ISSN 1512-1232

STUDY OF NANO DEVICE FOR EFFECTIVE DETECTION, DIAGNOSIS AND TREATMENT OF CANCER

[1]E.N.Ganesh, [2] R.Kaushik Ragavan, [3]Bandyopadhyay Arka Prava [4]M. Krishna Kumar
[1]Professor, Rajalakshmi Engineering College, Thandalam,Chennai - 602105, Tamilnadu, India
[2,4] Student Rajalakshmi ENGG Coll, Thandalam, Chennai-602105
[3]PhD Student, Department of Mathematics, Louisiana State University, Baton Rouge, LA-70820

Abstract

This paper gives detailed study of different Nanodevices used for detection, diagnosis and treatment of cancer cells. Nanodevices like cantilevers, Nanopores, Nanotubes, Nanoshells, Quantum dots and Dendrimers are studied. This paper compares all the devices and gives the effective way to eradicate the cancer cells. This gives motivation to compare function and characteristics of all the devices and their utilization for eradication of cancer cells.

1. *CANTILEVERS are Nano device anchored at one end and can be engineered to bind the molecule that represents some of changes associated with cancer cells. Here the property of surface tension that changes causing cantilever to bend.*
2. *NANOPORES are useful for reading genetic code and detect errors in genes that may contribute to cancer. As DNA passes through Nanopore the shape and electrical characteristics of the cells are studied..*
3. *CARBON NANOTUBES are carbon rods about half the diameter of a molecule that can only detect the presence of altered genes.*
4. *QUANTUM DOTS are tiny crystals that glow when simulated by UV light. Each bead emits light that serves as a sort of spectral bar code which identifies cancer cells. Here the optical properties are studied*
5. *NANOSHELLS are miniscule bead coated with gold. Nano shells are used to detect and also eradicate cancer cells.*
6. *DENDTRIMERS are man made molecules about size of average proteins and having branching shape. Dentrimers are used to link treatment with detection and diagnosis of cancer cells.*

It was concluded that devices like NANOTUBES, NANOPORES, CANTILEVERS are used to detect the cells in effective way. Devices like NANOSHELLS used to eradicate cancer cells and DENDIRMERS are used for diagnosis purposes. A detailed comparison also made for subsequent study.

Introduction

Nanotechnology is the creation of useful materials, devices and systems through the manipulation of matter on this miniscule scale. There are many interesting nonodevices being developed that have a potential to improve cancer detection, diagnosis and treatment. Nanostructures can be so small that the body may clear them too rapidly for them to be effective in detecting or imaging. Larger nanoparticles may accumulate in vital organs, creating toxity problems. This means that nanoscale devices can enter calls and organelles inside them to interest with DNA and proteins. Tools developed through nanotechnology may be able to detect disease in very small amount of cells or tissue. They may also be able to enter and monitor cells within living body.

Currently detection and diagnosis of cancer usually depend on changes in cells and tissues that are detected by a doctor's physical touch or imaging expertise. We would like to make it possible to

ISSN 1512-1232

detect earliest stages, we must be able to detect earliest molecule changes. In order to successfully devect cancer at its earliest stages, we must be able to detect molecular changes even when they occur only in a small percentage of cells. So necessary tools must be extremely sensitive. Many technology tools will make it possible for clinicians to run tests without physically altering the cells or tissue they take from a patient and also we can capture and preserve cells in their active state. In this paper the properties need to design for some of the nanodevices carbonnanotube, dendrimers, cantilevers, nanopores, nanoshells and qdots. Structure of the some of the nanotubes are simulated.

I CARBON NANOTUBE

It consists of long thin cylinder layers of carbon (graphite) layers of carbon atoms. The atoms are arranged within the layers at the corners of hexagons, which fills whole plane structure. The carbon atoms are strongly bound tjo each other. To build a nanotube, one single layer from the graphite sheet is stacked and wrapped into a cylindrical shape. This is done by cutting a slice and wrapped into a cylinder (atoms at the left and right edges of plane must be mapped). There are two types of carbon nanotubes. SINGLE WALLED CARBON NONOTUBE is a one-layer carbon nanotube of two-dimensional graphite end up with cylindrical structure of single wall. MULTIPLE WALLED CARBON NANOTUBE is more layers of graphite sheet end up with multiple walls.

Atoms are arranged in ZIGZAG and ARMCHAIR format.

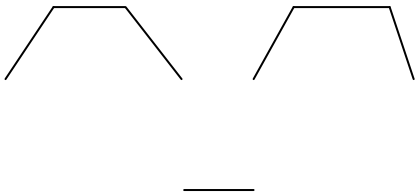

Fig 1 armchair format

Fig 2 Zig zag format

PROPERTIES OF CARBON NANOTUBE

1. Given CHIRAL VECTOR (N,M) EX (10,10) ARMCHAIR TUBE
   Diameter of tube1.2nm, Carbon bond length – 1.42 A^o (spires and brown etal)Overlap energy 2.5 ev (wilderetal), Lattice constant - 17 A^o , density – 1.40 g/cm^3, spacing between atoms 3.39A^o
2. HUMO / LUMO taken 0 ev, energy gap 1.7 to 2.0 ev (odom etal)
3. Thermal Conductance – 1/12.9 $k\Omega^{-1}$ (lombert and tamsfield etal),
   Resistivity – $10^{-4}\Omega$ - cm at 300^oK (Thess etal)
4. Conductivity – 10^7 A / cm^2 (frankeetal)
5. Young's modulus – 1 Tpa, Tensile strength – 30 gpa (yu etal)
6. Carbon bond length – 1.42 A^0, overlap energy – 2.5ev, Lattice constant – 17 A^0
7. Thermal conductivity – 1800 – 6000 w/m-k, carrier life time – 10e-11 sec.

ISSN 1512-1232

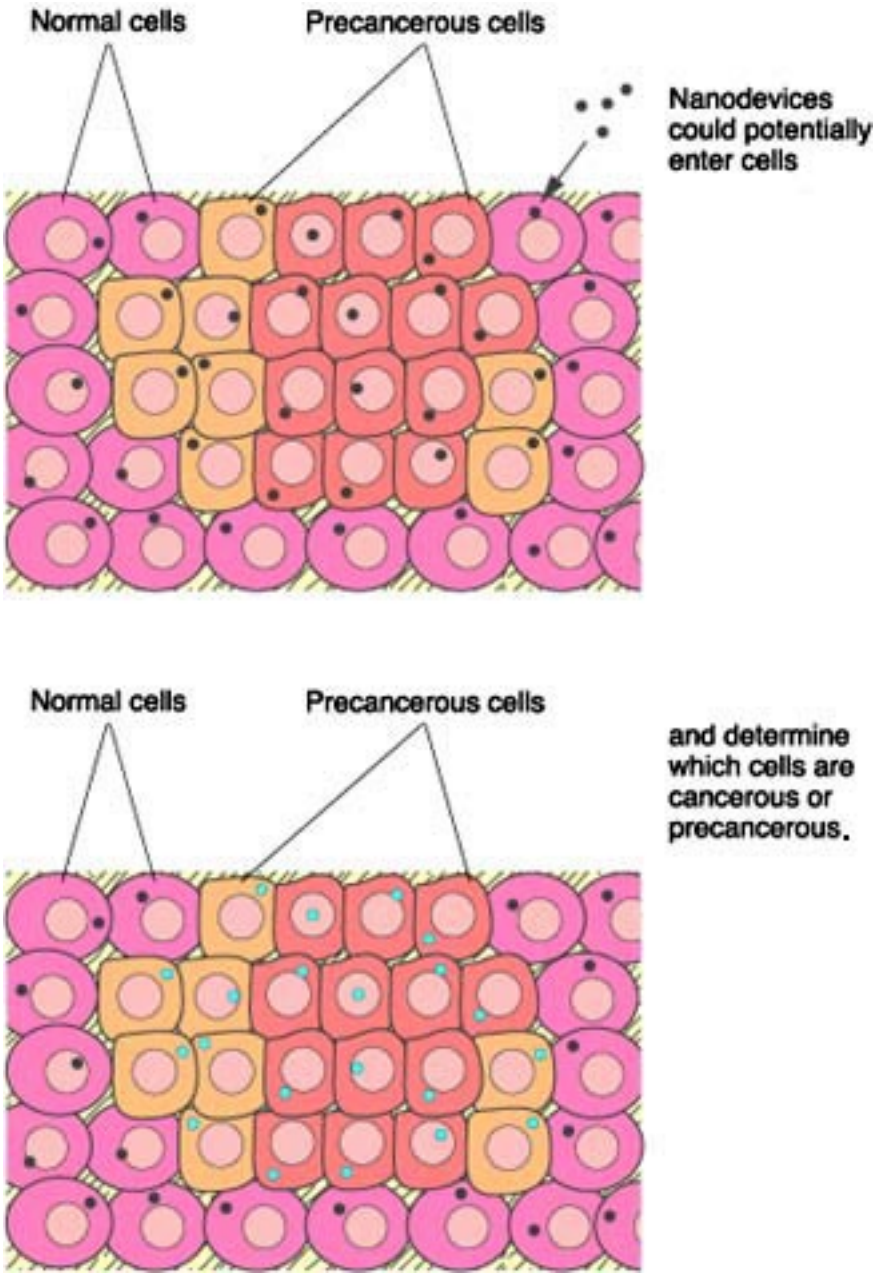

Figure 3 – DIFFERENCE BETWEEN NORMAL CELLS AND CANCER CELLS
Courtesy : Press2.nci.nih.gov/sciencebehind/nanotech

