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Study of Nano-Devices and Its Properties for Bio Chemical Applications: Review.

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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 discusses the properties of all the devices and gives the effective way to eradicate the 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. The fabrication of Nanoshells and MIS devices for Medical applications are also presented.

Keywords: Nano devices, biochemical.

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INTRODUCTION

Nanotechnology is the creation of useful materials, devices and systems through the manipulation of matter on the miniscule scale. There are many interesting nanodevices being developed that have a potential to improve cancer detection, diagnosis and treatment. Nanostructures can be so small but our body may clear them too rapidly and effective in detecting or imaging. Larger nanoparticles may accumulate in vital organs, creating toxity problems. But nanoscale devices can enter cells and organelles and interact 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 detect earliest stages and related molecule changes. In order to successfully detect 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. In this paper the properties need to design for some of the nanodevices carbonnanotube, dendrimers, cantilevers, nanopores, nanoshells and qdots are presented. The fabrication steps for Nanoshells and MIS devices for Medical Applications are also discussed.

Carbon Nanotube

It consists of a long thin cylindrical structure 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 to 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 nanotube is a one-layer carbon nanotube of two-dimensional graphite end up with cylindrical structure of single wall. Multiple walled carbon nanotube has more layers of graphite sheet and end up with multiple walls. Atoms are arranged in Zigzag and Armchair format. Both Single walled and Double walled Carbon Nano tube are simulated using Nano titan software tool. Figure 1 and 2 shows single and double walled carbon Nanotubes.

Properties of Carbon Nanotube

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

Properties are extracted from Nanotitan software tool for Medical applications.

Cancer Detection

Nanotubes – Mapping Mutations

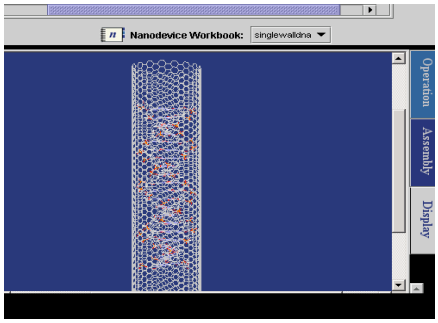

Figure 1: Structure of Single wall Carbon Nanotube with D.N.A inside.

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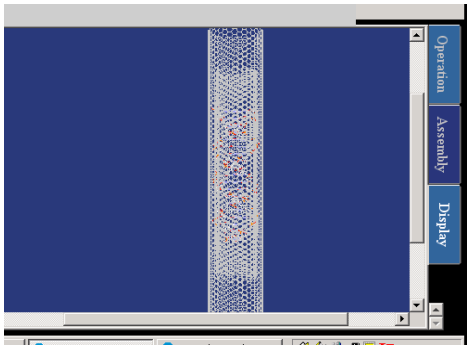

Figure 2: Structure of Multiple wall carbon Nanotube with D.N.A inside

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 the disease. Fig - 3 shows that how carbon nanotube used to predict the cancer treatment.

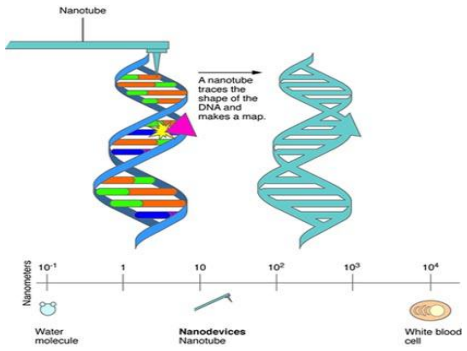

Figure 3: Nano tube with Mutation to detect Alteration in Gene structure [6]
(Courtesy: Press2.nci.nih.gov/sciencebehind/nanotech)

Nanoshells

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 wavelength 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 absorption/scattering profiles of the nanoparticles. We have fabricated Nanodots and its structure shown in fig. 4.

