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REVIEW ARTICLE

Camphor Based Carbon Nano Tubes: A Recent Advancement in Green Chemistry

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ABSTRACT
Green chemistry (sustainable chemistry) is a philosophy of chemical research and engineering that encourages the design of chemical products and processes that reduce or eliminate the use or generation of substances hazardous to humans, animals, plants, and the environment. Green Chemistry based on clean, environmentally-friendly or GAC methods. The main principles are to replace toxic reagents, to miniaturize and to automate methods, making it possible to reduce dramatically the amounts of reagents consumed and wastes generated, so reducing or avoiding side effects of analytical methods. New devices and protocols, with negligible waste generation or no hazardous substances are particularly needed for addressing the challenges of green analytical chemistry. Carbon nanotube (CNT) is the recent advancement in green chemistry. But conventional CNTs show much toxic effect in invertebrates and also cause genotoxicity in rates and in humans. Modern CNT are produced by chemical vapour deposition of camphor, an environment-friendly hydrocarbon. Camphor-to-CNT production efficiency is 50% higher than achieved from any other material or by any other method. these types of CNTs show less toxic effect to invertebrates and humans as compare to conventional one. Moreover camphor-based CNT synthesis technique stands fairly good against the 12-principle protocol of green chemistry.
Keywords: Camphor, Carbon nano tubes, green chemistry

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INTRODUCTION

Green chemistry is the use of chemistry for pollution prevention. The term *green chemistry* was coined by Paul Anastas in 1991 and the concept was originated by Trevor Kletz in his 1978 [1] It eliminates the use or generation of substances which are hazardous to human, animal and environment. Green chemistry is a way of dealing with risk reduction and pollution prevention by addressing the intrinsic hazards of the substances rather than those circumstances and conditions of their use that might increase their risk (Risk = Hazard ¥ Exposure). This Emerging area of green chemistry is useful for implementing the relationships between industry and academia. . Paul Anastas, then of the United States Environmental Protection Agency, and John C. Warner developed 12 principles of green chemistry [2],which are as follows

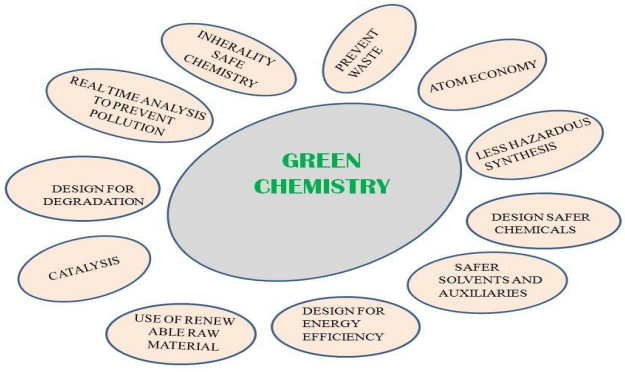

Figure-1 Twelve principles of green chemistry

Carbon Nano tubes (CNT) are the advancement in green chemistry. A Carbon Nanotube is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale. the mechanical and transport properties of Carbon Nanotube make them the best carbon fibers Carbon Nanotube show a unique combination of stiffness, strength, and tenacity compared to other fiber materials. It's Thermal and electrical conductivity is also very high, and comparable to other conductive materials.
Carbon Nanotubes can be categorized by their structures:

- Single-wall Nanotubes (SWNT)
- Double-wall Nanotubes (DWNT)
- Multi-wall Nanotubes (MWNT)