Nanotubes – Mapping Mutations

Once the mutation has been tagged, researchers use a nanotube tip resembling the needle on a record player to trace the physical shape of DNA and pinpoint the mutated regions. the nanotube creates a map showing the shape of the DNA molecule, including the tags identifying important mutations. Since the location of mutations can influence the effects they have on a cell, these techniques will be important in predicting disease. The following diagram Fig - 4 shows that how carbon nanotube used to predict the cancer treatment.

ISSN 1512-1232

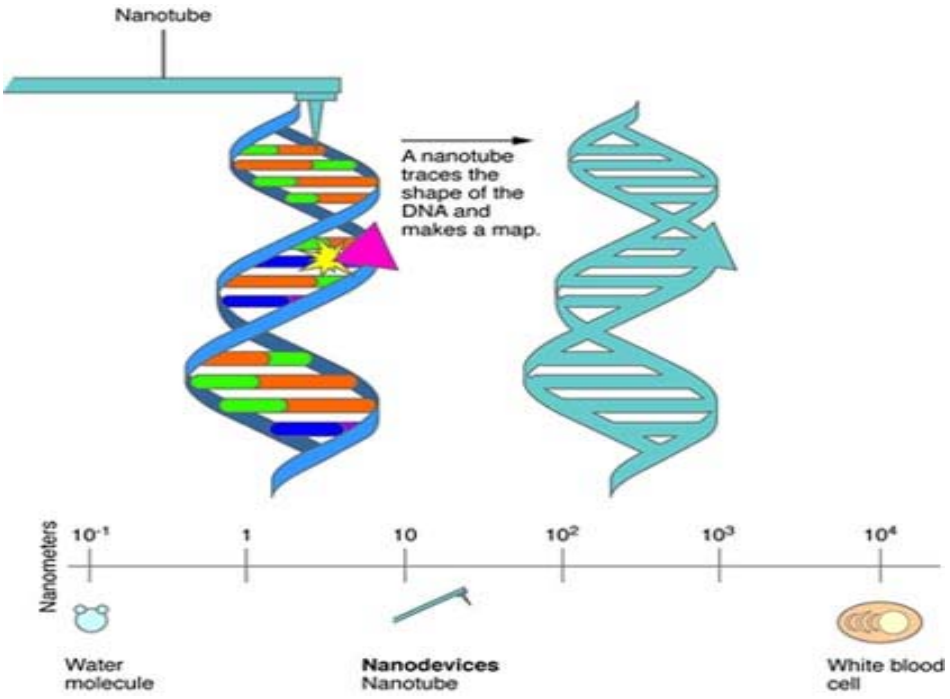

Figure 4 – Nano tube for predicting mutation of DNA shape
Courtesy: Press2.nci.nih.gov/sciencebehind/nanotech

Here the following diagrams give the simulated results for the structure of carbon nanotube. These devices can be used for cancer detection.

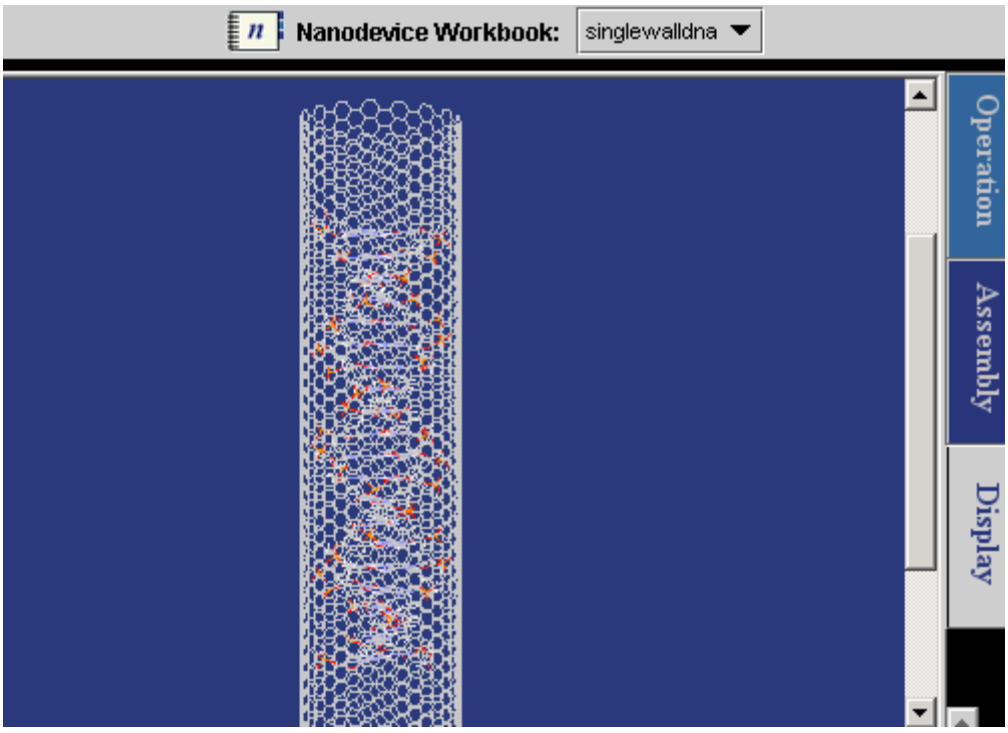

Figure 5 – structure of single wall carbon nanotube with DNA inside simulation of software nanoxplorer

