

Cancer and Carbon Nano Tubes: A Promising Hope of Future

Satish Kumar Samal

Department of Nanotechnology, Swarnandhra College of Engineering and technology, Narasapur, Andhra Pradesh-534280, India

Abstract

One way to alleviate the terrible side effects of chemotherapy is to find a way to better control what cells are needed to be targeted by the drugs in cancer patients. By being able to target only the cancerous cells within the body, less chemotherapy drugs would need to be injected into the patient for cancer treatment, thus reducing, if not completely wiping away, the side effects of the chemotherapy drugs. Cancer researchers have figured out a method that better delivers drugs, such as chemotherapy drugs, to cancer cells without damaging surrounding healthy ones, by discovering a way to use single-walled carbon nanotubes (SWCNTs) as targeted medicinal delivery mediums. For how small they are, their inner volumes are relatively large, leaving enough space to carry drugs into the body. Both the inner and outer surfaces of SWCNTs can be easily modified for “functionalization”. Their small size nature allows them to enter the nuclei of cells freely. Most importantly, single-walled carbon nanotubes are completely safe and nontoxic and proven to be stable to use in inserting and transporting drugs into the body. Presently, carbon nanotubes are not only being used as drug delivery systems, but as a means of directly killing malignant cells within the body. All of these applications of CNTs makes it promising and would lead to great advances in medicine in the future.

Keywords: Chemotherapy; Cancer; Single walled carbon nanotubes (SWCNTs); Functionalization; Malignant cells.



CC BY: [Creative Commons Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/)

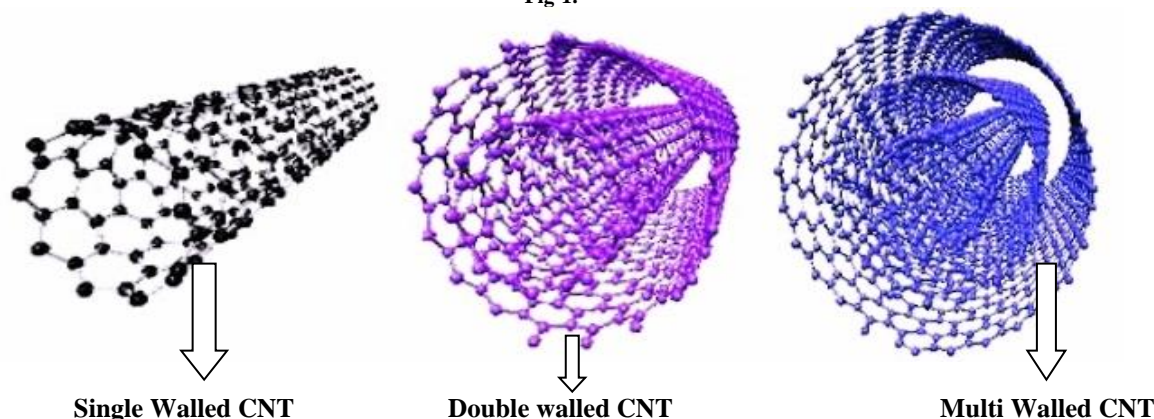
1. Carbon Nanotubes: Amazing Structures

The discovery of carbon nanotubes has led to huge breakthroughs in the biomedical field. Their chemical and structural properties allow them to be used for a variety of scientific practices on a molecular level. These carbon nanotubes allow research to be conducted on a nano scale. Researchers are currently conducting studies where they use carbon nanotubes (CNTs) as sensors that can locate harmful toxins that damage DNA, as a drug delivery system, and as a tool to destroy cancerous.

2. Discovery

The first carbon nanotube was discovered in 1991 by scientist Sumio Iijima. Iijima had discovered multi-walled carbon nanotubes which are cylindrical structures comprised of sheets of rolled up benzene ring carbons that are usually capped on at least one end [Martin \[1\]](#). They were described as several carbon tubes, nested like “Russian dolls” [\[2\]](#). A few years later in 1993, single walled carbon nanotubes (SWCNT) were discovered by Iijima’s group at NEC and Donald Bethune’s group at IBM’s Almaden Research Center in California [\[2\]](#). Single walled carbon nanotubes are also long cylindrical structures, but they are made up of only one layer of rolled up benzene ring carbons. CNTs are very small, but also very strong. In fact, carbon nanotubes are stronger than steel. Also, carbon nanotubes can act as either conductors or semiconductors [\[1\]](#).

