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# Carbon Nanotube Synthesis By Green Route Method And Its Characterization

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**Abstract**

Carbon nanotubes (CNTs) are one-dimensional nanomaterials with unique physical and chemical properties that have found applications in many areas, such as electronics, medicine, and energy-related fields. Their synthesis is possible via various techniques, including the green route method. The green route method is a low-temperature, environmentally friendly method for synthesizing CNTs that uses a renewable source of carbon, such as sucrose, as a carbon source. This method is based on the pyrolysis of sucrose in an inert atmosphere and the addition of catalysts to promote the formation of CNTs. The resulting CNTs are typically characterized using Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and Raman spectroscopy. SEM images can provide information about the morphology and size of the CNTs, while TEM and Raman spectroscopy can be used to analyze their crystallinity and electronic structure, respectively. The green route method for CNT synthesis is an attractive alternative to traditional methods due to its low cost and environmental friendliness. Furthermore, the CNTs produced by this method have excellent characteristics, making them suitable for various applications.

**Key Words**: Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Raman spectroscopy and Carbon Nanotubes (CNTs)

## Introduction

### Background and importance of green route synthesis of CNTs

Carbon nanotubes are taken into consideration by cylindrical substances which are evolved with the aid of the rolling up sheet of a single-layer carbon atom. The wall diameter of the carbon nanotube may be varied from single wall to multiwall. Looking at the inner shape of carbon nanotubes it's been observed that they're growing through interlinked nanotubes that have the potential of achieving out to 100nm. The length of a carbon nanotube can be within the kind of several micrometers even on occasion in millimeters. The method of growing carbon nanotube is fashioned utilizing the use of force of van Dar partitions through which herbal inclination is performed for the rope that effects in extremely-high power. Searching on the fundamental quality of carbon nanotubes it has been observed that they are inside the composition of lower-weight materials and feature higher thermal and electrical conductivity.

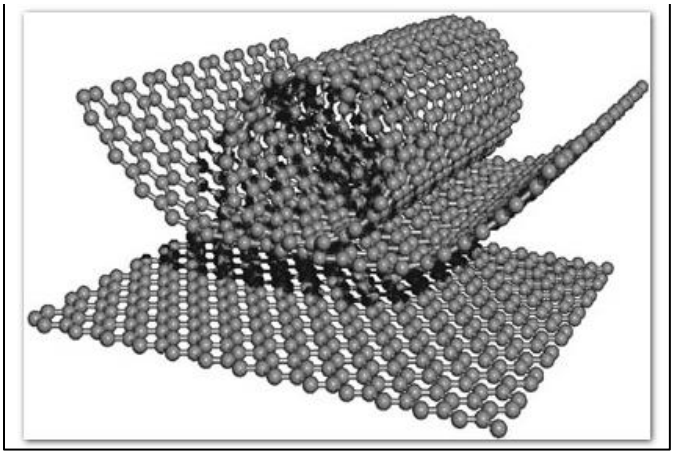

Figure 1: Schematic Structure of CNTs

(Source: Yan et al. 2019)

In recent years, carbon nanotubes (CNTs) have emerged as a category of nanomaterials with extraordinary residences, captivating the clinical community and industry alike. Those cylindrical nanostructures, composed of sp2-hybridized carbon atoms arranged in hexagonal lattices, showcase outstanding electric, mechanical, and thermal characteristics.