ISSN 1512-1232

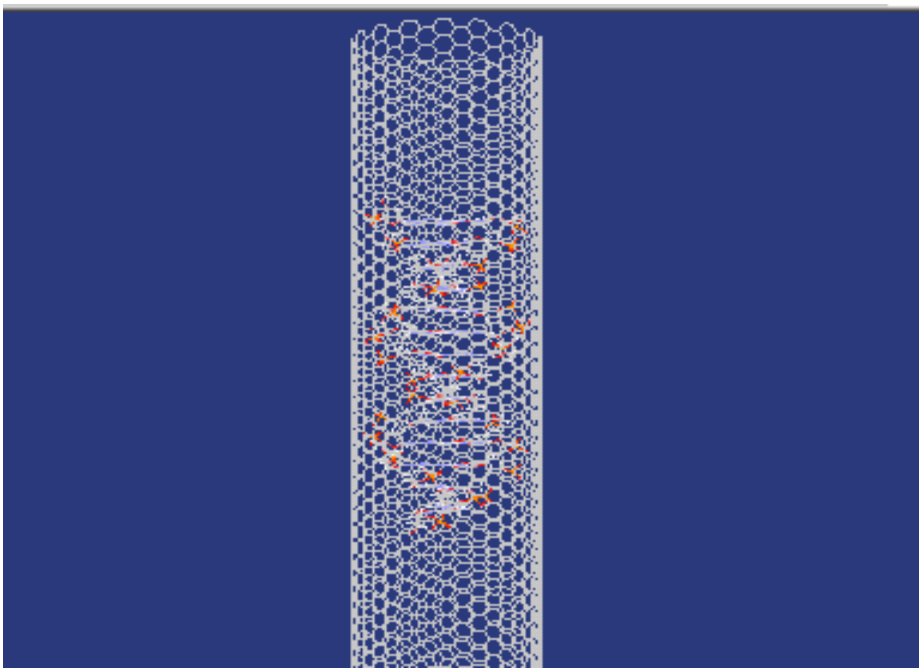

Figure 6 – single wall carbon nanotube with armchair format

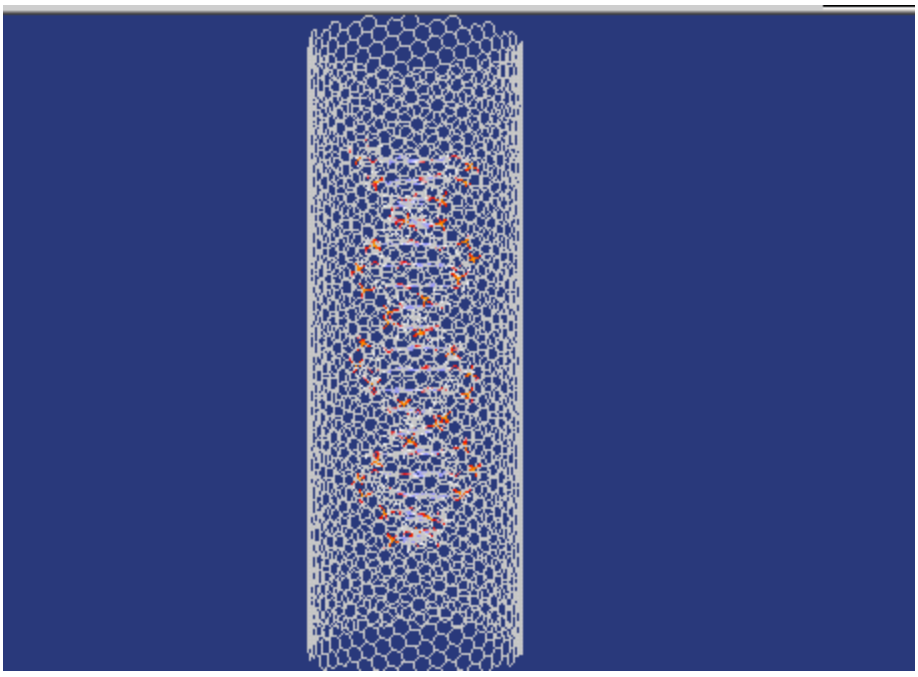

Figure 7 – single wall carbon nanotube with zig zag format

ISSN 1512-1232

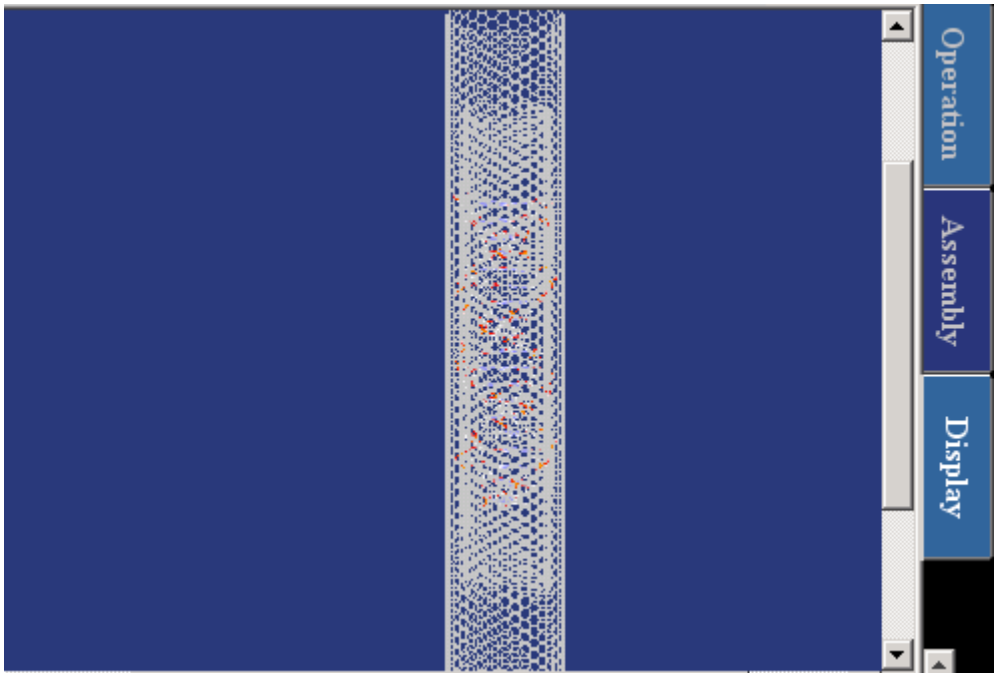

Figure 8 – multiwall carbon nanotube with armchair format

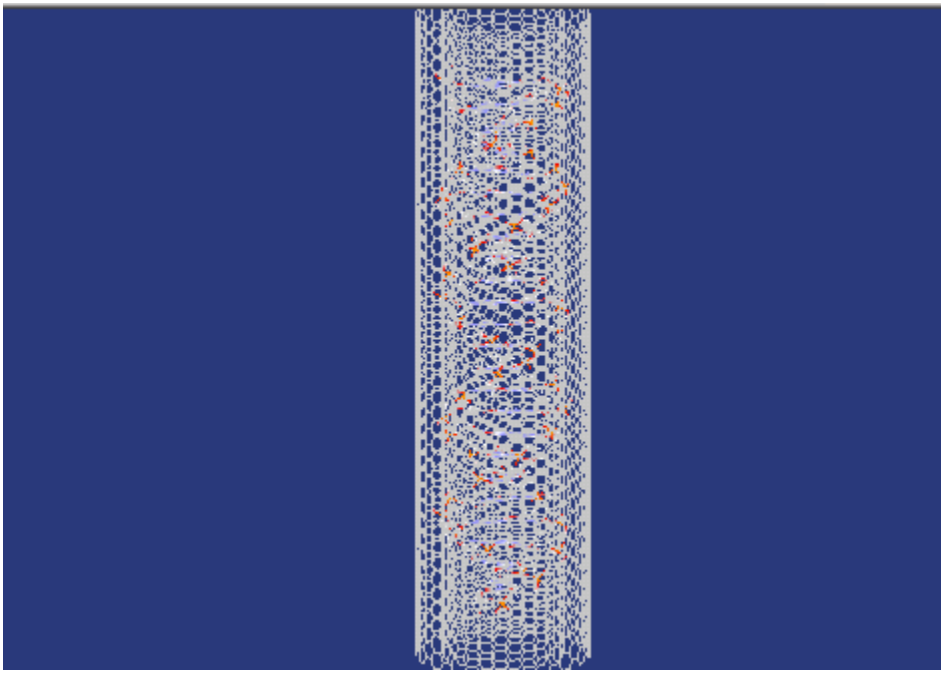

Figure 9 – multiwall carbon nanotube with zigzag format

EXPLANATION: Figure 5 gives the adequate structure of single wall carbon nanotube with DNA inside. Figure 6 gives single wall carbon nanotube for armchair format. Figure 7 gives single wall carbon nanotube for zigzag format. Figure 8 gives multiwall carbon nanotube for armchair format and Figure 9 gives multiwall carbon nanotube for zigzag format. All the above structures simulated in NANOEXPLORER software tool downloaded with the permission of nanotitan corporation. The tool is evaluation version. The working and communication of nanodevices can be carried out using the above tools. Still it gives appropriate properties for single wall carbon nanotube only. Yet the windows version to be released with full software. The present software gives only the structure and its appropriate properties only.

ISSN 1512-1232

It was conluded that the carbon nanotube device tag is yet to be designed for cancer detection and its working will be carried out by releasing next nanotitan version.

II DENDRIMERS

Dendrimers are spherical polymeric molecules. Dendrimers and proteins differ in that proteins are polymers made from 20 different monomers, while dendrimers are polymers made from two monomers: acrylic acid and a diamine. Dendrimers consist of a series of chemical shells built on a small core molecule. Each shell consists of two chemicals, always in the same order. Dendrimers are branching molecules with the branching beginning at the core. Depending on the core, the dendrimer can start with 3 to 8 (or more) branches, with 3 and 4 being the most common number. Starting from the core, the dendrimer consists of long chains of atoms with a branch point about every half dozen atoms. At each branch point, the current chain of atoms becomes two chains of atoms. The molecular structure has the form of a tree with a great number of branches. The name "dendrimer" is derived from the ancient Greek word "dendron" (tree), and from the Greek suffix "-mer" (segment).