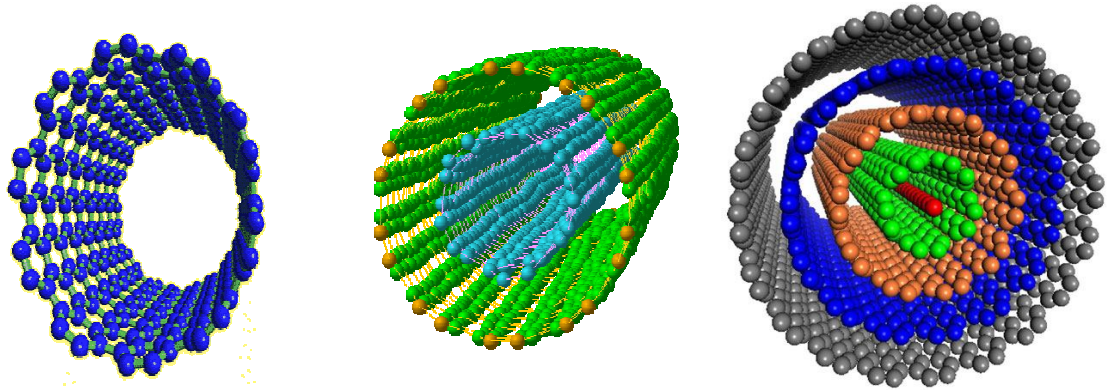

Figure- 2 Single-wall Nanotubes (SWNT), Double-wall Nanotubes (DWNT) , Multi-wall Nanotubes (MWNT)

Carbon nano tubes are widely used in areas such as medical sectors, electronics, composites, and materials science [3]. CNTs have various applications like in Conductive plastics, Structural composite materials, Gas storage, and Antifouling paint, Micro- and nano-electronics, Radar-absorbing coating, and Technical textiles, Ultra-capacitors, Atomic Force Microscope tips, Biosensors for harmful gases and as Extra strong fibers .

ROLE OF CARBON NANO TUBES IN ENVIRONMENT

Carbon nano tubes are widely used to clean up the oil spills. This is done by adding boron atoms during the growth of CNTs so that nano tubes will changes into sponge like material because spongy material has the capacity to absorb heavy oil content. In this way CNTs are playing a major role to prevent water from pollution.
Chemical vapor deposition (CVD) is the most popular method of producing CNTs. In this process, thermal decomposition of a hydrocarbon vapor is achieved by the action of a metal catalyst. That is why, it is also known as thermal CVD or catalytic CVD.Camphor based CNT production is cheap and also user-friendly for CVD due to its volatile and non-toxic nature. Camphor is readily obtained from renewable resources, making it an ideal "green" biosource for the production of Nanotubes. Camphor is simply extracted from the latex of cinnamomum camphor tree of lauracea family. It is a white crystalline solid that sublimates at room temperature. Camphor, a well-valued material in biotechnology research, was successfully brought to nanotechnology research with the first report of CNTs from camphor [4] 2001.
First carbon nanotube reported by Iijima [5] [was found in Professor Ando's specimen. He was the first Head of the Department of Materials Science and Engineering in Meijo University. From April 2009, he is the Dean of the Faculty of Science and Technology in Meijo University. He worked on the synthesis of CNTs and explained their application as composite materials. Dr. Mukul Kumar worked on the synthesis, characterization and application of CNTs grown by CVD method, and electron field emission. In Jan 2003, Dr. Kumar has been a senior scientist at the 21st Century Centre of Excellence. Kumar and Ando have proposed that the bicyclic structure of camphor is a key to the growth mechanism of CNTs.

TOXIC EFFECT OF CARBON NANO TUBES

Carbon nanotubes shows various kind of toxicity CNTs can enter in the aquatic environments through sources such as general weathering, disposal of CNT-containing consumer products, accidental spillages, and waste discharges [6]. CNTs are hydrophobic and nonbiodegradable in nature [7] thus these materials can accumulate in aquatic biota when released into aquatic environments and causes toxic effect on invertebrates and significantly reduced the survival or growth of the invertebrates. Traditional carbon

nano tubes shows measurably harmful effects on good algae found in waterways. Apart from this CNT causes asbestos related diseases in humans and also causes irritation in mouse lungs.

CAMPHOR

Camphor ($C_{10}H_{16}O$) is a botanical hydrocarbon. Mainly, it is useful for its great medicinal uses in India. It is also used as a room freshener and food disinfectant.