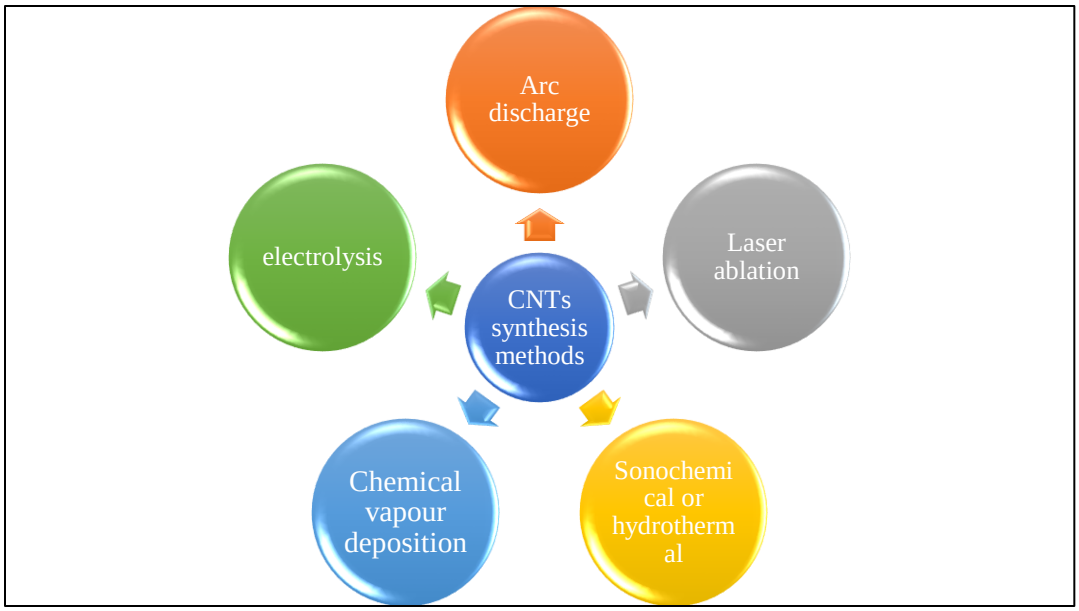


Figure 2: Nanomaterials

(Source: Xiang et al. 2019)

Inside the realm of CNTs, there are two primary classes: single-wall carbon nanotubes (SWCNTs) and multi-wall carbon nanotubes (MWCNTs), each imparting particular attributes that keep gigantic promise for numerous programs.

The CNTs synthesized through the green route approach are in general single-wall carbon nanotubes (SWCNTs). Single-wall carbon nanotubes are one-dimensional nanostructures consisting of a single layer of carbon atoms organized in a cylindrical shape. These SWCNTs own unique residences and are frequently famous for numerous applications due to their outstanding electric conductivity and different advantageous characteristics (Wang et al. 2019). Consequently, in the context of the observation mentioned in the advent, the emphasis is on the synthesis and characterization of SWCNTs.

## Objectivity of the Study

- To analyze the operational method of CNT synthesis.
- To analyze the importance of green route synthesis for CNTs.
- To analyze the existing synthesis methods' favourability in real-life applications.

## Literature Review

### Overview of CNT synthesis methods

Different types of CNT synthesis methods are used in the real field of synthesis. Here the discussion has been developed for the most vital method that is widely used for CNT synthesis.

**Chemical Vapor Deposition**

This technique involved vaporized reactants involved in the chemical reaction and developed a nanomaterial that is deposited as the product of this technique. In this process, different factors need to be considered including the carbon source that is used which can be acetylene or methane.

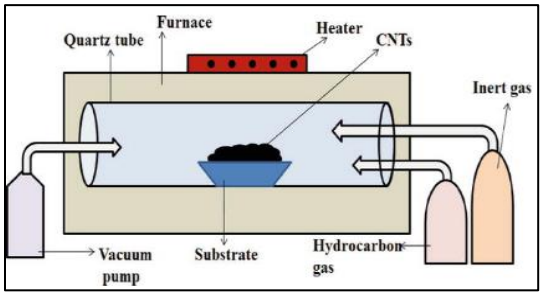


Figure 3: CVD Technique

(Source: Amiri and Mahmoudi-Moghaddam 2021)

The growth of the CNT substrate is another requirement for this technique of synthesis. Identified generally used materials as substrates include zeolite, silica, and sometimes iron particles. In need of developing single-wall CNTs some common use of catalysts includes nickel and molybdenum. Temperature and magnitude are both influencing factors in the process of CNT synthesis (Fleming et al. 2019). In this technique, different sources of CVD use are also involved.

It is another type of technique that is used for synthesis and it is also known as the Plasma arcing method. Here the involved requirement for the synthesis method flow is discussed. The electrode is one of the first factors or requirements that is used here for pure graphite rods. It helps to maintain the gap between two electrodes. As per Zhang et al. (2021) reliability of the measuring outcome is way more secure in this method of synthesis.

