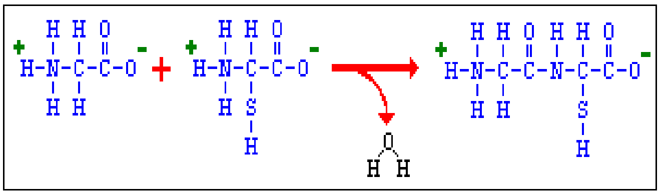
Optical ignition: A layer of 29% iron enriched swnt is placed on top of a layer of explosive material such as pent, and can be ignited with a regular camera flash.

Solar cells: ge's carbon nanotube diode has a photovoltaic effect. Nanotubes can replace into in some solar cells to act as a transparent conductive film in solar cells to allow light to pass to the active layers and generate photocurrent.

Materials and Methods

Chemical approach for CNTs: we take the protein as carbon source from Egg albumin and Manganese salts. The choice of protein is because of the presence of two connecting sites (-NH_2 and –COOH) within one single molecule. Due to the presence of two connecting sites and Mn^{2+} present in Manganese salt different protein chains are clubbed together and hence concentration of carbon at a point is increased.

Proteins are classified by their physical size; they are nanoparticles having particle size between 1–100 nm. Each protein polymer – also known as a polypeptide – consists of a sequence formed from 20 possible L-α-amino acids, referred to as residues. For chains under 40 residues the term peptide is frequently used instead of protein. Peptide bonds are formed between the carboxyl group of one amino acid and the amino group of the next amino acid. Peptide bond formation occurs in a condensation reaction involving loss of a molecule of water.



Preparation of CNTs using egg protein and Manganese salt: CNTs are prepared by the reaction between egg protein and Manganese salt. Now we discuss about the process of the protein content of egg and the chemical composition of egg protein.

Protein content of egg: Egg protein contains all the essential amino acids that the human body requires. It is found that on an average one large egg contains about 6.5 grams of protein. In terms of percentage it is around 12.6%.

Chemical composition of egg protein: Egg protein contains various types of amino acids. Names of some of the amino acids present in egg are: c

Preparation of CNTs using Egg and Manganese salt in aqueous medium

Process: CNTs can form only when the concentration of carbon at a particular point is high so to club various protein molecules together, aqueous solution of Manganese Salt is allowed to react with amino acids present in present in Egg the lone pair present on nitrogen of –NH_2 and oxygen of COO- of COOH group present in amino acid form complex with Mn++. In this way Manganese++ forms cross link between two amino acid chains.

First of all Egg yolk is separated from egg white and kept in two glass beakers. Now 1N and 2N solution of $MnCl_2$ are prepared in water and are mixed with egg yolk for the reaction to occur. Now the reaction mixture is kept undisturbed in desiccators for around fifteen days. After that the compounds formed are now ready to decompose.

The samples formed are decomposed at different temperatures as 900 °C, 950 °C and 1000 °C to 1200 °C in a muffle furnace.

Preparation of CNTs using egg and manganese salt in organic medium: In organic medium protein is denatured and waste changes are observed in the structure of protein. So it is necessary that before concentrating on the process we must get an idea of denaturation of protein.

Results and Discussion

SEM Images of CNTs of Manganese salt and Egg protein in aqueous medium at 800 °C-

SEM images of chemical compound formed by the reaction of egg protein and Manganese salt in aqueous medium and decomposed at 800 °C in muffle furnace.

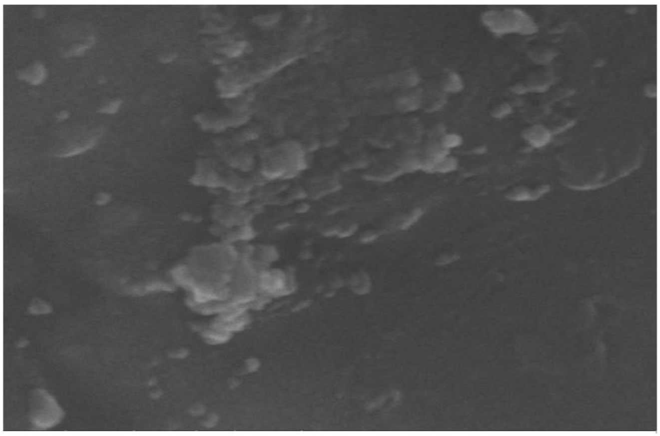


Fig 1: SEM Image of CNTs of Manganese salt and Egg protein in aqueous medium

SEM Images of CNTs of Manganese salt and Egg protein in aqueous medium at 900 °C-

