Chapter 30
DNA Computing Using Carbon Nanotube-DNA Hybrid Nanostructure

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ABSTRACT

DNA computing is a branch of biomolecular computing using the physical and chemical properties of deoxyribonucleic acid or DNA. It is a fast-developing interdisciplinary research area consisting of nano-biotechnology, computer science and biochemistry. DNA computing is widely used now-a-days for logic design, biomarker, cryptography, disease detection etc. In recent years, carbon nanotube or CNT research has reached a new peak with its various applications including nano-biocomputing. DNA plays a pivotal role in biology and CNT is considered as a wonder material of this century in nanoscience. This chapter combines these two promising research areas including CNT and DNA to form CNT-DNA based nanostructured system and its applications in diverse fields like electronics, biomedical engineering, drug delivery, gene therapy, biosensor technology etc. CNT-DNA hybrid and its various suitable combinations open up a new dimension called CNT-DNA computing.

INTRODUCTION

In 1994 Leonard Adleman of University of Southern California put his first step in the field of DNA computing (Liu, 2000) by solving the Hamiltonian path problem (Adelman, 1994). CNTs are extremely sensitive for molecular detection (Valentini, 2004) for their large aspect ratio. Needle-like tip of the tube and surface property of CNT enable it to penetrate the plasma membrane (Chen,1994) of cell and help

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to act as a delivery system (Khaled, 2005; Singh et al, 2006; Singh 2014; Gentschev, 2000, 2001)) of different types of therapeutic molecules (Bianco, 2004), DNA, siRNA to the target cells (Fortina, 2005). In nanomedicine, synergistic approach of CNT-DNA (Khusenov, 2014) has opened up a new avenue (Tardani, 2014) for the treatment of different diseases (Frusawa, 2015) including cancer detection (Elhissi, 2011; Jabir, 2012) and treatment (Ali-Boucetta, 2013; Liu, 2011; Liu, 2012). Furthermore, in targeted gene therapy, controlled release of designed genes or DNA (Rajaee, 2014; Kolosnjaj, 2007; Corredor, 2013) to the diseased cells can be achieved due to the remarkable optical and electrical properties of CNT (Cheung, 2010). Owing to the strong base pairing rule the base sequence of single-strand (ssDNA) DNA (Chaves,2014) attached over CNT can recognize their complementary sequence and bind together to form the helical structure of double-strand (dsDNA) DNA (Wu, 2015). In 1982, Nadrian C. Seeman first established an idea of DNA nanotechnology (Seeman, 1982, 2004). This technology provides us an unprecedented opportunity to fight against various diseases by designed nucleic acid sequences. Apart from the diverse applications in biomedicine, CNT-DNA nano-hybrid structure finds its use in CNT-DNA computing also. In Biology, genetic information are passed from generation to generation through DNA in living cells while in DNA computing, DNA is considered to be a non-biological engineering nanomaterial (Amir, 2014). Nowadays DNA computers (Borush, 2015) are widely used for simulation procedure. Computer data storage capacity can be increased using human DNA (Alaudeen, 2015). For ternary computing, DNA as a functional material using of three-valued oligonucleotide inputs is introduced recently (Orbach, 2015).

CARBON NANOTUBES: STRUCTURE, PHYSICAL AND CHEMICAL PROPERTIES

A nanotube is a tube-like hollow structure measured in nanometer scale. Sumio Iijima discovered carbon nanotubes in 1991. Graphite and diamond are the common allotropes of carbon. But in recent years, the third allotropic form of carbon, the CNTs, have been found. They are the members of the fullerene structural family and are formed of one-atom-thick sheet of carbon which is pie-stacked and sp^2 bonded, called graphenewhich is folded to form a tubular structure. CNTs are considered to be the most promising material in nanoscience due to their interesting physical, chemical, electrical and thermal properties.

Based on their structure, CNT exhibits two morphological forms – single walled carbon nanotube (SWCNT) and multi walled carbon nanotube (MWCNT). Each nanotube form a rope-like structure supported by van der Waals (vdW) force of attraction. Diameters of SWCNTs are about 0.4-2.0 nanometer and the tube length may be of several hundred nanometers to several micrometers (Cheung, 2010). SWCNT, as shown in Figure 1, is represented by a mono-layer of tubular graphene sheet. MWCNTs have diameter of about 2-100 nm. Several concentric tubes of sheets of graphene in the form of multiple layers constitute MWCNT (Sinha, 2005).

Different forms of nanotubes with different diameters and chirality can be achieved by rolling the graphene sheet of SWCNT in various ways. The way of graphene sheet rolling is shown in Figure 2. CNTs exist in three forms depending on chiral vectors which describe the two-dimensional direction along which a nanotube is formed by rolling a graphene sheet. The graphene lattice vector or chiral vector is represented by n and m indices. In metallic form of nanotubes, the relation between two indices are n=m or n-m as a multiple of 3. Other group of CNTs are semiconductor in nature (Charlier, 2007; Wilder, 1998).The three chiral forms of nanotubes are chiral where $n \neq m$, zigzag in which n=0 or m=0