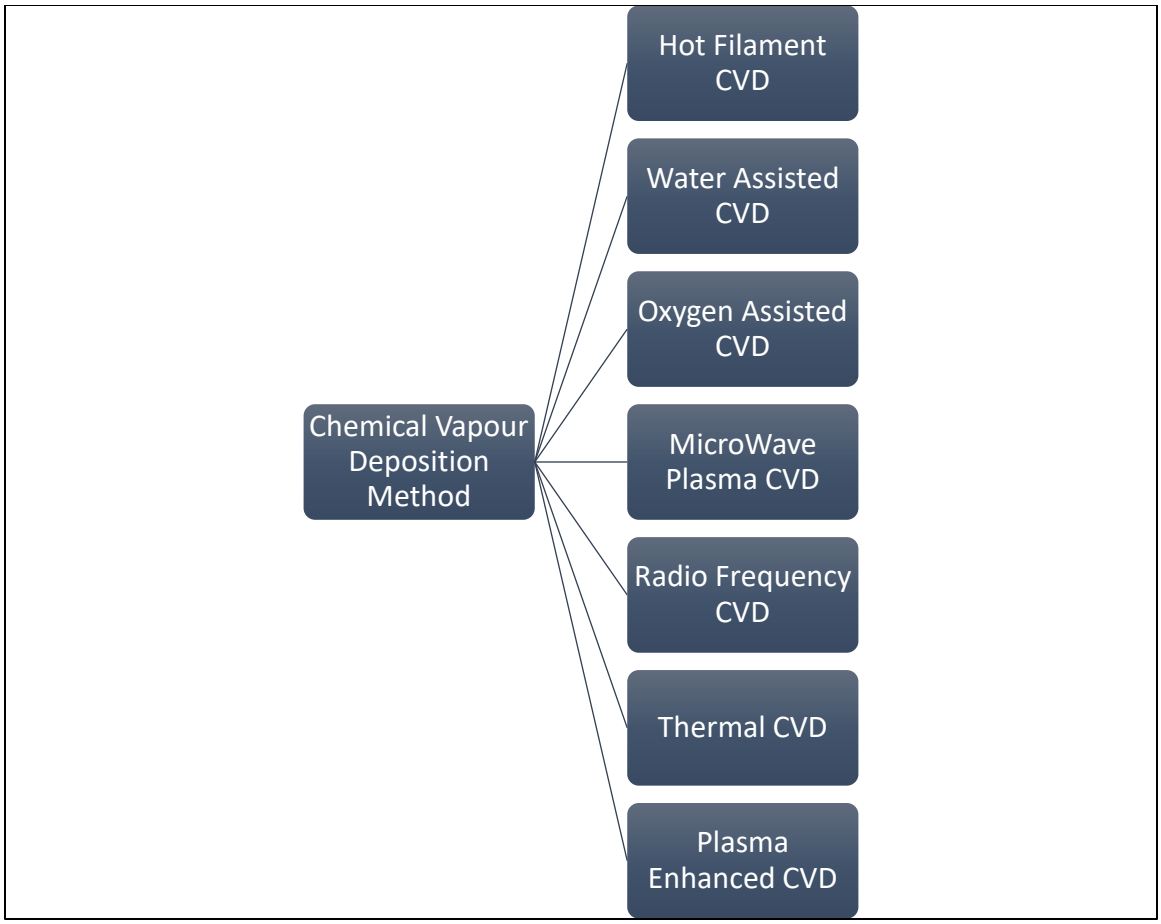


Figure 4: Chemical Vapor Deposition Method and its different methods

(Source: Gonzalez-Fuentes et al. 2020)

**Advantages of Green Route Carbo Nanotube Synthesis**

Green routes for CNT synthesis aim to decrease environmental impact and decrease the use of unsafe chemical substances. Here are a few advantages and variations as compared to conventional methods. First of all, the less ash and residue is one of the major advantages of this tube synthesis. Data justification, stable reusable catalyst, and green workflow are also some positive impacts of green route carbo nanotube synthesis. Green techniques frequently produce CNTs with fewer impurities, resulting in less ash and residue, which can be important for programs like electronics and composites (Sasrimuang et al. 2020). green routes may additionally utilize catalysts that are more solid and reusable, decreasing the cost and environmental effect of catalyst materials. These techniques are designed to be more environmentally pleasant, often the usage of more secure chemical compounds and lowering energy consumption. Researchers using inexperienced methods must provide strong data and proof to guide their claims of environmental friendliness, which is crucial for transparency and credibility.

**XRD Data**

The XRD evaluation confirms that the synthesized CNTs show off a crystalline shape. That is an essential function of CNTs and suggests that the carbon atoms are organized in an exceedingly ordered hexagonal lattice. These facts can be valuable for understanding the structural houses of the CNTs.