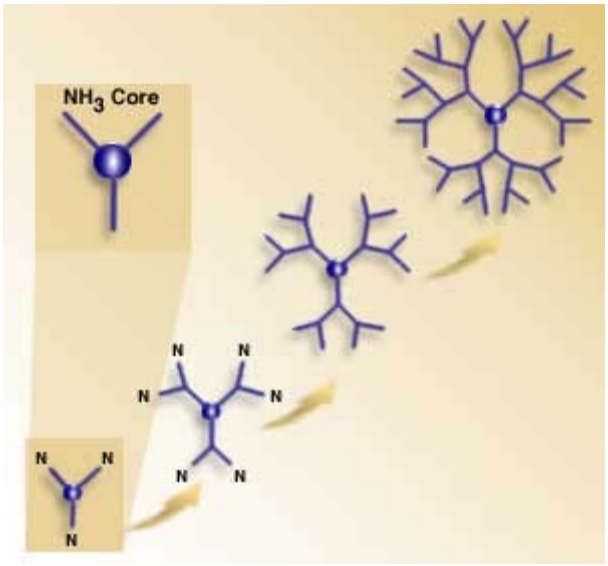

Figure 10 – Structure of DENDRIMERS

The above diagram shows the structure of DENDRIMERS.

CANCER TREAMENT : A single dendrimer can carry a molecule that recognizes cancer cells, a therapeutic agent to kill those cells, and a molecule that recognizes the signals of cell death. Researchers hope to manipulate dendrimers to release their contents only in the presence of certain trigger molecules associated with cancer. Following drug release, the dendrimers may also report back whether they are successfully killing their targets. Fig 11 shows how dendrimers are used to find cancer cells with certain trigger.

