Are Emerging Applications of Carbon Nanotubes Safe?

Current State of Art Applications of Carbon Nanotubes in Biomedical Applications: Limitations vs Success.

R. Sharma*

*Center of Interdisciplinary Magnetic Resonance,
National High Magnetic Field Laboratory, Florida State University, Florida 32310

ABSTRACT

Carbon nanotubes are tiny cage like structures with great potentials in biomedical engineering and sciences. However, their great emergence in bioscience applications is not risk free. In present report several known or possible risks and limitations of carbon nanotube material in biosciences and bioengineering are documented. Major breakthroughs of carbon nanotubes such as MRI buckyballs, computing elctronics, tiny diagnostic chips, solar tubes, plasma displays, neural sensors, healing drops, drug nanospheres, nanocircuits, nanobullets, nanomonitors, nanomedicine, chemodots are exciting. Other hand, it also poses serious question on unsafe use of carbon nanotubes such as tiny toxins, nano-explosives, smart intruder targeting nanomolecules. A critical view of limited outcome from each application is presented with possiblility of limited use of bio-applicable carbon nanotubes to get maximum outcome in future.

Key words: Carbon nanotube, safety, biomedical use

1 INTRODUCTION

The "carbon nanotube" is carbon fullerene, molecular weight between about 840 and greater than 10 million. Carbon nanotubes have emerged as potential materials for both biomedical use and development of optical, electrical and mechanical usage as light, tough and fast-communicable material as some applications are shown in table 1. Our purpose was also focused to design carbon nanotube material for different purposes [1]. We present here our strategy of design and characteristics of CNT material to develop it as potential nanosphere. Basically aligning of carbon nanotubes and making a composite material as aligned carbon nanotubes. Aligning comprises adsorbing magnetic nanoparticles to carbon nanotubes dispersed in a fluid medium to form a magnetic particle-carbon nanotube composite in the fluid medium. Exposing this composite to a magnetic field effective aligns the nanotubes in the fluid medium. The composite material is prepared by: (1) adsorbing magnetic nanoparticles to carbon nanotubes to form a magnetic particle-carbon nanotube composite; (2) dispersing the magnetic particle-carbon nanotube composite in a fluid matrix material to form a mixture; (3) exposing the mixture to a magnetic field effective to align the nanotubes in the mixture; and (4) solidifying the fluid matrix material to form aligned nanotube/matrix material composite. Carbon nanotubes Graphite Fiber and Filament is strongest single or double walled fibers. Nanotube well-dispersed carbon nanotubes in a polymer makes cheaper aligned carbon nanotubes in a polymer matrix using silanization and electrochemical modification.

2 PREPARATION OF BIOMEDICAL GRADE CARBON NANOTUBE

First, iron, nickel, cobalt, or an alloy maghemite mixed with carbon nanotubes 100:1-1:2 ratio and coated with thermoplastic polymer or epoxy resin at a low cross-linking temperature and solidification to self-cross link and orientation of magnetic nanotubes by physically attaching magnetic nanoparticles to the surface of the carbon nanotubes. Good choices are crosslinkable matrix material or thermoset polymers and epoxies. The nanotubes with adsorbed magnetic particles are incorporated into a gel, a metal, or a ceramic matrix material. The magnetic nanoparticles" includes magnetic, paramagnetic, and superparamagnetic materials. The nanoparticles can comprise iron, nickel, cobalt, and/or their alloys magnetite or maghemite (λFe_2O_3) iron-neodymium-boron nanoparticles of 3 nm and about 100 nm diameter. Adsorption of the nanoparticles to the nanotubes is done by sonication in "nonsolvent" acetone, ethanol, methanol, and n-hexane. The adsorption step includes inserting into

the annular opening of the nanotubes a quantity of nanoparticles that have a smaller diameter than the inner diameter of the nanotubes. The magnetic field induces effective alignment of the nanotubes dependent on fluid viscosity and applied 0.5-1 T magnetic field. The ideal matrix material are polyolefins, polyesters, nonpeptide polyamines, polyamides, polycarbonates, polyalkenes, polyvinyl ethers, polyglycolides, cellulose ethers, polyvinyl halides, polyhydroxyalkanoates, polyanhydrides, polystyrenes, polyacrylates, polymethacrylates, polyurethanes. The fluid matrix material "polymer precursor cyanoacrylate" make "crosslinkable material". The aligned nanotube/matrix material composites are high strength, lightweight, structural components for automotive body parts, athletic equipment, spacecraft, nanoelectronics, optical equipment and video displays (e.g., field emission displays), organic transistors(polyaniline doped single wall nanotubes) for aircraft and spacecraft, long power-transmission lines and suspension bridges. Preparation of Single Wall Nanotubes-Magnetite Composite: Ferrous chloride and ferric chloride added with 10 M NaOH solution and sonicated to get 6 nm to 30 nm ferrous oxide(magnetite) and it was added with. 0.1 mg of single wall carbon nanotubes dispersed in methanol by ultrasonication. Polymer composite of single wall nanotubes and magnetite mixed with epoxy resin and crosslinked with a hardener (3:1) after 24 hoursit makes solid polymeric composite block. Scanning transmission electron microscopy micrographs of the 100 nm films showed iron oxide coupled with SWNTs aligned in the epoxy by external magnetic field. Near-infrared Raman spectra of carbon nanotubes showed three important regions(radial breathing mode (RBM), tangential mode (TM), the intermediate frequency range.

