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A Conceptual Study of Nanoelectronic Devices and Nanosensors

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Abstract:

Nanosensors are gaining increasing attention due to the need to detect and measure chemical andphysical properties in difficult to reach biological and industrial systems that are in the nano-scaleregion. This conceptual review surveys various nanosensors, basically Optical nanosensors, Carbon based sensors, NEMS. The sensing concepts and their corresponding study is highlighted.Also we have discussed the Nanoelectronic Devices and the topic basically relates the basic knowledge regarding their memory storage, advantages are discussed with reference to their applications.

Key words: Nanosensor, memory storage, CNT, carbon nanotubes, SWNT.

INTRODUCTION

WHAT IS NANOTECHNOLOGY?

Nanotechnology is the understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nanometres in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications. Nanotechnologyis cross-disciplinary in nature, drawing on medicine, chemistry, biology, physics and materials science.

New properties at the nanoscale, matter begins to demonstrate entirely new and unique properties. It can become stronger, conduct heat better, and show extraordinary electrical properties. Creating nanostructures with a bottom-up approach, nanostructures are formed molecule by molecule, using methods such as chemical vapour deposition or self-assembly. By contrast, top-down fabrication can be likened to sculpting from a base material, and typically involves steps such as deposition of thin films, patterning, and etching.

WHY NANOTECHNOLOGY MATTERS----

The advances in nanotechnology have brought new tools to the field of electronics and sensors. New designed materials offer new and unique properties enabling the development and cost efficient production of state-of-theart components that operate faster, has higher sensitivity, consume less power, and can be packed at much higher densities. Numerous products based on nanotechnology have been reaching the market for some years, all the way to end users and consumers. For instance, at the nanoscale, the resistance dependence of a material on an external magnetic field is significantly amplified, which has led to the fabrication of hard disks with a data storage density in the gigabyte and terabyte ranges. Nanotechnology has also enabled the development of sensors suitable for measurements at the molecular level with an unprecedented sensitivity and response time, mainly due to their high surface to volume ratio.

A nanosensor is a sensor built on the atomic scale based in measurements of nanometers. There have been a number of advances in the research and development of nanosensors for a number of different applications. Some of the major applications are the medical field, national security, aerospace, integrated circuits, and many more. Along with many different applications for nanosensors, there are also many different types of nanosensors, and a number of ways to manufacture them. There are a number of challenges currently with the production of these nanosensors. A nanosensor is a sensor that is built on the nanoscale, whose purpose is mainly toobtain data on the atomic scale and transfer it into data that can be easily analyzed. These sensors can also be defined as “A chemical or physical sensor constructed using nanoscale components, usually microscopic or submicroscopic in size.” These sensors are ultra sensitive and can detect single virus particles or even ultra-low concentrations of a substance that could be potentially harmful. Nanosensors can be manufactured in a number of different methods. The three most commonly known methods are top-down lithography, bottom-up assembly, and molecular self-assembly. Researchers have also found a way to manufacture a nanosensor using semiconducting nanowires, which is said be an “easy-to-make” method of producing a type of nanosensor. Other methods of creating the sensors include the use of carbon nano tubes (CNTs). Presently, there are several ways proposed to make nanosensors, including top-down lithography, bottom-up assembly, andmolecular self-assembly.

An ideal sensor must contain following characteristics:

1. Output signal must be suite with the type rate of the case goal.

2. Act much more specific against considered case.

3. High resolution and selectivity

4. High repeatability of correction.

5. High speed response (Ms)

6. Non responding to disturbance environment factor such as temperature and environment ionic power.

Nanosensors are any biological, chemical, or surgical sensory points used to convey information about nanoparticles to the macroscopic world. Their uses mainly include various medicinal purposes and as gateways to building other nanoproducts, such as computer chips that work at the nanoscale andnanorobots.

Nanosensors are sensing devices with at least one of their sensing dimensions being not greater than 100 nm. In the field of nanotechnology, nanosensors are instrumental for

(a) monitoring physical and chemical phenomena in regions difficult to reach,

(b) detecting biochemicals in cellular organelles, and

(c) measuring nanoscopic particles in the industry and environment.

The advance in scientific understanding is naturally followed by technological development. Although sensors have a long and illustrious history, the realm of nanosensors is relatively new.

Nanosensor type	***Sub- category***	***Measured specimens or physical properties***
Optical	Fibre optic	Benzonepyrene tetrol, benzo[a]pyrene, caspase-9 (an apoptosis protein),cytochrome c (a protein involved in producing cellular energy),pH ,K^+ , Ca^{2+} , NO , No_2^- , Cl^- , Na^+
Electromagnetic	Current measurement	Lactase oxidase, dehydrogenase, hydrogen peroxide, catalase, organophosphorus pesticides, DNA , ATP, etc
	Magnetism measurement	Molecular interactions, oligonucleotide sequence , enzymatic activity, viral particles, magnetic field, speed, position sensing
Mechanical	Vibrational	Resonance frequency, spring constant
	Interial	Pressure, acceleration, yaw rate

Table 1. A summary on various types of nanosensors and their applications.