ISSN 1512-1232

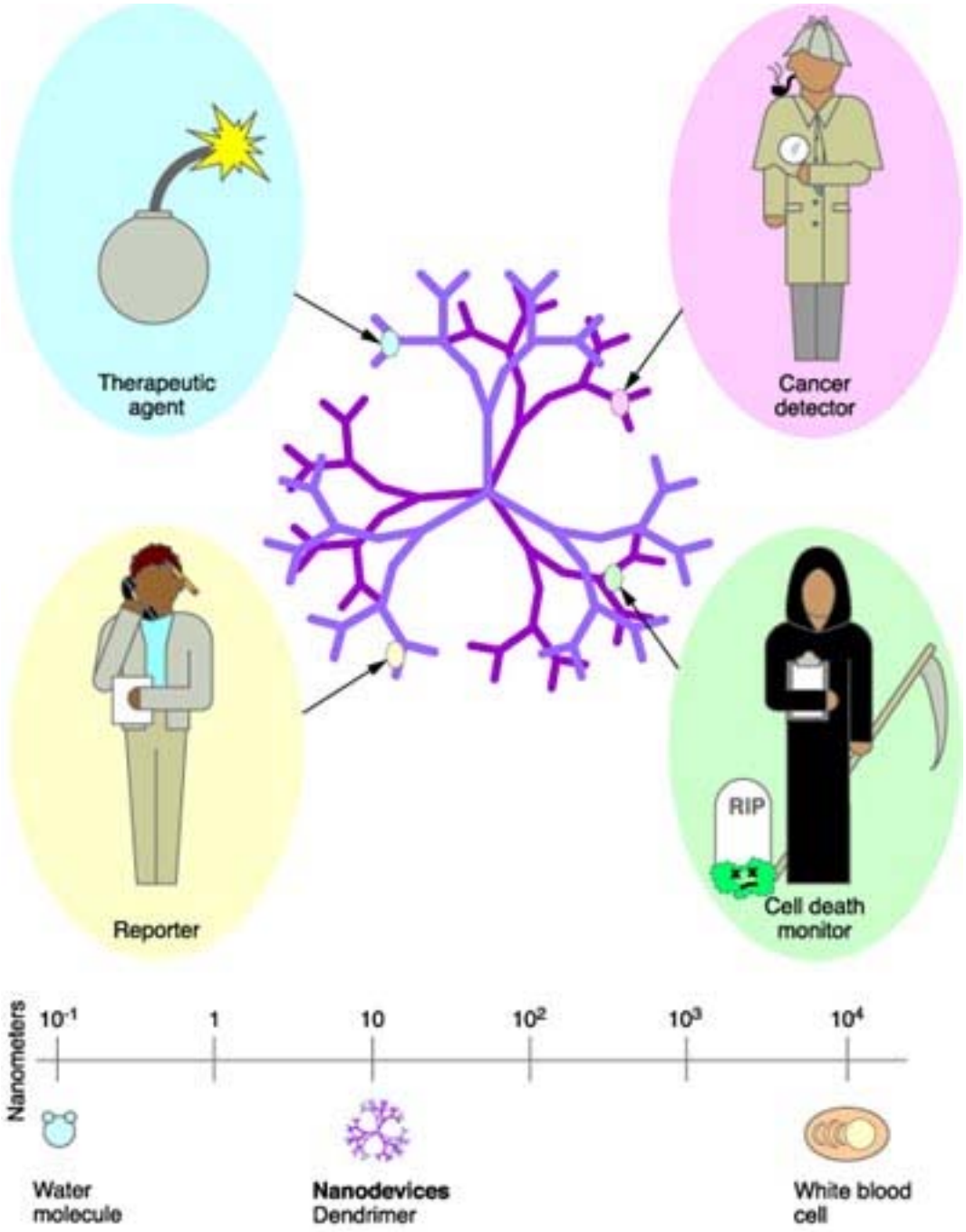

Fig 11 - Figure shows Dendrimers carries cancer cells with certain tag

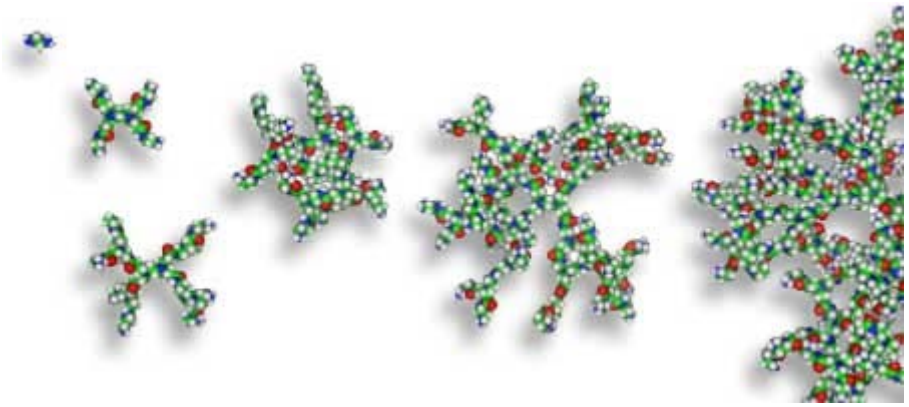

Fig 12 – strucutre of dendrimers

ISSN 1512-1232

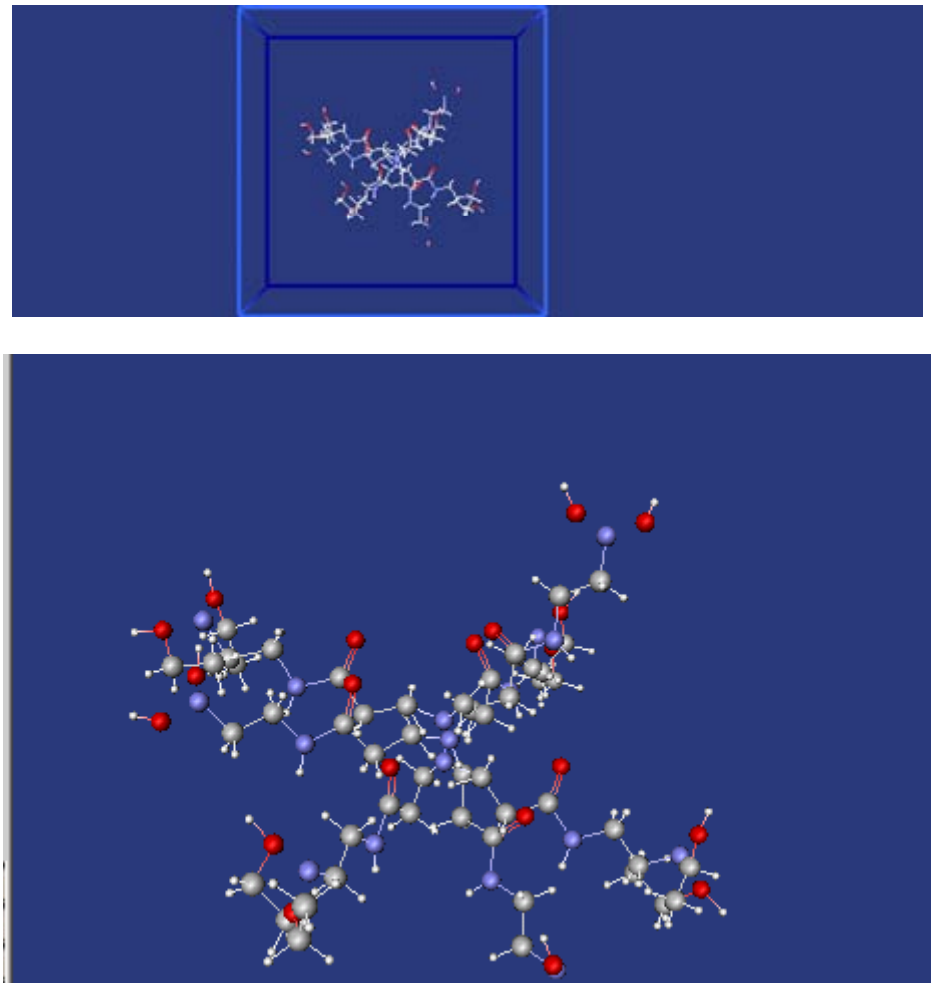

Fig 13 a – Simulated structure of dendrimers, 13 –b Dendrimer structure with 2D view with acrylic acid and diamine molecule

The above diagram simulated using nanoxplorer tool. This may be useful for constructing.

PROPERTIES : For PAMAM dentirmers

Mass – 1st generation – 1024 / nm^3 no of terminal groups 6 (goes up to 3024 terminal).

Diameter – 124 A^0 / 6024 monomer units, shape –asymmetric shape with open structures.In general 9nm diameter and 2nm thickness.

III CANTILEVER

One nanodevice that can improve cancer detection and diagnosis is the cantilever. Cantilevers can make cancer tests faster and more efficient. These tiny levers, which are anchored at one end, can be engineered to bind to molecules that represent some of the changes associated with cancer. They may bind to altered DNA sequences or proteins that are present in certain types of cancer.

When these molecules bind to the cantilevers, surface tension changes, causing the cantilevers to bend. By monitoring the bending of the cantilevers, scientists can tell whether molecules are present. Scientists hope this property will prove effective when cancer-associated molecules are present--even in very low concentrations--making cantilevers a potential tool for detecting cancer in its early stages.

ISSN 1512-1232

STRUCTURE :

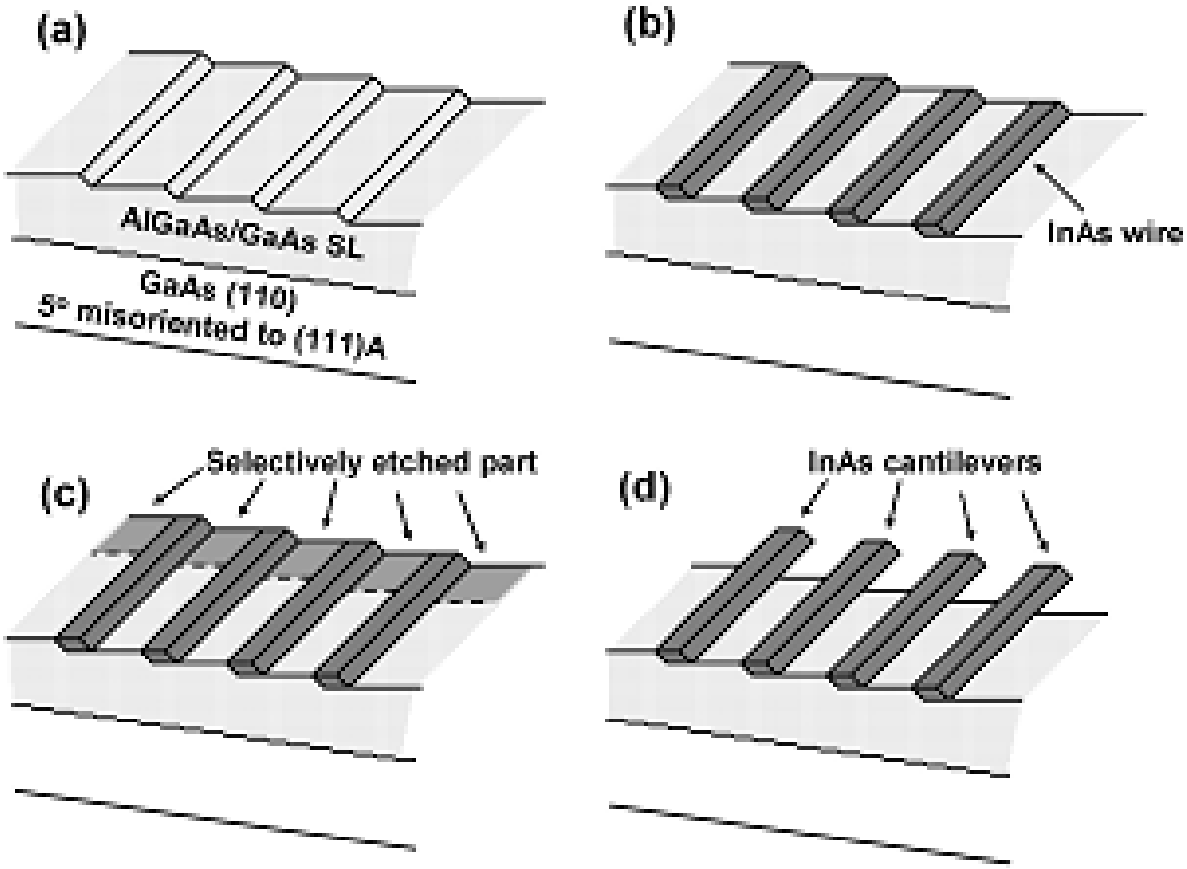

Fig 14 – schematic illustration of fabrication of cantilevers.
Courtesy : Hiroshi Yamaguchi and Yoshiro Hirayama NTT Basic Research Laboratories

InAs cantilevers are fabricated on GaAs substrate. Here GaAs (110) wafers are taken (111) direction. A 100nm GaAs layer and 30nm thick is taken, 5nm thick InAs then deposited resulting in the formation of InAs along the bunched steps. After formation photo-lithographic patterning is done and selective etching also preferred over this layer.

PROPERTIES : Thickness of cantilever – 30nm

Force / elasiticity - 0.5 to 10 N/m (spring constant), Resonant frequency – 30 to 500 MHz, Length – 100 nm, Step size $20A^{o}$, Min radius – $50A^{o}$

CANCER DETECTION

The diagram shown below describes how cancer is detected, when there is change in surface tension of molecules, cantilever bends that recognizes presence of cancer cells.