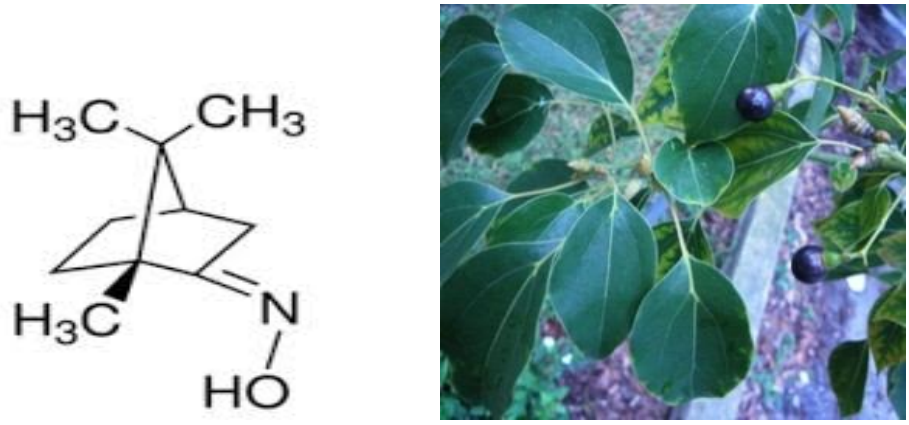

Figure-3 Structure of a camphor molecule and Picture of a camphor tree

Indian people use to burn camphor in temples while offering prayer. Unlike common fumes, the camphor fume is non-irritant to eyes. Its modern applications include use as a plasticizer.

PRODUCTION OF CNTs FROM CAMPHOR:

In a small CVD reactor (1-m long and 26-mm wide), 3 g camphor is vaporized at 200°C under a mild argon flow of 50 sccm, and is pyrolyzed over 0.3 g Fe-Co-impregnated zeolite support at 650°C. Such a simple process for 1 hour apparently inflates the zeolite bed over 50 times by volume and yields 1.62 g MWNTs of diameter ~10 nm with an as-grown purity over 88%. Camphor-to-CNT production efficiency is ~50%, which is incomparably higher than that of 644 any CNT precursor by any method. Most efficient ways of MWNT production by CVD have a carbon source-to-CNT conversion efficiency around 20-30% [8].

Camphor based CNTs are preferred over the conventional CNTs:

Camphor plays a vital role in CNT growth. It is carbon rich, hydrogen rich and oxygen present as compared to CNT precursors such as CH4, C2H4, C2H2, and C6H6.Oxygen atom present in camphor molecule helps oxidizing amorphous carbon *insitu*, as proposed by [4].

Thus, we can say that every atom of camphor has a positive role towards CNT synthesis. A probable growth mechanism of CNTs from camphor was first reported in 2003 [9]. In particular, low-temperature camphor CVD rules out the possibility of spontaneous (unanalyzed) decomposition of camphor vapor in the reactor, and results in CNTs free from amorphous carbon. There is no trace of carbon deposit in any portion of the quartz tube except on the zeolite bed. [10].

Camphor based CNTs applied in green chemistry:

Camphor based CNT follows all the 12 principles of green chemistry

1. **Waste Prevention**: CNTs which are produced by camphor show higher efficiency than others and these CNTs prevent waste accumulation.
2. **Atom Economy**: Camphor based CNT shows maximum constituents of camphor in to the end product.
3. **Less Hazardous Chemical Syntheses**: All the processes and substances involved in the camphor based CNT production shows no toxicity to human, animals and the environment.
4. **Designing Safer Chemicals**: chemicals used in camphor based CNT technique are designed in such a way that it shows no hazardous effect to environment.
5. **Safer Solvents and Auxiliaries**: The auxiliary used in the camphor based CNT is metal catalyst which is quite safe.
6. **Design for Energy Efficiency**: camphor based CNT process follows low temperature atmospheric pressure. So the energy requirement in this process is low.
7. **Use of Renewable Feedstock's**: is reusable and regenerative compound so there is no chance of depl eting this compound so that we can save the natural resource.
8. **Reduce Derivatives**: Camphor based CNT process involves no derivatives because 1derivatives lead to the formation of new product which shows hazardous effect.

9. **Catalysis**: this process involves pure catalyst (zeolite) and, no stoichiometric reagents are involved.
10. **Design for Degradation**: CNTs produced by the camphor are designed in such a way that these are fully biodegradable and causes no harm to environment.
11. **Real-time analysis for Pollution Prevention**: In this process continuous monitoring is done prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention**: Camphor based CNT process involve the chemicals which cause no accidental effects including explosion and fires.

CONCLUSION

With the help of Green chemistry we can design chemical processes and product that can reduce or eliminate the waste that are hazardous to humans, animal and environment. Camphor based CNTs are applicable in green chemistry as it follows all the 12 principles of green chemistry and it causes to no toxicity to humans and animals. Camphor based CNTs have shown several advantages over conventional CNTs due to which they have become very popular and their use should be highly encouraged.

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