A STEP AHEAD IN CANCER TREATMENT:CARBON NANOTUBES

SRUSHTI SODHA
Department of Pharmaceutical Sciences and Technology
Institute of Chemical Technology, India

Received on December 22, 2013; Revised Manuscript accepted on July 29, 2014

Abstract: Cancer is a disease taking millions of lives worldwide. As of today, various methods have been devised in order to bring this deadly disease under control. Radiation therapy had once gained momentum over chemotherapy, but soon its disastrous side effects turned up. Hence, today we largely depend upon the chemotherapy.

Times ago, drugs had to be used in tremendously large quantities so as to produce some noticeable effects. But, as there have been advancements in newer Drug Delivery Systems, the requirement of drug quantities have decreased, as a result of which the side effects have been brought to control. One such method is discussed herein, which is the use of Carbon Nanotubes as an efficient Drug Carrier.

Introduction

Nanotechnlogy is a branch of science which deals with the '*nano*' scale implementation of basic principles of physics, engineering, electronics and material science. Covering the entire range of composite materials including nanoparticles, quantum dots, dendrimers, etc. it encompasses the entire molecular level applications, including DNA targetting, delivery of peptides, and also serves as a novel tool as sensors, actuators and composites.

One of such extremely efficient and widely explored area of nanotechnology is the use of ***carbon nanotubes*** (CNT). As the name suggests, CNTs are substances of polymeric nature, with a hollow tube shaped structure. Discovered by Iijima in 1991, this allotrope of carbon can be isolated as well as prepared either as single walled or multi walled tube as shown in figure 1. The properties which make CNTs suitable for their application are:

i. High conductivity
ii. Higher Surface Area
iii. Tensile strength
iv. Typical length to diameter ratio upto about 28 000 000:1
v. Potential absorption abilities

The following article deals with harnessing the CNTs as 'Magic Guns' for targeting drug molecules to specific site, in cancerous cells, in tumors.

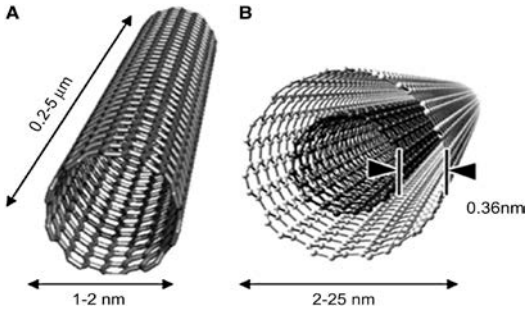

Fig 1. A- Single Walled Nanotube
B- Multi Walled Nanotube

Structure and classification

CNTs belong to the family of Fullerenes (C60). Nowadays, technology has paved ways for development of a wide variety of such subunits ranging from C20s to C70s, called *Graphenes*. These consist of sp2 hybridised carbon rings, with Tensile Strength of about 1GPa (Giga Pascals) and Young's modulus around unity.

These CNTs are further classified as single walled nanotubes (SWNTs) and multiwalled nanotubes (MWNTs), based upon the number of layers present in the cylindrical structure. Both these types differ substancially in **structure** and **function**.

Why CNTs?

The unique properties of CNTs make them ideal carriers for treatment of cancerous cells.

i. Typical structure capable of binding to multiple drug molecules.
ii. Ability to form easy reversible bonds with with drug as well as substrate molecules.
iii. Substrate specificity.
iv. Notable physical properties.
v. Receptive in *Near Infrared* region of light spectrum making it capable of targetting cancer cells without damaging surrounding cells.

By attaching Antibodies to the NanoTubes, cancerous cells can be targetted as shown in figure 2.