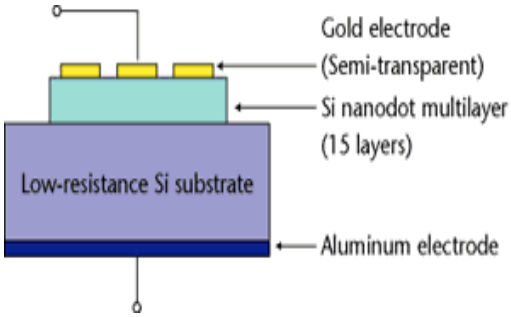

Figure 4: Si Nano dot Fabrication.

Fabrication steps for the Nanodot is given below

- Silicon wafer of low resistance around 10 ohm-cm is cleaned with TCE and ACETONE for cleaning purpose.
- Back Al Metallization for Alumunium electrode using Metallization unit. Area 1.96 x 10^{-3} cm^2 and pressure 6 X 10^{-6} torr
- Epitaxial Growth of Silicon from $SiCl_4$ + H_2 in epitaxial Reactor for Si Multilayer formation of thickness of 20nm
- Gold Metallization of thickness 5 nm on Multilayer silicon thickness

Nanoshells for Cancer Detection

The ability to "tune" Nanoshells to a desired wavelength is critical in 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 can be used to absorb or scatter light. Depending on the Color and Intensity Tumor can be destroyed. RED color having highest wavelength and low extinction rate.

Dendrimers

Dendrimers are spherical polymeric molecules. Dendrimers and proteins differ in the proteins. 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).

Dendrimers for Cancer Treament

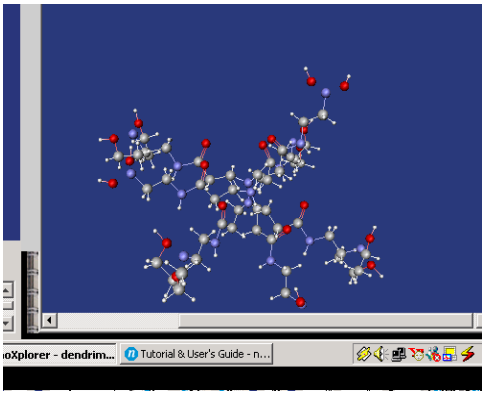

Figure 5: Simulated structure of Dendrimers

A single dendrimer can carry a molecule that recognizes cancer cells, It acts as 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 killed their targets. Fig 5 shows simulated structure of DENDRIMERS using NANOTITAN tool.

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Properties

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.

Cantilevers for Cancer Detection

InAs cantilevers ar 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 of photolithographic layers patterning is done and selective etching also preferred over this layer. When there is change in surface tension of molecules, cantilever bends and recognizes the presence of cancer cells

Properties

Thickness of cantilever – 30nm

Force / elasticity - 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

Qunatom Dots

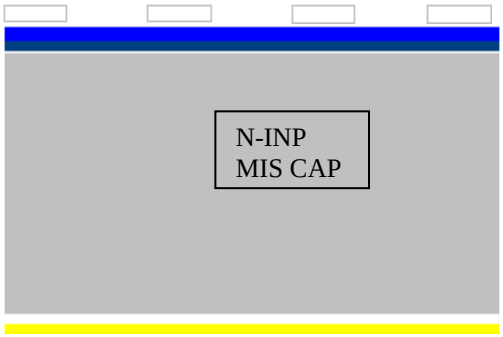
Another minuscule molecule that will be used to detect cancer is a quantum dot. Quantum dots are tiny crystals that glow when they are stimulated by ultraviolet light. The wavelength, or color, of the light depends on the size of the crystal. Latex beads filled with these crystals can be designed to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

Optical Properties

CDSE (Cadmium selenium) Qdots has 625nm wavelength for red and 525nm for blue. Emission in blue has 525nm. 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 brightness, extinsion and emission intensity. We measured wavelength using spectrometry by sending laser rays on the CDSE dots and observed wavelength for RED and BLUE.

Mis Device Fabrication for Electrode Manufacturing

Figure 6: MIS Capacitor using Indium Phosphide wafer.



Metal Insulator semiconductor devices are used to fabricate Bio-electrodes for Medical Applications. We have fabricated the MIS capacitor device as test vehicle for MISFET device and given detailed fabrication steps.