The various nanosensors can be loosely groupedinto three broad categories of nanosensors:

(i)optical nanosensors,

(ii) electromagnetic nanosensors, and

(iii) mechanical and/or vibrational nanosensors,bearing in mind other nanosensors that do not fall into the above-mentioned categories.

OPTICAL NANOSENSORS

The first reported optical nanosensor was based onfluorescein which is trapped within a polyacrylamide nanoparticle, and was used for pH measurement. In the most basic concept, fluorescent chemosensors are molecules composed of at least one substrate binding unit(s) and photoactive component(s). The luminescence phenomenon is a process by which a fluorophore absorbs light of a certain wavelength, which is followed by emission of a quantum of light with an energy corresponding to the energetic difference between the ground and excited states .In a typical luminescent sensor, the reflected light changes in color when the receptor binds with the analyte. The change in photo-vibrational properties underlies the sensing concept.

The most basic type of optical nanosensor is that of a molecular dye probe inside a cell,

An advantage of this basic approach is to minimize the physical perturbation of the cell, unlike that of the opticalfiber probe. However, a disadvantage of the free dye is the inherent dye-cell chemical interference as a result of protein binding, cell sequestration and toxicity. A slightly different deviation from the free dye method is that known as the labelled nanoparticles that consist of a reporter molecule attached to the outside of the nanoparticles. The major difference between the labelled nanoparticles as compared to the free dye method is the solid state and fluid nature of the former and latter, respectively. Notwithstanding this difference, the labelled nanoparticles are freely flowing and the reporter molecules are in contact with the intracellular components –

just like the free dye. These outer-labelled particles have been used for intracellular sensing, but retain similar drawbacks of using the freefluorescent dyes because the signal is derived from receptor molecules not insulated from the cellular environment.

FIBER OPTICAL SENSORS

Conventional methods for intracellular investigation need "fixing" of cell samples before performing the analysis. This fixing process usually destroys cellular viability and may, to a considerable extent, change theintracellular structure. Fiber optic nanosensors havethe potential to analyze important cellular processes invivo. Fundamental monitoring of biological processes at the cellular level is important to enhance further understanding of dynamic cellular functions. The interaction between the target molecule (A) and the receptor (R) is designed to produce a physicochemical perturbation that can be converted into an electrical signal or other measurable signal R+A → RA+measurable signal. This measurable signal is then picked up by the optical probe and transmitted into the database. The disadvantage associated with the dye-cell chemical interference prevalent in the free dye method is overcome by using the optical fiber probe due to the physical separation between the environment and the sensing tip. Another advantage of the optical nanosensor is the minimal invasiveness of this technique as compared to conventional wire-probe devices.

Fiber optic nanosensors have so far been successful with their capability in the following applications:

(a) Measurement of benzopyrene tetrol (BPT) and benzo[a]pyrene (BaP) inside single cells. These biochemicals are important for cancer studies.

(b) Monitoring apoptosis. Apoptosis, or programmed cell death, is a process in which cells degenerate

(i) during normal development,

(ii) due to aging, or

(iii) as a result of disease. The fiber optic nanosensor has been used for monitoring of caspase-9, an apoptosis protein, in human mammary carcinoma cells (MCF-7).

CARBON-BASED SENSORS AND ELECTRONICS

The semiconductor industry has been able to improve the performance of electronic systems for more than four decades by downscaling silicon-based devices but this approach will soon encounter its physical and technical limits. This fact, together with increasing requirements for performance, functionality, cost, and portability have been driven the microelectronics industry towards the nano world and the search for alternative materials to replace silicon. Carbon nanomaterials such as one-dimensional (1D) carbon nanotubes and two-dimensional (2D) graphene have emerged as promising options due to their superior electrical properties which allow for fabrication of faster and more power-efficient electronics. At the same time their high surface to volume ratio combined with their excellent mechanical properties has rendered them a robust and highly sensitive building block for nanosensors. Carbon nanotube electronics When a layer of graphene is rolled into a tube, a single-walled carbon nanotube (SWNT) is formed. Consequently, SWNTs inherit the attractive electronic properties of grapheme but their cylindrical structure makes them a more readily available option for forming the channel in field-effect transistors. Such transistors possess an electron mobility superior to their silicon-based counterpart and allow for larger current densities while dissipating the heat generated from their operation more efficiently. During the last decade, carbon nanotube-based devices have advanced beyond single transistors to include more complex systems such as logic gates and radiofrequency components. Carbon-based nanosensors In addition to the exceptional electrical properties of graphene and carbon nanotubes, their excellent thermal conductivity, high mechanical robustness, and very large surface to volume ratio make them superior materials for fabrication of electromechanical and electrochemical sensors with higher sensitivities, lower limits of detection, and faster response time. A good example is the carbon nanotube-based mass sensor that can detect changes in mass caused by a single gold atom adsorbing on its surface. An artistic expression of an integrated circuit based on individual carbon nanotubes.