Table 1: The emerging applications of carbon nanotubes in biomedical and material science applications.

1. Nanotechnology in Biomedical Use

- Superparamagnetic gadonanotubes are high-performance MRI contrast agents.
- "Lab on a chip" as sophisticated portable blood tests.
- Exciton resonances quench the photoluminescence of zigzag carbon nanotubes.
- Isotope engineering of carbon nanotube systems.
- Frequency dependence of the dielectrophoretic separation of single-walled carbon nanotubes.
- Visualization of individual single-walled carbon nanotubes by fluorescent polymer wrapping.
- DNA-decorated carbon nanotubes for chemical sensing.
- The observation of superparamagnetic behavior in molecular carbon tube nanowires.
- Smart "nanocarriers" as single-shot nanospheres for safe drug delivery and diagnostics.
- Nanoparticles filled with tumor-destroying drugs
- (1)H/(19)F magnetic resonance molecular imaging with perfluorocarbon

2. Nanotechnology in material science

- electron-phonon coupling of individual single-walled carbon nanotubes.
- Nanoscale vibrational analysis of single-walled carbon nanotubes.
- Optical transitions in metallic single-walled carbon nanotubes.
- Electron-microscopic imaging of single-walled carbon nanotubes grown on silicon and silicon oxide substrates.
- Growth of carbon nanotubes on metal nanoparticles: a microscopic mechanism from ab initio molecular dynamics simulations.
- Electron transport in very clean, as-grown suspended carbon nanotubes.
- Constrained iron catalysts for single-walled carbon nanotube growth
- Electronically selective chemical functionalization of carbon nanotubes:correlation between Raman spectral and electrical responses.
- Synthesis of carbon nanotubes.

3 POSSIBLE SAFETY ISSUES: SUCCESS AND LIMITATIONS

Several studies suggested that carbon nanotubes are excellent high performance fluorescent imaging contrast agents, drug carriers, cell tracking agents, miniatured efficient superlight weight strong DNA bio-sensors and tumor targeted destroyers one hand as shown in Table 1. On other side of coin, it easily penetrates through membrane, nuclei, DNA disrupting receptor, protein regulatory machinery and energy chain at molecular level perhaps due to insert nature at molecular active sites to get access unrestricted physiologically. It remains to see if these nanoparticles change the conformation and structural-functional relationship in vivo before its wider acceptance in several in vivo biomedical uses. However, success in ex vivo and in vitro biomedical uses is immense for smart miniature purposes but the unproven risks still restrict their use in in vivo biomedical, surgical purposes or public health. No doubt, their growing demand in aerospace, nanotechnology, mechanical, composite materials, optics, biosensing, biomimetics, solar, electronics, molecular physics put them at top as nanotubes as future of material science. In due course, major limitations may be preconditioned, controlled, characterized and highly monitored, restricted use of these nanotubes in both biomedical and material science applications followed by cost-effective utility, superiority and safety in using them for different purposes mentioned or newly explored applications vital or technologically demanded. Major success is likely due to their nanosize, inert nature and physical-chemical characteristics. So far, biochemical-physiological characteristics are less known that put them in bracket of limited use. Health safety issues are infancy today [1, 2].