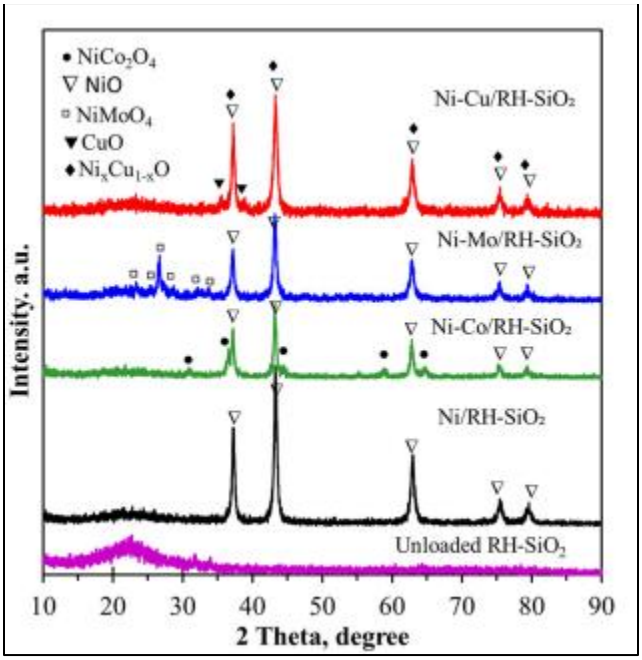


Figure 5: XRD Pattern Syntheis

(Source: Zhang et al. 2022)

XRD can also reveal the presence of impurities or other phases inside the synthesized CNTs. A smooth and properly defined XRD pattern suggests an excessive degree of purity, which is crucial for many packages, consisting of power storage. XRD facts serve as a nice control measure, making sure that the synthesized CNTs meet the preferred structural criteria. Any deviations from anticipated XRD patterns should suggest versions in CNT fine or structure.

**Synthesis Procedure and Novelties**

The inexperienced direction technique adheres to the principles of inexperienced chemistry, emphasizing sustainability and environmental friendliness. It minimizes the usage of toxic reagents and reduces the era of dangerous byproducts, that is a great departure from conventional CNT synthesis techniques that regularly involve risky chemicals. A standout characteristic of this technique is the utilization of a solid, reusable catalyst. in contrast to traditional methods that require the disposal of catalysts after use, this technique promotes catalyst sustainability and decreases the overall cost of CNT manufacturing (Sarno et al. 2020). It also minimizes the environmental effects related to catalyst disposal. By means of

employing a green workflow, the synthesis technique aims to reduce waste era all through the CNT manufacturing procedure. that is an essential thing of sustainability and aligns with the growing call nanomaterial synthesis. The inexperienced synthesis approach considerably reduces the environmental footprint of CNT manufacturing. It aligns with global efforts to reduce the carbon footprint and environmental harm associated with nanomaterial manufacturing, making it an extra responsible and sustainable choice (Nguyen and Shim 2015). Despite its nature, the inexperienced course approach does not compromise the satisfaction of the synthesized CNTs. The XRD, TEM, and FESEM analyses stated in advance verify the crystalline nature and structural integrity of the CNTs, indicating that they meet the necessary standards for numerous applications. As environmental issues continue to grow, there is an increasing call for sustainable and green technology. The green synthesis of CNTs positions this research at the vanguard of destiny developments, where environmentally pleasant production methods are highly valued.

**TEM Analysis**

Before giving the TEM analysis, CNT samples need to be properly prepared. Basically, a small amount of the synthesized CNT sample is dispersed in a suitable solvent to create a suspension. A droplet of this suspension is then located on a TEM grid, which is usually a thin, flat piece of with a perforated shape (Lan et al. 2022). TEM makes use of a beam of electrons to interact with the pattern. The electrons pass through the sample, and the resulting transmission image is captured on a detector. This high-decision picture provides information about the internal structure and morphology of personal CNTs.