SEM images of chemical compound formed by the reaction of egg protein and Manganese salt in aqueous medium and decomposed at 900 °C in muffle furnace.

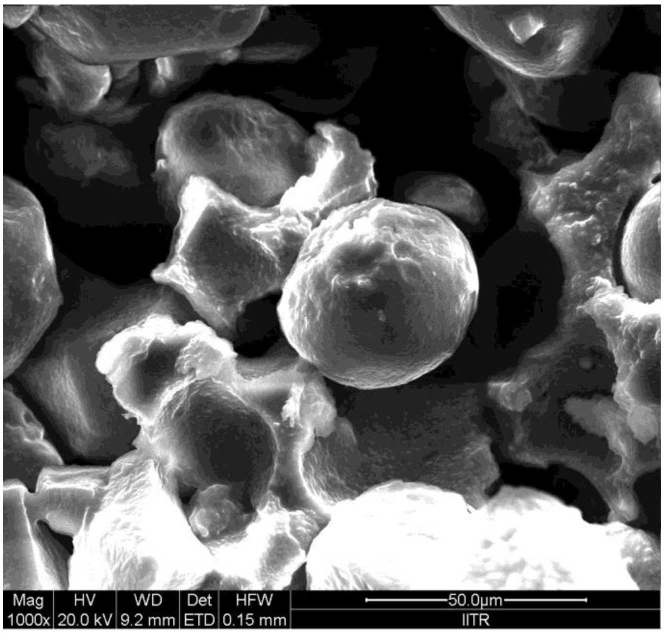


Fig 2: SEM Image of CNTs of Manganese salt and Egg protein in aqueous medium

XRD Graph of Egg protein and Manganese salt in aqueous solution at 900 °C

The sample was prepared by using egg protein and Manganese salt in aqueous medium and decomposed in muffle furnace at 900 °C.

The value of 2Theta=11.28, Intensity=1156

The graph of XRD analyses of the sample is shown below:

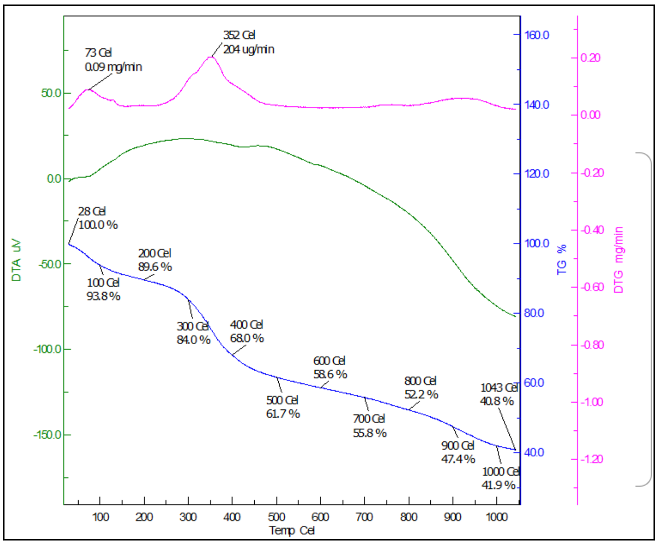


Fig 3: Raman Graph of Egg protein and Manganese salt in aqueous solution at 900 °C-

The sample was prepared by using egg protein and Manganese salt in aqueous medium and decomposed in muffle furnace at 900 °C.