4 MAJOR APPLICATIONS AVAILABLE WITH LIMITATIONS

1. Carbon cages filled with metal molecules could improve MRI diagnostics and make high-efficiency solar cells. However, the exact mechanism is not yet understood and needs more validation before to be practicable.
2. A new way to move fluids around on a "lab on a chip" could make sophisticated portable blood tests more practical. But one problem in developing these microfluidic devices is how to precisely pump fluids through a chip without using a significant amount of power. Still miniaturization is a problem with practical utilities.
3. A tiny sensor that tracks calcium levels may one day provide clearer pictures of the brain at work. Unfortunately, current fMRI techniques provide only a rough estimate of what the brain is doing at any given moment. FMRI scans also have a relatively low spatial resolution, measuring activity in areas of 100 microns, a volume that typically contains 10,000 neurons, each with varying activation patterns. It needed advanced high power magnets with keeping lower SAR within limit a real challenge.
4. A biodegradable liquid offers a new way to quickly treat wounds and promote healing. However, the passage of nanolotion for this application is not proven if it does not affect the surrounding cells.
5. Smart "nanocarriers" for drug delivery and diagnostics using parts of living cells in a smart nanotechnology-based system, can target specific types of cells and light up in response to conditions in their immediate environment. However, drug kinetics and drug action may get affected by nanocarrier during drug delivery.
6. Nanoparticles filled with tumor-destroying drugs have promise as a way to effectively target and kill ovarian cancer cells. Many approaches have devastating side effects, attacking a lot of normal cells like hair follicle and gastrointestinal cells. Ovarian cancer is a tempting target for the technology because it is particularly difficult to treat and often has a high relapse rate. But pH is not true viable marker for cancer cells. The sites of infection are also highly acidic, and could potentially throw pH-sensitive cancer drugs off their course.
7. Electrodes made of nanowires can measure the complex signals in a single brain cell. They could also be used in neural prosthetics, providing electrodes far more sensitive than those currently used. By detecting electrical activity in many places along a neuron, the researchers can watch how it processes and acts on incoming signals from other cells. However, many brain pathologies are difficult to observe these small changes with the existing tools.

8. Modeling software could lead to more efficient design of nanoparticles to find ways of delivering drugs directly to cancer cells or creating fast, inexpensive diagnostic tools such as over-the-counter tests for avian flu. But the expertise in materials science needed is limited. One limiting factor could be the speed of computers.
9. A powerful but cheap nanotech tool available soon could test for everything from genetic diseases to heart-attack signs. However, accuracy, precision and user friendly issues are unresolved.
10. An ultrasensitive DNA and protein detector detects genetic and infectious diseases by gold coated nanoparticles with multiple complementary strands of DNA to the target DNA sequence to localize density of the DNA for multiple genetic markers with one test. Some types of nanoparticles might pose a health hazard. That's bad news for nanotechnology. Carbon nanotubes are known to cause lesions that got progressively worse over time much more toxic than carbon black and quartz, which is considered a serious occupational health hazard."
11. The fluorescent "cadmium selenide quantum dot," in bioimaging and glowing nanodots with antibodies, injected into subjects, can be toxic and it is not yet known whether the dots will linger in the body, or whether the coating will degrade, releasing its cargo. Sensible regulation of nanoparticles will require new methods for assessing toxicity.
12. The use of nanoparticles like cosmetics and sliver has unresolved safety concerns of health problem.
13. Nanospheres that target cancer cells and gradually release drugs could make treatment safer and more effective. A single treatment of drug-bearing nanoparticles effectively destroys prostate cancer tumors in mice, but treatment has side effects and damage to healthy tissue.

5 CONCLUSION

Carbon nanotubes demonstrate great potentials in both biomedical and material science applications growing day by day but some of these applications are not risk free. Before adopting any application in practice it needs a lot of ground analysis and lab standardization, cost-effect benefits, user friendly and risk free utility. It is too early to predict the real success of nanotubes as stars of future nanomedicine and nanotechnology.

References

[1]. Xi Li, Yinghua Peng, and Xiaogang Qu. Nucleic Acids Res. 2006; 34(13): 3670–3676.
[2].Robert Roy Britt
http://www.foxnews.com/story/0,2933,184242,00.html

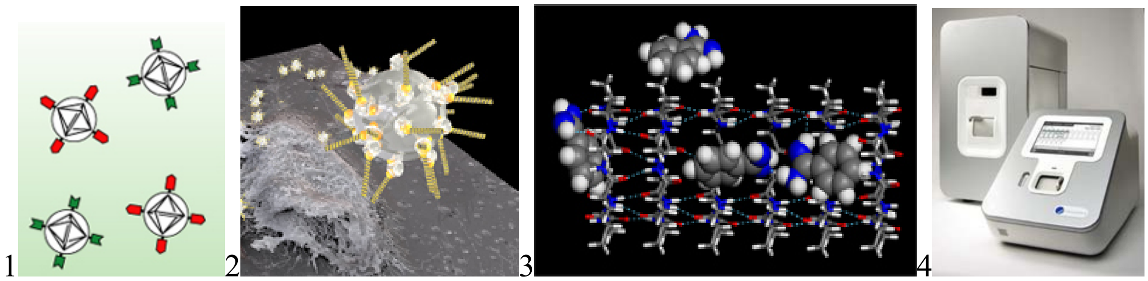

Figure 1:CNT use as nanowire(1),nanocarriers(2),molecule models(3) & diagnostics(4).

1.