Fig-1.



The discovery of these impressive structures and their interesting properties ignited much research within the scientific community. Through this research, it was discovered that carbon nanotubes have many different scientific applications. However, it is the carbon nanotubes impact on the medical field which proves to be the most beneficial to society.

2. Bio Medical Applications

Over the past few years, breakthroughs have been made pertaining to the use of carbon nanotubes in the medical field. Many of these advances have been specifically focusing on the use of carbon nanotubes in cancer research. Scientists have been trying to find ways to utilize the amazing properties of carbon nanotubes to fight cancer and to alleviate some of the side effects associated with other cancer treatments, such as chemotherapy

To understand why it is so important to find new cancer treatments and to improve already existing ones like chemotherapy, one must understand the side effects that cancer patients must endure every day. Patients treated with chemotherapy are injected with large doses of medicine to ensure that enough will hopefully reach many of the cancerous cells in the body. Chemotherapy drugs damage any quickly dividing cell. When chemotherapy drugs are simply injected into the body, the drugs cannot distinguish between malignant cells and healthy cells which are also dividing quickly, therefore the drugs, in addition to killing the cancerous cells may damage normal cells as well. Common healthy cells which are damaged during chemotherapy include: the cells of hair follicles, the cells lining the digestive tract, the cells of the skin and mouth, and bone marrow and blood cells. The damaging of these cells is what causes the many awful side effects that chemotherapy patients must experience while undergoing treatment. The damaging of the hair follicles is what causes hair loss. Nausea and vomiting are caused by the damage of the cells lining the digestive tract. The damage of the cells in the skin and mouth causes dryness and sores in the patient's mouth and also dry skin. All of these side effects are awful; however the damage of the bone marrow and blood cells is dangerous [3].

During chemotherapy, bone marrow, which is the liquid inside a person's bones that makes blood cells, may not be able to produce enough cells to allow the body to function properly. Not having enough red blood cells is known as anemia, which causes fatigue and the feeling of being short of breath. White blood cells are what fight off infection within the body; therefore the lowering of the white blood cell count makes a patient more susceptible to disease. Lastly, chemotherapy lowers the platelet count in the body. Platelets are the small specimens that form the blood clots that stop bleeding from cuts or bruises; therefore if there are not enough of them within the body, the cancer patients may bleed too much even from the most miniscule wound. Although chemotherapy is a wonderful tool for the fight against cancer, its side effects are alarming. Fortunately, CNTs may be utilized to help diminish the awful side effects of chemotherapy.

3. Chemotherapy Sensors

Carbon nanotubes have many uses, one of which being the ability to be used as sensors. SWCNTs can act as highly specific electronic sensors for detecting clinically important bio molecules [1]. The sensors can detect chemotherapy drugs as well as toxins and free radicals in the body. These sensors are created by wrapping carbon nanotubes in DNA so they can be injected safely into living tissue. Scientists from MIT have been working on this project and have developed nanotechnology that can be placed inside living cells to determine whether chemotherapy drugs are reaching their targets or attacking healthy cells. The sensors would work by giving off a fluorescent light whenever the nanotubes would come in contact with different agents within the body. The different drugs or agents would change the intensity or wavelength of the light given off by the nanotubes. This would allow doctors to determine exactly what the sensors have come in contact with. This discovery could allow doctors to monitor chemotherapy treatment in patients and to know exactly where the drugs are, and whether or not the drugs are attacking their intended targets [4]. Although knowing whether or not the chemotherapy drugs are reaching the right cells is important, an even bigger step has been made. Researchers at several universities believe that carbon nanotubes may be used not only as sensors, but as drug delivery systems in the future.