- Al – Metallization – 20 nm
- Silicon nitride – 100nm
- Anodic oxide of InP – 100nm
- Back Au Metallization – 20 nm
- Au:Ge Metallization – 50 nm

Details of Fabrication steps

- Cleaning the InP wafers with TCE, Acetone and Back AL Metallization
- Au:ge Metallization on Al Metallization.
- Sulphur passivation on InP and Anodic oxide of thickness 10 nm
- Silicon Nitride Deposition on Oxide layer
- Final Alumunium Metallization.

Silicon nitride and Anodic oxide acts ass double dielectric layer. Anodic oxide is carried out at room temperature using anodisation. Figure 6 shows Capacitance structure of MIS device

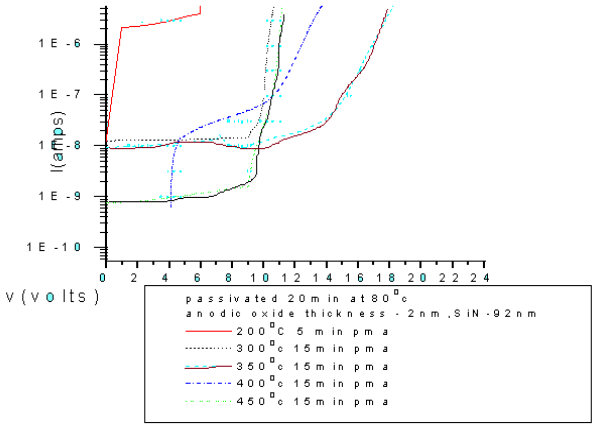


Figure 6: I-V characteristics of InP MIS

Figure 6 and 7 shows I-V characteristics and C-V characteristics of MIS device. I-V characteristics are drawn using Parametric analyzer and C-V characteristics using C-V Meter HP 4275 Multilayer LCR Meter.

Breakdown Voltage and Leakage current of the above device are found to be 9e-9 amps, -12 volts. The amount of impurities found on the surface of the device can be calculated from its interface state density. For MIS device it is found to be 5.31 e12 / cm^2/ev. Therefore MIS device are used to fabricate Bio-electrodes. Therefore MIS devices are used to sense Potential from Milli .volts to Micro volts.

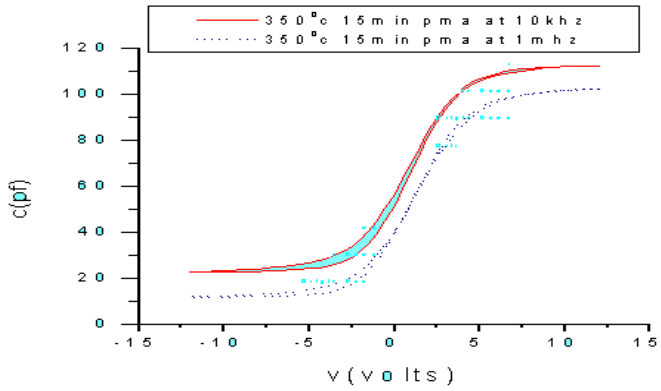


Figure 7: C-V characteristics of InP MIS device

At 350 degree 92 nm thickness of nitride gives well-defined C-V Characteristics. C-V characteristics show depletion, accumulation and dispersion regions of MIS capacitor. The studies on these MIS devices are

used to fabricate Bio-electrodes. Finally we conclude that MIS devices are able to detect Milli to Microvolt ranges.

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 The 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.

- CARBON NANO TUBE is used for cancer detection and mainly depends on changes in DNA(mutation) structure.
- CANTILEVER is used for cancer detection and mainly depends on surface tension properties
- NANOPORES AND NANOSHELLS – These devices mainly depends on genetic code and its sequence for detecting the cancer.
- QUANTOM DOTS mainly depends on the emission of light if there is change in cell structure.
- DENDRIMERS carry molecules and identify the cell and destroy the cells itself.

A Nanodevice acts as a link between detection, diagnosis, and treatment of cancer. In this paper some of the simulated structures are presented. Here only the carbon nanotube and dendrimers structures are simulated.

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