ISSN 1512-1232

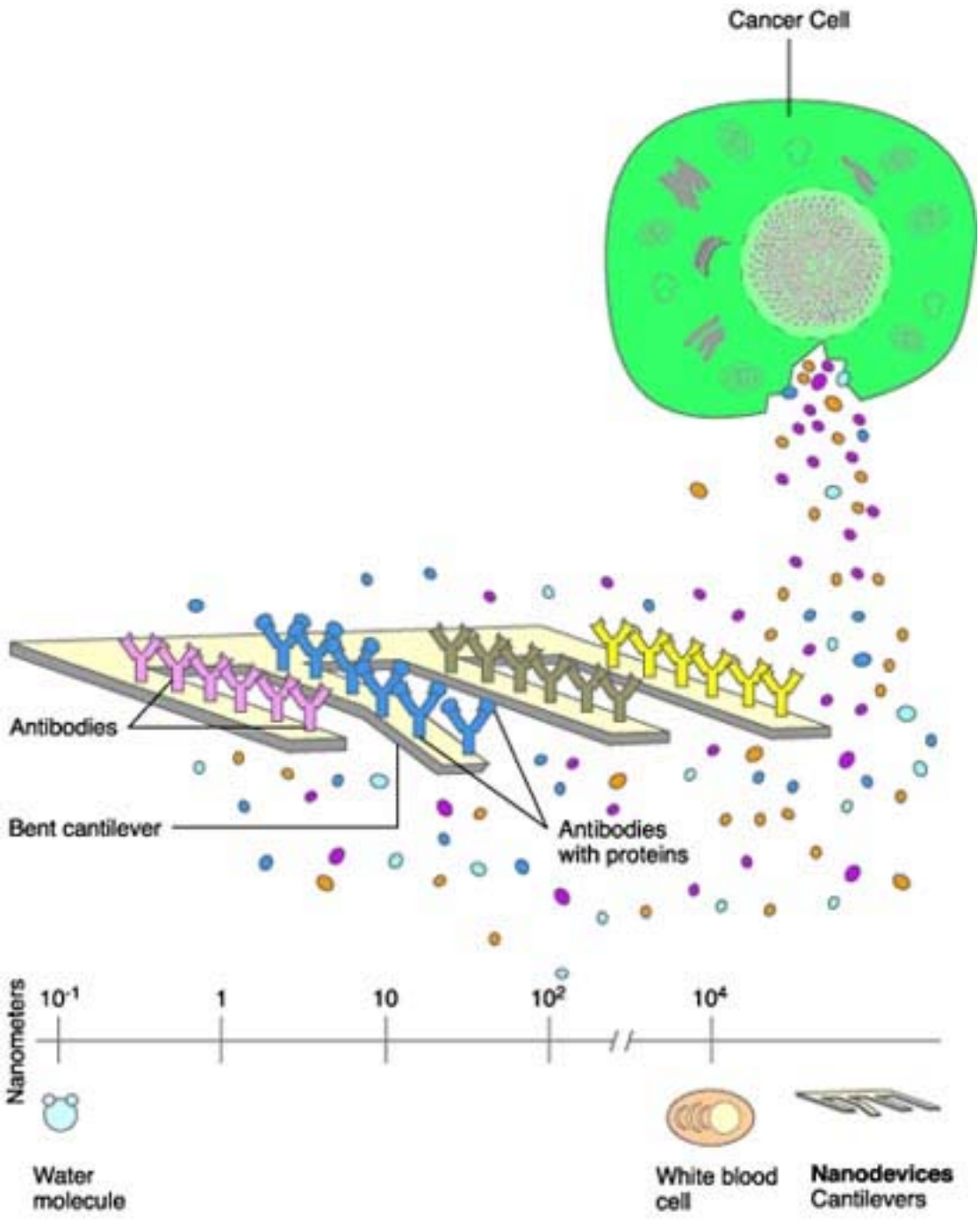

Fig 15 – cantilevers for cancer detection

The above diagram shows how cancer detected, when there is change in surface tension of molecules, cantilever bends that recognizes presence of cancer cells.

IV QUNATOM DOTS

Another minuscule molecule that will be used to detect cancer is a quantum dot. Quantum dots are tiny crystals that glow when they are stimulated by ultraviolet light. The wavelength, or color, of the light depends on the size of the crystal. Latex beads filled with these crystals can be designed to bind to specific DNA sequences. By combining different sized quantum dots within a single bead, scientists can create probes that release distinct colors and intensities of light.

ISSN 1512-1232

When the crystals are stimulated by UV light, each bead emits light that serves as a sort of spectral bar code, identifying a particular region of DNA.

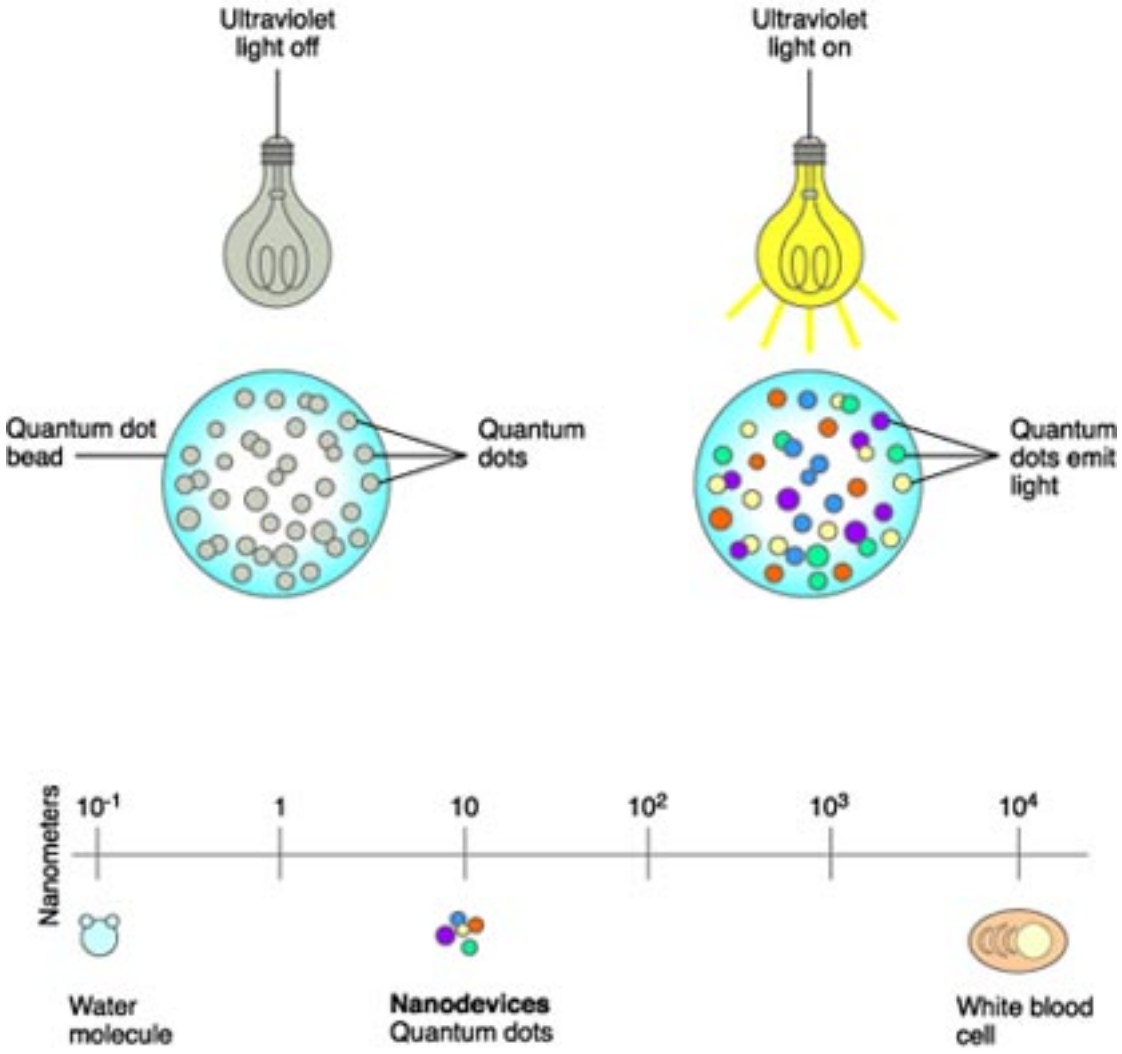

Fig 16 – Quantum dots for cancer detection

When the quantum dots are stimulated with light, they emit their unique bar codes, or labels, making the critical, cancer-associated DNA sequences visible. The diversity of quantum dots will allow scientists to create many unique labels, which can identify numerous regions of DNA simultaneously. This will be important in the detection of cancer, which results from the accumulation of many different changes within a cell. Another advantage to quantum dots is that they can be used in the body, eliminating the need for biopsy.

STRUCTURE:

Quantum Dots (QDs) are solid state structures made of semiconductors or metals that confine a countable, small number of electrons into a small space. The confinement of electrons is achieved by the placement of some insulating material(s) around a central, well conducting region. If the insulation of the QD is strong enough and if the QD is small enough quantum mechanical effects due to the discrete electron charge and/or discrete electron energies can be observed macroscopically. QDs have therefore also been called artificial atoms. Neighboring, weakly coupled QDs have been called artificial molecules. Pyramidal or Dome Shaped QDs or Trench shaped QD's available.