4. Chemotherapy Drug Delivery

One way to alleviate the terrible side effects that chemotherapy has on cancer patients is to find a way to better control what cells the drugs attack. By being able to target only the cancerous cells within the body, less chemotherapy drugs would need to be injected into the patient for cancer treatment, thus reducing, if not completely wiping away, the side effects of the chemotherapy drugs. Cancer researchers have figured out a method that better delivers drugs, such as chemotherapy drugs, to cancer cells without damaging surrounding healthy ones, by discovering a way to use single-walled carbon nanotubes as targeted medicinal delivery mediums [4].

It is the single-walled carbon nanotubes' amazing properties which allow it to be such a useful delivery tool. Firstly, their small nature allows them to enter the nuclei of cells freely. For how small they are, their inner volumes are relatively large, leaving enough space to carry drugs into the body. Drugs, however, can also be attached to the tips and walls of the single-walled carbon nanotubes. Moreover, both the inner and outer surfaces of SWCNTs can be easily modified for "functionalization" [2]. This means that the surfaces can be manipulated to function in a specific way for different drugs. Thus single-walled carbon nanotubes can be modified to bind with whatever drug (in this case chemotherapy drugs) they are delivering, while at the same time not changing the properties of the drug. In addition, it is also possible to make their surface compatible with the cancerous areas which they are targeting so that other areas will remain unaffected [2]. Most importantly, single-walled carbon nanotubes are completely safe and nontoxic. Researchers from the University of London, UK, Institute of Molecular and Cellular Biology/CNRS, France, and University of Trieste, Italy conducted research using lab mice to determine whether single-walled carbon nanotubes were safe for use in drug delivery. Kostas Kostarelos, a researcher from the University Of London School Of Pharmacy stated that "Functionalized carbon nanotubes were shown to be cleared from blood circulation and into the urine quite fast as intact nanotubes, in the absence of any appreciable tissue accumulation or organ

function complication” [5]. All of these properties allow SWCNTs to be the perfect candidates for chemotherapy drug delivery vehicles [6]. Scientists at Stanford University have been conducting research on using SWCNTs as drug delivery systems. The scientists at Stanford used the size of their single-walled carbon nanotubes to prevent the chemotherapy drug from reaching healthy cells. The holes in the walls of blood cells within tumors are larger than those within normal cells; therefore the scientists adjusted the size of the carbon nanotubes so that they would fit through the cancerous cells, but were too large to pass through the healthy ones, thus preventing the drugs from damaging normal cells. Also, the scientists did not place the chemotherapy drug within the SWCNT but on the outside. They did this by coating the single-walled carbon nanotubes with polyethylene glycol or PEG. The structure of the PEG compound is that of a trunk with three little branches. The scientists placed the trunk within the SWCNT but allowed the branches to still stick out. The researchers then attached the chemotherapy drugs onto the branches of the nanotubes. After conducting their research, the scientists have received very exciting results. They have noted that the nanotubes allow them to insert up to “10 times as much medication into the tumor cells” [4]. Moreover, the scientists stated that after twenty-two days, the tumors of the mice treated with the single-walled carbon nanotubes drug delivery system were “on average, less than half the size of the mice that were treated traditionally”

5. Other Cancer Treatment Applications

SWCNTs do not only aid in chemotherapy treatment, but in several other innovative cancer treatments as well Ajima, *et al.* [7]. Presently, carbon nanotubes are not only being used as drug delivery systems, but as a means of directly killing malignant cells within the body. Scientists at Stanford University have found one possible way to do this. The scientists first coat carbon nanotubes with folate molecules and then insert them into the cancer patient’s body. The CNTs are coated with folate molecules because cancerous cells, unlike healthy ones, contain receptors for the vitamin folate [8]. Thus the carbon nanotubes will only enter the malignant cells and not the healthy ones. The CNTs are then hit with a near-infrared laser, whose beams pass safely through normal cells. The near-infrared light waves heat up the CNTs, within the malignant cells, “to about 158°F in two minutes” [9]. Thus killing the cancerous cells from the inside out. Because of the folate molecules, this process targets and kills only the cancerous cells within the body, leaving the healthy ones untouched and undamaged [9]. Another way in which scientists are killing cancerous cells is very similar to the one discussed in the previous paragraph. In this case, scientist Balaji Panchapakesan, from the University of Delaware, patented a process in which he uses exploding carbon nanotubes to kill cancerous cells. Panchapakesan wishes to fill carbon nanotubes with water before adding them to the body. Once the water-filled nanotubes enter the tumors (Panchapakesan plans on labelling the nanotubes with an antibody specific to the cancer cell receptors of the tumors, such as folic molecules), they are hit with a laser. The water within the CNTs begins to boil and the resulting rise in pressure causes the CNTs to explode killing the nearby cells [9, 10]. Both of these processes bring about a new way to directly kill cancer cells.

