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Nano Biomedical Applications of Carbon Nanotubes

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Abstract-Recent progress in synthesis and characterization of carbon based nanostructured materials has demonstrated tremendous development in the field of devices used in almost every field of engineering. Carbon Nano Tube (CNT), an allotrope of carbon is one of the most probable candidate for use in nanoscale paradigm. In this paper, various applications of CNTs in the field of Biomedical engineering have been discussed.

***Keywords*:** Carbon Nano Tubes, Functionalized CNTs, Biosensors**,** Targeted drug delivery.

1. INTRODUCTION

Continuous miniaturization of electronic components and circuits has been instrumental in improvisation of systems in all fields. With the advances in technology, it has become possible to fabricate and study the nano scaled quantum systems. The silicon based transistors are no longer shrinking and the circuits based on them leaks current and gets hot. Carbon based nanostructures with high tensile strength and good thermal and electrical properties have become the prominent material in all disciplines. Various materials have been studied for use in electronics but Carbon Nano Tubes (CNTs) have raised expectations in number of different applications. CNTs, an allotrope of carbon that are hollow carbon tubes having diameter in nanometer scale and length in microns to few centimeters. These are the graphene sheets rolled up with continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons. These CNTs have varying structures differing in length, thickness, types of helicity and layers of graphene sheets. CNTs can be categorized as Single Wall Nano Tubes (SWNTs) with single layer of graphene sheet and diameter of 1nm to 20 nm and Multiwall Nano Tubes(MWNTs) having multi wall concentric cylinders of graphene sheets having diameter upto 50 nm.[1,2]

Though formed with the same lattice structure the CNTs can behave as metals or semiconductors depending upon the orientations of the carbon atoms. There are three different confrontations in which these carbon atoms can be placed i.e. arm chair, zig-zag and chiral. CNTs exhibits extra ordinary properties of high mechanical strength, low weight, excellent thermal and chemical properties, high surface area and electrical, electronics and optical properties.

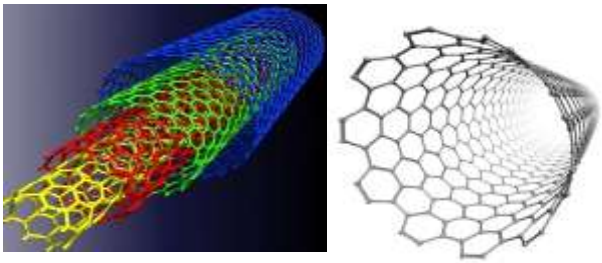

Fig 1. MWNT and SWNT

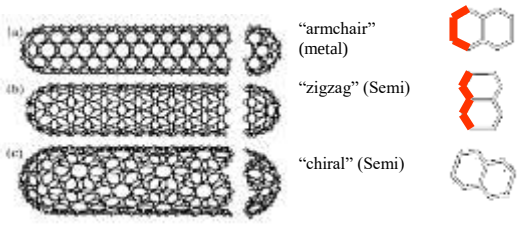

Fig 2. Different confrontations of CNTs

Owing to their unique features CNTs present exciting opportunities for scientific, research, industrial and commercial applications. Ever since its discovery ,researchers have been exploring its potential in biomedical

applications. These applications include use of CNTs in energy conversion devices, nano probes, nano biosensors, actuators, bio markers(quantum dots) and bio imaging.

2. FUNCTIONALISED CNTS(*f*-CNTs)

CNTs individually are chemically inert and incompatible with almost all organic and inorganic solvents. So CNTs are being functionalized in which various functional groups are placed at the tips and around the sidewalls of CNTs[3]. Functionalized CNTs have improved surface properties for enhanced dispersion, solubility, biocompatibility ; thereby reduces cytotoxicity in biological systems for biomedical applications. Different methods that can be used for functionalization of CNTs are

2.1 Covalent Functionalization: In this method various chemical groups like COOH, OH and CO are covalently attached with CNTs that increases the oxygen content of the CNTs and decreases their cytotoxicity.

2.2 Non Covalent Fuctionalization: CNTs are non covalently interact with various molecules through weak interactions such as surface adsorption onto the sidewalls of the CNTs , π-π stacking , electrostatic interactions, hydrogen bonding and vander walls forces . [4]

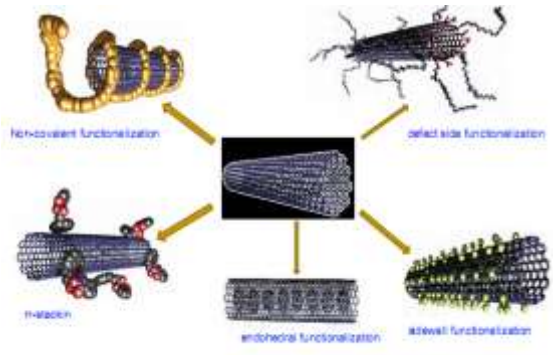

Fig 3. Different types of CNT functionalization

π-π stacking occurs between proteins and CNTs which have been found very beneficial in biosensor fabrication, drug delivery and cancer therapy.