ISSN 1512-1232

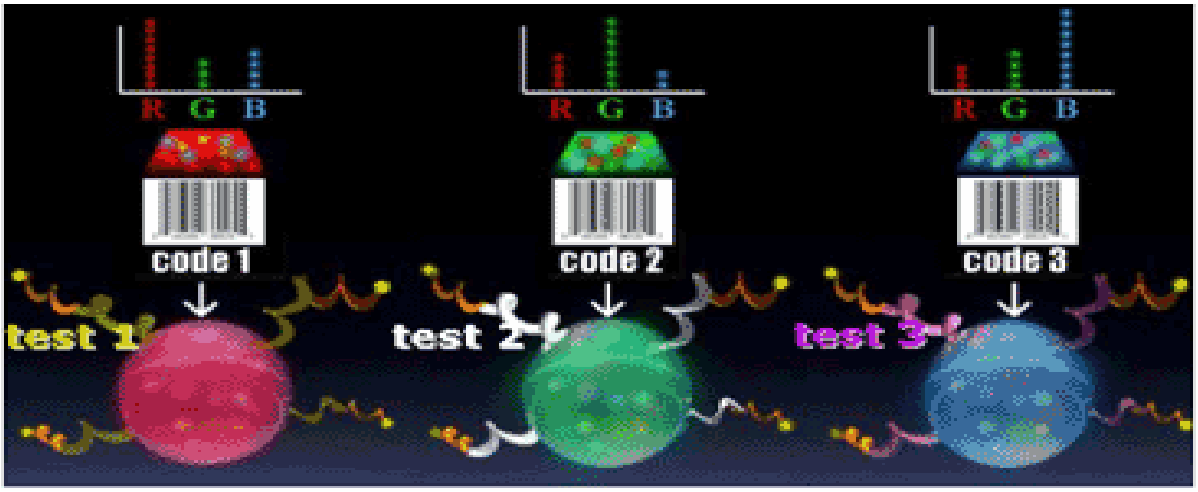

Figure 17 – Example of spectral barcodes from quantum dots

Courtesy : qdot.com

The above figure shows that quantum nano dots emit lights of different wavelength of different colors.

Qdots are made of either cadmium sulfide or cadmium telluride of 10nm in size. The shape of the crystal may vary (sphere, rods, pyramids etc) depending on the application. In the above figure it is clear that color depicts the size red color shows largest size comparing with the blue which is smaller one.

OPTICAL PROPERTIES : CDSE Qdots are taken, emit of qdot is 625nm for red and 525nm for blue. Emission in blue color that is smallest say 525nm and absorption for all the wavelength. Extinction is greater for blue and Emission intensity is greater for green. The wavelength for green color is in the range between 625 and 525nm. Qdot can be excited using single light source and emission in only particular color or wavelength. The excitation and sensitivity depends on the the brighness, extinsion and emission intensity.

V NANOSHELL, NANOPORES

Another interesting nanodevice is the nanopore. Improved methods of reading the genetic code will help researchers detect errors in genes that may contribute to cancer. Scientists believe nanopores, tiny holes that allow DNA to pass through one strand at a time, will make DNA sequencing more efficient. As DNA passes through a nanopore, scientists can monitor the shape and electrical properties of each base, or letter, on the strand. Because these properties are unique for each of the four bases that make up the genetic code, scientists can use the passage of DNA through a nanopore to decipher the encoded information, including errors in the code known to be associated with cancer.

ISSN 1512-1232

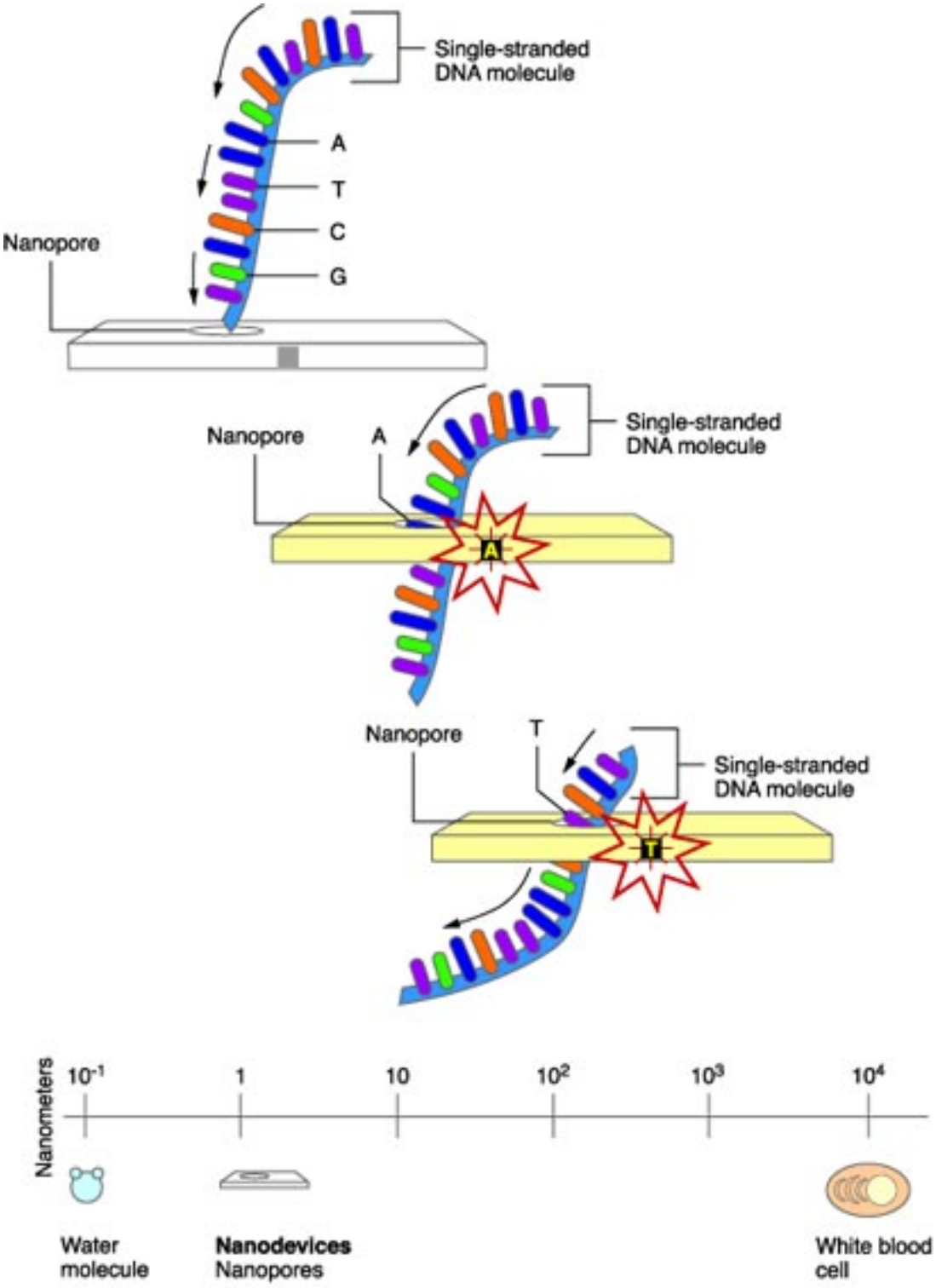

Figure 18 – Nanopores for detecting cancer

The above diagram shows that Nanopores can be used to detect and find ATCG combination which gives genetic code and any difference in the code gives identification of cancer cells.

Nanoshells

Nanoshells are miniscule beads coated with gold. By manipulating the thickness of the layers making up the nanoshells, scientists can design these beads to absorb specific wavelengths of light. The most useful nanoshells are those that absorb near-infrared light, which can easily penetrate

ISSN 1512-1232

several centimeters of human tissue. The absorption of light by the nanoshells creates an intense heat that is lethal to cells.