6. Other Medical Benefits

Carbon nanotubes have made an impact on the entire medical field, not just in cancer research. On top of being excellent delivery systems for chemotherapy drugs, SWCNTs may also function as a means of delivering gene therapies and vaccines. Moreover, the CNTs usefulness as a sensor can be utilized in creating things such as heart pacemakers. Lastly, there is a possibility that in the future CNTs may be embedded on tools used in surgery to “aid surgeons by providing specific properties of tissue to be cut and provide information about performance of their instruments during surgery”[11]. All of these applications of CNTs would lead to great advances in medicine in the future undergoing treatment.

7. Sustaining Life

Sustainability is a major issue that is impacting the world today. When most people think of the word sustainability, the first thing that usually comes to mind is environmental issues; however the term sustainability also applies to many other things which are equally important, such as the improvement of humanity. As stated previously within the paper, the most promising applications concerning carbon nanotubes are those pertaining to advancements within the field of medicine. These advancements which are implemented by the use of carbon nanotubes in medical treatments, directly impact the quality of life of patients. The impact of the quality of life of people in society is one form of sustainability, because medical advances prolong life.

One way in which carbon nanotubes sustain life is by utilizing them as drug-delivery systems within the body [10, 12, 13]. The discomfort that chemotherapy patients experience while is a direct result of the drugs not only killing cancerous cells but healthy blood cells as well. The carbon nanotubes ability to directly deliver chemotherapy drugs to cancerous cells would leave all healthy cells unharmed by the drugs. The fact that carbon nanotubes can be utilized as a way to target only malignant cells would greatly diminish the side effects of chemotherapy drugs. Reducing these side effects would in turn improve the health of the cancer patients as well as letting them undergo their treatment more comfortably than ever before. Not only would this application of carbon nanotubes in medicine alleviate the truly awful side effects of chemotherapy drugs that patients currently must endure, but it would also improve their effectiveness. The increase of the effectiveness of the drug would sustain the lives of many cancer patients. If this technology is fully harnessed, chemotherapy patients would experience a vast improvement in their quality of life while undergoing treatment. Another way, in which carbon nanotubes sustain the life of cancer patients, is by using them as direct tools in killing cancerous cells, as explained in one of the preceding sections titled, “Other Cancer Treatment Applications”. If either of the two methods where heated carbon nanotubes are used

to either roast or blow up tumors can be developed for use in humans, the quality of life of cancer patients would greatly improve. Both of these processes were designed to alleviate the side effects that chemotherapy and other cancer treatments cause. These awful side effects such as loss of hair and low white blood cell count (which can lead to infections), as previously stated, are a result of other treatments killing both cancerous cells and healthy cells. However with these recent advancements, doctors in the future may be able to only treat and kill the malignant cells, leaving the healthy ones untouched. If this is so, cancer patients will no longer have to endure as much discomfort as they have had to in the past. Moreover these methods of killing the cancer cells would be more effective than any other treatment before [14, 15]. These possible uses of carbon nanotubes in cancer treatments may lead to vast progression in sustainability relating to the improvement of human life [16] Both of these applications not only hold the ability to improve the quality of life of the patients, but also to prolong their lives.

8. Future Scopes

Researchers, who have been heavily studying cancer for years, might have found the cure they have been waiting for in carbon nanotubes. Single-walled carbon nanotubes have been proven safe and stable to use in inserting and transporting drugs into the body. Though very small, their properties allow them to make a huge impact on the field of science. If advances continue, Single-walled carbon nanotubes may just be the answer to a brighter future for cancer and chemotherapy treatment.