Nano sensors are divided into three groups according totheir architecture:

Quantum points, Carbons nanotube and Nanotools.

Manufacturers are currently using nanomaterials to build sensors in several ways, including the following:

- **Sensors using semiconductor nanowire detection elements:** These sensors are capable of detecting a range of chemical vapors. When molecules bond to nanowires made from semiconducting materials such as zinc oxide, the conductance of the wire changes. The amount that the conductance changes and in which direction depends on the molecule bonded to the nanowire.

  For example, nitrogen dioxide gas reduces how much current the wire conducts, and carbon monoxide increases the conductivity. Researchers can calibrate a sensor to determine which chemical is present in the air by measuring how the current changes when a voltage is applied across the nanowire.

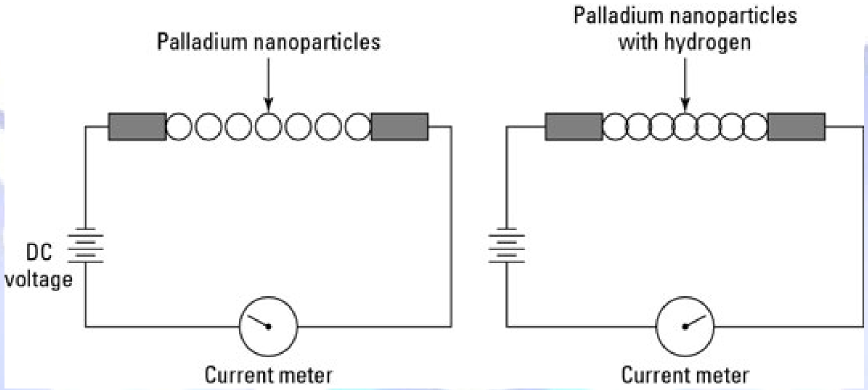
- **Semiconducting carbon nanotubes:** To detect chemical vapors, you can first functionalize carbon nanotubes by bonding them with molecules of a metal, such as gold. Molecules of chemicals then bond to the metal, changing the conductance of the carbon nanotube. As with semiconducting nanowires, the amount that the conductance and its direction changes depends on the molecule that bonds to the nanotube. This type of sensor is now commercially available.

- **Carbon nanotubes and nanowires that detect bacteria or viruses:**These materials can be used also to sense bacteria or viruses. First you functionalize the carbon nanotubes by attaching an antibody to them. When the matching bacteria or virus bonds to an antibody, the conductance of the nanotube changes.

  In this process you attach nanotubes to metal contacts in the detector and apply a voltage across the nanotube. When a bacteria or virus bonds to the nanotube, the current changes and generates a detection signal. Researchers believe that this method should provide a fast way to detect bacteria and viruses.

  One promising application of this technique is checking for bacteria in hospitals. If hospital personnel can spot contaminating bacteria, they may be able to reduce the number of patients who develop complications such as staph infections.

- **Nanocantilevers:** These devices are being used to develop sensors that can detect single molecules. These sensors take advantage of the fact that the nanocantilever oscillates at a resonance frequency that changes if a molecule lands on the cantilever, changing its weight. Coating a cantilever with molecules, such as antibodies, that bond to a particular bacteria or virus determines what bacteria or virus will bond to the cantilever.
    - One example of nanoparticles used in sensors is a hydrogen sensor that contains a layer of closely spaced palladium nanoparticles that are formed by a beading action similar to water collecting on a windshield. When hydrogen is absorbed, the palladium nanoparticles swell, which causes shorts between nanoparticles and lowers the resistance of the palladium.
    - Another use of nanoparticles is in the detection of volatile organic compounds (VOCs). Researchers have found that by embedding metal nanoparticles made of substances such as gold in a polymer film, you create a VOC nanosensor.
    - Sensors are also being developed to detect molecules that indicate that a particular disease is present in a blood sample.



NANOELECTRONIC DEVICES

Nanoelectronics offers a broad set of opportunities by focusing on quantum devices and addressing their potential for high performance through increases in density (factors of 5 to 100), speed (factors of 10 to 100), and reduced power (factors of more than 50)

Current high-technology production processes are based on traditional top down strategies, where nanotechnology has already been introduced silently. The critical length scale of integrated circuits is already at the nanoscale (50 nm and below) regarding the gate length of transistors in CPUs or DRAM devices.