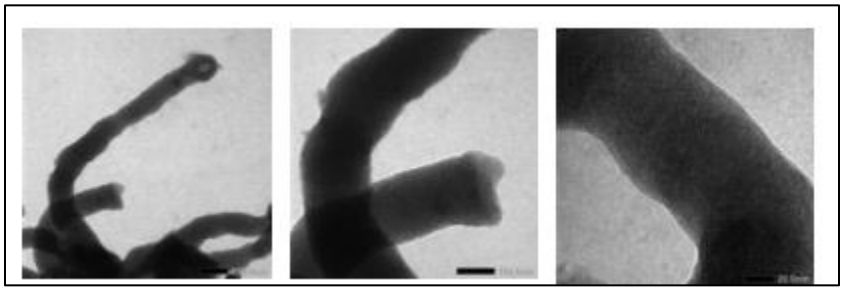

Figure 6: TEM Using Carbon Characterization

(Source: Sasrimuang et al. 2020)

TEM can reach nanometer-scale resolution, taking into consideration the visualization of personal CNTs, their diameter, duration, and structural defects. This can also monitor details about the arrangement of carbon atoms within the nanotubes. TEM snapshots are used to measure the diameter and period of CNTs. This information is vital for information on the size distribution and uniformity of the synthesized CNTs. TEM can come across structural defects within CNTs, consisting of vacancies, dislocations, or kinks (Ijaz et al. 2020). Figure out defects is essential for assessing the niceness of the nanotubes, as well as their suitability

for particular packages. TEM evaluation can monitor how CNTs are distributed within the pattern. This may visualize whether or not they're well-dispersed or have a tendency to agglomerate, which is critical for packages where uniform dispersion is favored. By using selected-place electron diffraction (SAED) in TEM, it is feasible to achieve crystallographic records of approximately the CNTs. SAED styles can reveal the crystal planes and orientations present inside the nanotubes. TEM gives excessive-resolution pictures which are crucial for characterizing nanomaterials. It offers researchers the capability to study personal CNTs and check their structural integrity (Hakim et al. 2018). TEM analysis is often used alongside different characterization strategies, inclusive of X-ray diffraction (XRD) and area emission scanning electron microscopy (FESEM), to reap complete know-how of CNT residences.

**Characteristics of the FESEM Manuscript**

FESEM is a powerful microscopy method that may provide excessive-decision pix of nanoscale materials like carbon nanotubes (CNTs). Within the context of carbon nanotube synthesis through an inexperienced course technique, FESEM may be used for a few followings. Morphological analysis, characteristics of catalyst, distribution analysis, and quality controls are some major characteristics of the FESEM manuscript (González-Fuentes et al. 2020). FESEM can reveal the morphology and shape of CNTs, allowing researchers to assess their length, shape, and alignment. it could help in assessing the fine of CNTs, which includes the presence of defects or impurities (Fleming et al. 219). FESEM may be used to study the catalyst debris used in the synthesis technique. For inexperienced techniques, this can be crucial in knowledge of the catalyst's stability and reusability. It provides statistics on the distribution of CNTs on a substrate, which is critical for uniformity in applications.

**Chemical Stabilities in Energy Storage Applications**

Electrolyte Compatibility is used in some way like, this tool utilized in the energy storage system, should be chemically lasting to prevent and maintain long-term performance with degradation (Aravind et al. 2022). Anode and Cathode stability must be illustrated and identified for chemical stability, specifically dealing with systems named by high-energy-destiny. Preventing Side Reactions is one of the major applications of chemical stability connects to minimize some undesirable perceptions of reaction through the energy storing device which can fade or any safety concern. Environmental Impact is also a main thing for chemical stabilities (Amiri and Mahmoudi-Moghaddam 2021). With CNT synthesis, maintaining the impact of the environment for energy storage devices and all essential methods with valuable green routes.

## Conclusion

In the part of the conclusion, it will be informed that FESEM is an important gadget for featuring carbon nanotubes synthesized with the help of green routes. After giving some visual their quality and morphology. Finally, CNTs are being utilized in a ramification of other applications. CNTs are being used to create nanoscale medical gadgets, inclusive of biosensors and drug shipping structures. CNTs are also getting used to create new materials for use in the aerospace and automotive industries, as they may be extra lightweight and robust than conventional materials. Existing complications for the use of different physio-chemical strategies for CNTs manufacturing are determined that get the chances of overcoming via inexperienced synthesis using. Environment pleasant production makes the higher scope of ensuring long-term period production stability formation for CNTs production. An environmentally pleasant mindset usually makes the possibility of producing its impact on the market of CNT manufacturing.

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