References

- [1] Martin, B., 2006. "practical applications of carbon nanotubes in medicine." *MMG 445 Basic Biotechnology Journal*, Available: <https://www.scribd.com/document/264994699/Practical-Applications-of-Carbon-Nanotubes-in-Medicine>
- [2] Sinha, N., John, T., and Yeow, W., 2005. "Carbon nanotubes for biomedical applications." *IEEE Transactions on NanoBioscience*, vol. 4, pp. 180-195.
- [3] What are the possible side effects of chemotherapy?, 2008. "American Cancer Society." Available: http://www.cancer.org/docroot/ETO/content/ETO_1_4X_What_Are_The_Side_Effects_of_Chemotherapy.asp?sitearea=ETO
- [4] Gaudin, S., 2008. "Researchers use nanotech to target chemo cancer treatment." *Computerworld IDG*, Available: <https://www.computerworld.com/article/2534637/app-development/-smart-bomb--nanoparticles-stop-cancer-s-spread.html>
- [5] Kalaugher, L., 2006. "Carbon nanotubes pass through body fast Nanotechweb.org." Available: <http://nanotechweb.org/cws/article/tech/24223>
- [6] Feazell, R., Ratchford, N., Dai, H., and Lippard, S., 2007. "Soluble single-walled carbon nanotubes as longboatdelivery systems for platinum(IV) Anticancer drug design." *J. Am. Chem. Soc.*, vol. 129, pp. 8438-8439.
- [7] Ajima, K., Yudasaka, M., Murakami, T., Maigne, A., Shiba, K., and Iijima, S., 2005. "Carbon nanohorns as anticancer drug carriers." *Molecular Pharmaceutics*, vol. 2, pp. 475-480.
- [8] Dhar, S., Liu, Z., Thomale, J., Dai, H., and Lippard, S., 2008. "Targeted single-wall carbon nanotube-mediated Pt(IV) Prodrug delivery using folate as a homing device." *J. Am. Chem. Soc.*, vol. 130, pp. 11467-11476.
- [9] Vaibhav, R., 2014. "Carbon nanotubes: An emerging drug carrier for targeting cancer cells." *Journal of Drug Delivery*, vol. 2014, p. 23.
- [10] Alberto, B. and Kostas, K., 2005. "Maurizio prato, Applications of carbon nanotubes in drug delivery." *Current Opinion in Chemical Biology*, vol. 9, pp. 674-679.
- [11] Schönenberger, 2000. "Christian multiwall carbon nanotubes Physicsworld.com." Available: <http://physicsworld.com/cws/article/print/606>
- [12] Hong, X., Long, L., Guohong, F., and Xiangfeng, C., 2018. "DFT study of nanotubes as the drug delivery vehicles of Efavirenz." *Computational and Theoretical Chemistry*, vol. 1131, pp. 57-68.
- [13] Bhirde, A. A., Patel, V., and Gavard, J., 2009. "Targeted killing of cancer cells In vivo and In vitro with EGF-directed carbon nanotube-based drug delivery." *ACS Nano*, vol. 3, pp. 307-316.
- [14] Singh, R., Pantarotto, D., McCarthy, D., Chaloin, O., Hoebeke, J., Partidos, C., Briand, J., Prato, M., Bianco, A., *et al.*, 2005. "Binding and condensation of plasmid DNA onto functionalized carbon nanotubes, Toward the construction of nanotube-based gene delivery vectors." *J. Am. Chem. Soc.*, vol. 127, pp. 4388-4396.
- [15] Moghimi, S. M., Hunter, A. C., and Murray, J. C., 2001. "Long-circulating and target-specific nanoparticles, theory to practice." *Pharmacol Rev.*, vol. 53, pp. 283-318.
- [16] Dai, H., 2002. "Carbon nanotubes, synthesis, integration and properties." *Acc. Chem. Res.*, vol. 35, pp. 1035-1044.