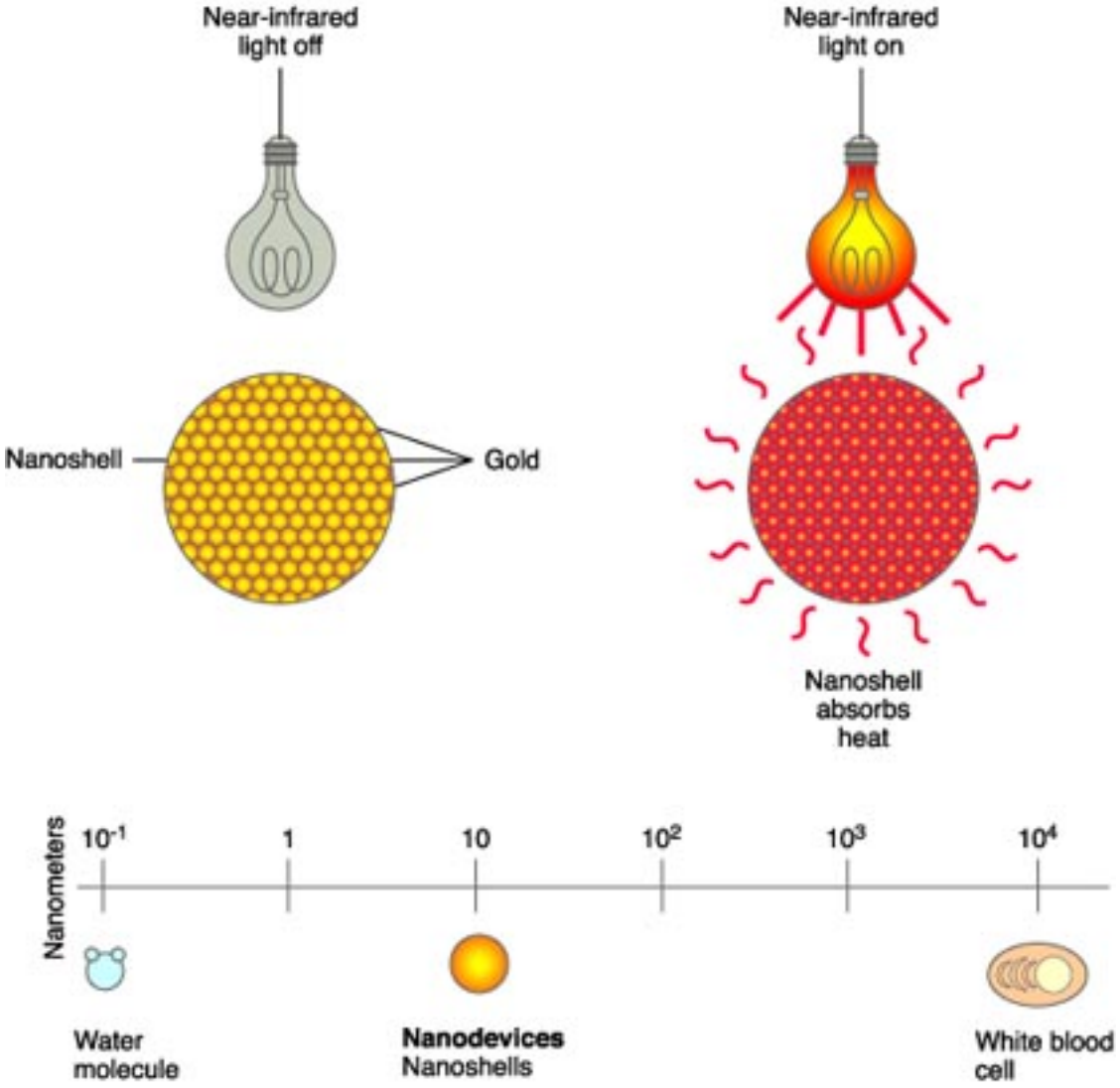

Figure – 19 Nanopores for cancer detection and destruction of cancer cells

Researchers can already link nanoshells to antibodies that recognize cancer cells. Scientists envision letting these nanoshells seek out their cancerous targets, then applying near-infrared light. In laboratory cultures, the heat generated by the light-absorbing nanoshells has successfully killed tumor cells while leaving neighboring cells intact.

STRUCUTRE AND PROPERTIES OF NANOSHELLS AND PORES

Tiny golden "bullets" could eventually be used to target and destroy cancerous tumours while leaving healthy tissue unharmed... researchers used nanoshells - tiny particles of silica coated with gold - to apply heat to tumours and destroy them using near-infrared light, a type of low-energy radiation. Nanoshells are a new type of nanoparticle with tunable optical properties. For medical applications, these particles can be designed to strongly absorb or scatter light in the near infrared where tissue and blood are relatively transparent. In a cancer therapy application, nanoshells are designed to absorb light and convert the energy to heat for tumor destruction. By conjugating antibodies or peptides to the nanoshell surfaces, binding of nanoshells can be targeted to cancerous cells, and subsequent exposure to near infrared light results in specific and localized destruction of the cancerous cells.

ISSN 1512-1232

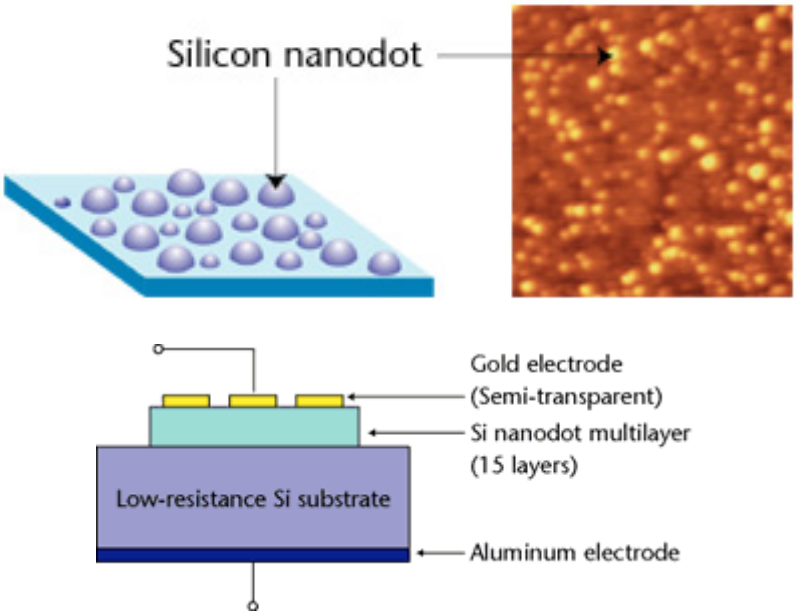

Figure 20 – Si Nanodot production fabrication

The above diagram shows that silicon nanodot fabricated on si substrate. Size 1nm.

Nanoshells are concentric sphere nanoparticles consisting of a dielectric (typically gold sulfide or silica) core and a metal (gold) shell (6). They are considered a very special kind of nanoparticle because they combine infrared optical activity with the uniquely biocompatible properties of gold colloid. In simple words, they can be described as spherical glass particles with an outer shell of gold. Their size is about 1nm - 100 nanometers in diameter.

Nanoshells are nanoparticles with a unique property — they can be optically tuned to either absorb or scatter particular wavelengths of light. Nanoshells are created from a dielectric core (like silica) and an outer shell of gold or another metal. By varying the diameter of the core and the thickness of the metal shell, Nanoshells can be crafted to reflect or absorb different wavelengths. By altering the structure of Nanoshells, we can drastically change the absoprtion/scattering profiles of the nanoparticles.

Figure 21: Nanoshells designed to absorb various wavelengths of light (the six vials on the right), including infrared (vial at far right) compared to gold colloid (far left). – nanospectra.com

ISSN 1512-1232

The ability to "tune" Nanoshells to a desired wavelength is critical to in vivo therapeutic applications. Human blood and tissue minimally absorb certain near-infrared wavelengths of light, enabling us to use an external laser to deliver light to Nanoshells either in a tumor (for thermal destruction or imaging), a wound (for wound closure or tissue repair) or whole blood (to diagnose disease. Gold nano shells either to absorb or scatter light. RED color having highest wavelength and low extinction rate.

CONCLUSION

Nanotechnology may also be useful for developing ways to eradicate cancer cells without harming healthy, neighboring cells. Scientists hope to use nanotechnology to create therapeutic agents that target specific cells and deliver their toxin in a controlled, time-released manner. In this study This means that nanoscale devices (less than 100 nanometers) can enter cells and the organelles inside them to interact with DNA and proteins. Tools developed through nanotechnology may be able to detect disease in a very small amount of cells or tissue. They may also be able to enter and monitor cells within a living body.

1. CARBON NANO TUBE is used for cancer detection and mainly depends on changes in DNA(mutation) structure.
2. CANTILEVER is used for cancer detection and mainly depends on surface tension properties
3. NANOPORES AND NANOSHELLS – These devices mainly depends on genetic code and its sequence for detecting the cancer.
4. QUANTOM DOTS mailnly depends on the emission of light if there is change in cell structure.
5. DENDRIMERS carries molecules and identifies the cell and destroys the cells itself.

From the above, Nanodevices acts as a link between detection, diagnosis, and treatment of cancer. In this paper some of the simulated structure presented and its working for cancer treatment mainly depends on future version of nanoxplorer tool, which will be released in short. Here only the carbon nanotube and dendrimers structures are simulated. Other structures can be simulated using software QDESIGN CAD- windows version yet to be released.

REFERENCES

1. http://press2.nci.nih.gov/sciencebehind/nanotech
2. NANOSPECTRA.COM
3. QDOT.COM
4. NANODEVICES.COM
5. NANOTECH.COM

Article received: 2010-08-04