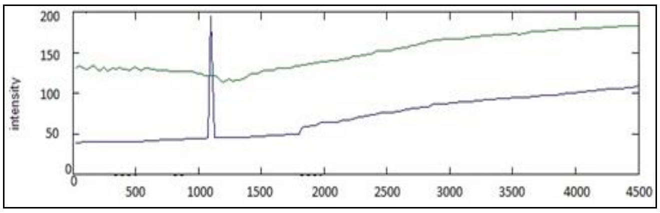


Fig 4: Raman shift cm^{-1}

The potential tools for the conformation of functionalization of MWNTs and SWNTs are FTIR, UV-Vis Absorption spectroscopy, and quantitative analysis using Elemental Analysis, for morphological studies SEM and AFM has been carried out. Each one has its advantages and disadvantages. SEM takes few hours time but where as AFM take days to scan one sample entirely.

To find that the MWNTs and SWNTs get functionalized, we need to go step by step, like first functional group confirmation using FTIR. The chemical functionalization can be confirmed using FTIR. The intrinsic properties of chemically functionalized MWNTs and SWNTs might have

TGA, DTA, DTG Thermos gram of CNTs of egg protein and Manganese salt in aqueous medium

VSM Graph of Sample prepared by using Manganese salt and Egg protein in aqueous medium

Graph of Magnetic properties of CNTs prepared by using Manganese salt and egg protein in aqueous medium and by decomposing the compound at 900 °C.

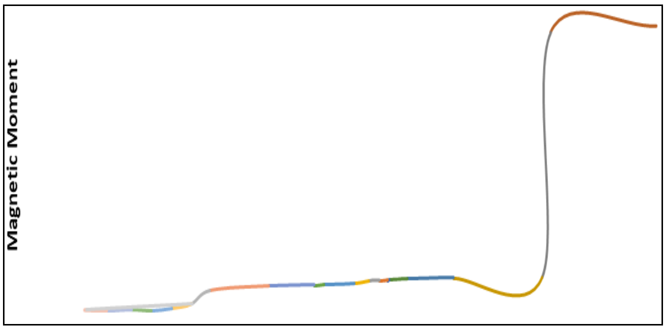


Fig 5: Magnetic field

Photo Luminescence (PL): Light is directed onto a sample, where it is absorbed and imparts excess energy into the material/ CNTs. Photoluminescence excitation spectroscopy can be used to identify the chirality of carbon nanotubes.

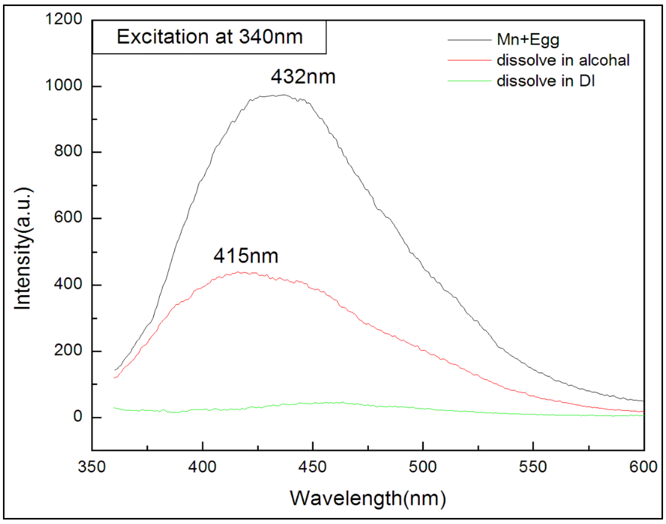


Fig 6: Wavelength (nm)

Conclusion

CNTs can be prepared by the reaction of Amino Acid with Manganese salt and by decomposing at different temperatures the compound formed. Chemical compound can be formed in both aqueous and organic medium. This shows that even after denaturation protein formed desired compound with Manganese salt. This indicates that primary peptide structure is involved in compound formation.

Decomposition temperature also plays a vital role in the formation of CNTs. PL, XRD, Raman Spectroscopy, VSM, TGA and SEM results indicate the study of Electrical, Mechanical, Optical and Electronic properties of Carbon Nano Tubes.

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