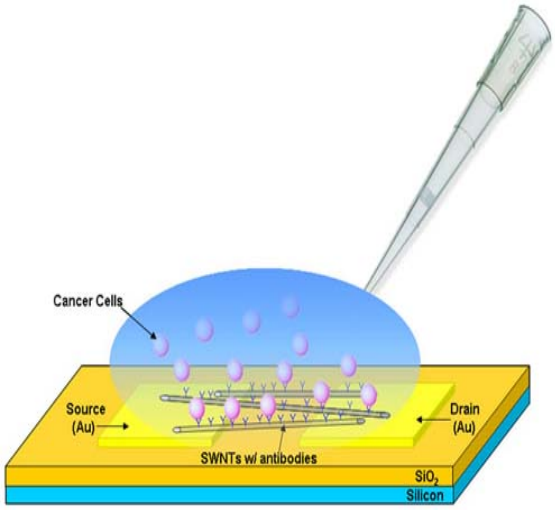

Figure 2. Y-shaped antibodies attached to the nanaotubes,targetting the spherical shaped tumor cells.

Role of CNTs in targetting Cancerous cells

Cancer is typically characterised by the formation and development of **Tumors**.The cells capable of causing such tumors are called '*tumorigenic'* or *'tumoripotent'* cells, or rather as **cancer stem cells** (CSCs). These cells are found to better resistant to drugs than the normal cancer cells, due to increased expression of Multidrug Resistance Proteins. In normal Chemotherapy, a huge mass of tumor is destroyed, if detected at an early stage. However, these CSCs being better resistant may survive. This is the reason for the re-emergence of cancer after a certain period. This is what makes this disease a completely incurable one.

Thus, in order to eradicate the cancerous tumor completely, there are only two ways:

i. Completely destroy the CSCs
ii. Make the CSCs incapable of division and differenciation.

iii. Converting the CSCs into non-CSCs (differenciation therapy).

The Carbon Nanotubes serve as a novel tool in targetting such CSCs. They are biocompatible and supportive substrates. Such advanced drug delivery enhances the efficacy of existing drugs against CSCs. The CNTs can be conjugated with a number of therpeutic and targetting agents, including small molecules, proteins and even genetic materials. They enhance the effect of chemotherapy by suitably delivering the drug to CSCs as well as promoting a better retention of drugs into these cells.

Mechanism of drug delivery

Drugs or biomolecules can be loaded inside the hollow tube or can be directly attached to the walls of CNTs. It has been postulated that the tubes develop a combined Van der Waals force as well as a hydrophobic interaction force, where the Van der Waals force is dominantly more important for insertion of drug molecules. The special characteristic that makes nanotubes promising drug delivery carriers is their hollow monolithic structure having an outer and inner core, which can be modified by the method of functionalization with desired groups on the outer and inner areas. This helps in insertion of required drug molecules in the inner core environment while the outer surface can be modified for achieving biocompatibility and biodegradation.

Paclitaxel conjugated with CNTs

SWNTs used for *in vivo* tumor supression in mice.

Conjugate PTX (Paclitaxel), a widely used chemotherapy drug, to branched polyethylene glycol chain, via a cleavable ester bond to obtain a water soluble SWNT-PTX conjugate. Thus, the drug molecules can be carried into reticulo-endothelial systems. They are released from SWNTs and excreted via biliary pathway. This mechanism not just facilitates efficient drug delivery and high treatment efficacy, but also ensures minimum side effects and treatment with low drug doses.

CNTs in Radiaion Therapy

Recently, Stanford University disclosed a newer applicative advantage, that the CNTs have their own cancer-curing properties.

CNTs are recptive at the near infrared region of the electromagnetic spectrum. An alternative way of mass destruction of tumors is through radiation therapy, in which the tumor is subjected to infrared radiation. The CNTs generate heat in response, and heat upto about a hundred degrees celsius in a very few seconds. The tumor can be thermally destroyed.

Conclusion

Carbon Nanotubes greatly help in treating cancer, and are toxicologically safe. In classical chemotherapy, along with tumor cells, there is a mass destruction of surrounding cells.Targetting using nanutubes make chemotherapy more specific at low drug doses.

However, much more development in this sector is desired. May be, a better biological and chemical understanding of drug resistance of cancerous cells, as well as a technological approach towards increasing

the target specificity of CNTs may altogether destroy cancer, making it a completely curable disease.

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