3. APPLICATIONS OF CNTS IN BIOMEDICAL ENGINEERING

CNTs have numerous scope in the field of biomedical engineering. CNTs are playing a major role in existing and future applications in biomedical industry. In this paper few applications of CNTs in bio medical field have been discussed and their role in detection and curing the diseases have been studied. Various applications of CNTs are:

3.1 Diagnostic Tools And Devices: The traditional method of generating X-rays based on thermoionic emission has the limitation of slow response time , limited lifetime, and consumes high energy. Recent research has reported that field emission is better mechanism than thermoionic emission [152 153] and CNTs having high melting point and low work function can be used as cathode in field emitters. The advantage of CNT based X-ray devices are fast response time, fine focal spot, low power consumption possible miniaturization, longer life and low cost.[6]

3.2 Atomic Force Microscopy (AFM): AFM has been widely applied to investigate surface topographies at the nano scale. CNTs can be attached to the tip of AFM probe to make the tip sharper. This allows much higher atomic resolution of the surface under investigation. Also the flexibility of the CNTs prevents damage to the sampled surface and the probe tip if the probe tip happen to crash into the surface.[7]

3.3 CNT Sensors: CNT pressure or stress sensors are basically amperometric biosensor and are also based on the principle that nano tube experience a change in electric resistance when experience stress or strain. This peizo resistive effect changes the current flow through the nano tube, which can be measured to quantify the applied stress. Peizoresistive pressure sensors made by incorporating CNTs can bring drastic change to the biomedical industry. These pressure sensors can be helpful in kidney dialysis, blood pressure monitoring, eye surgery and respiratory devices. CNTs sensors can be used as to check the level of cholesterol, sodium, glucose and other ions in the blood stream in the body[7-9,16].

3.4 Quantum Dots: Quantum dots are basically functionalized CNTs in which the molecules with fluorescent characteristics are attached. To detect the unhealthy cells, CNT based quantum dots bound themselves to sequences of DNA that are associated with the disease. When the quantum dots are stimulated with light, they emit their unique bar codes, or labels, making the critical, diseases-associated DNA sequences visible. The diversity of quantum dots create many unique labels, which can identify numerous regions of DNA simultaneously. Another advantage of quantum dots is that they can be used in the body, eliminating the need for biopsy.

3.5 Targeted Drug Delivery: CNTs possess unique structure that brings opportunities for improved and fast diagnosis of the diseases and targeted drug delivery. CNTs being in the nano meter scale are small enough to enter directly into cells and hence very beneficial in targeted drug delivery and therapies**.** In case of cancer treatment, the chemotherapy, not only kills the infected cells but also affects the healthy cells.[4] Through targeted drug delivery drugs will be punctured into the targeted cells. The CNT based drug delivery has not only been experimentally demonstrated at the cellular level, but also applied for the treatment of cancer in animal models [10-12]. CNTs based targeted drug delivery has applications in field of cancer treatment, AIDS treatment, gene delivery and vaccine delivery.

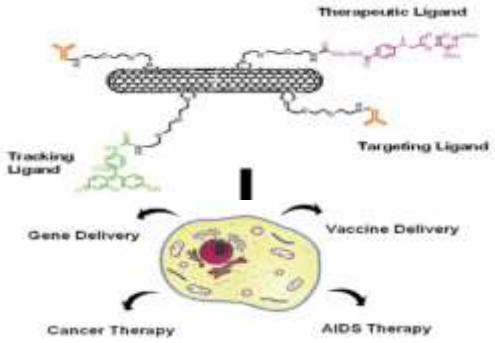

Fig 4. CNTs for drug delivery to therapies

3.6 Tissue Engineering: CNTs have been reported as a promising material in tissue engineering. CNTs are used for preservation of cells , delivery of growth factor and promote integration with the host tissue and are used in scaffolding the bone tissue engineering applications. The extraordinary ability of CNTs to reinforce polymeric composites is due to its high surface to volume ratio[8].

4. CONCLUSION

This paper reviews the features of carbon nano tubes and its potential applications in the field of biomedical engineering. The cytotoxicity of the CNTs can be reduced through various methods of surface functionalazations. The exceptional physical, mechanical, and electronic properties of CNTs allow them to be used in sensors, quantum dots, actuators, nanoelectronic devices, and drug delivery systems within biomedical applications. With the increasing interest shown by the nanotechnology research community in this field, it is expected that plenty of applications of CNTs will be explored in future. At the same time, it is believed that the continued development and application of CNTs can enhance the practice of biomedical industries.

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