Nanoelectronics holds the promise of making computer processors more powerful than are possible with conventional semiconductor fabrication techniques. A number of approaches are currently being researched, including new forms ofnanolithography, as well as the use ofnanomaterials such as nanowires orsmall molecules in place of traditionalCMOS components. Field effect transistors have been made using both semiconducting carbon nanotubes[8] and with heterostructured semiconductor nanowires.

In 1999, the CMOS transistor developed at the Laboratory for Electronics and Information Technology in Grenoble, France, tested the limits of the principles of the MOSFET transistor with a diameter of 18 nm (approximately 70 atoms placed side by side). This was almost one tenth the size of the smallest industrial transistor in 2003

(130 nm in 2003, 90 nm in 2004, 65 nm in 2005 and 45 nm in 2007). It enabled the theoretical integration of seven billion junctions on a €1 coin. However, the CMOS transistor, which was created in 1999, was not a simple research experiment to study how CMOS technology functions, but rather a demonstration of how this technology functions now that we ourselves are getting ever closer to working on a molecular scale. Today it would be impossible to master the coordinated assembly of a large number of these transistors on a circuit and it would also be impossible to create this on an industrial level.

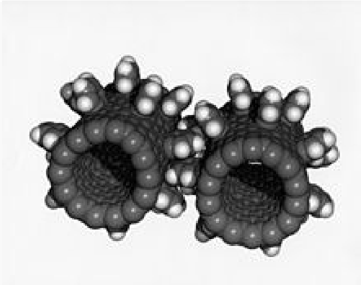
MEMORY STORAGE

Electronic memory designs in the past have largely relied on the formation of transistors. However, research into crossbar switch based electronics have offered an alternative using reconfigurable interconnections between vertical and horizontal wiring arrays to create ultra high density memories. Two leaders in this area are Nantero which has developed a carbon nanotube based crossbar memory called Nano-RAM and Hewlett-Packard which has proposed the use of memristormaterial as a future replacement of Flash memory.

An example of such novel devices is based on spintronics.The dependence of the resistance of a material (due to the spin of the electrons) on an external field is called magnetoresistance. This effect can be significantly amplified (GMR - Giant Magneto-Resistance) for nanosized objects, for example when two ferromagnetic layers are separated by a nonmagnetic layer, which is several nanometers thick (e.g. Co-Cu-Co). The GMR effect has led to a strong increase in the data storage density of hard disks and made the gigabyte range possible. The so-called tunneling magnetoresistance (TMR) is very similar to GMR and based on the spin dependent tunneling of electrons through adjacent ferromagnetic layers. Both GMR and TMR effects can be used to create a non-volatile main memory for computers, such as the so-called magnetic random access memory or MRAM.

NOVEL OPTOELECTRONIC DEVICES

In the modern communication technology traditional analog electrical devices are increasingly replaced by optical or optoelectronic devices due to their enormous bandwidth and capacity, respectively. Two promising examples are photonic crystals and quantum dots. Photonic crystals are materials with a periodic variation in the refractive index with a lattice constant that is half the wavelength of the light used. They offer a selectable band gap for the propagation of a certain wavelength, thus they resemble a semiconductor, but for light or photons instead of electrons. Quantum dots are nanoscaled objects, which can be used, among many other things, for the construction of lasers. The advantage of a quantum dot laser over the traditional semiconductor laser is that their emitted wavelength depends on the diameter of the dot. Quantum dot lasers are cheaper and offer a higher beam quality than conventional laser diodes.



DISPLAYS

The production of displays with low energy consumption might be accomplished using carbon nanotubes (CNT). Carbon nanotubes are electrically conductive and due to their small diameter of several nanometers, they can be used as field emitters with extremely high efficiency for field emission displays (FED). The principle of operation resembles that of the cathode ray tube, but on a much smaller length scale.

RADIOS

Nanoradios have been developed structured around carbon nanotubes.[11]

ENERGY PRODUCTION

Research is ongoing to use nanowires and other nanostructured materials with the hope to create cheaper and more efficient solar cells than are possible with conventional planar silicon solar cells.[12]

There is also research into energy production for devices that would operate called bio-nano generators. A bio-nano generator is a nanoscale electrochemical device, like a fuel cell or galvanic cell, but drawing power from blood glucose in a living body, much the same as how the body generates energy from food. To achieve the effect, an enzyme is used that is capable of stripping glucose of its electrons, freeing them for use in electrical devices. The average person's body could, theoretically, generate 100 watts of electricity (about 2000 food calories per day) using a bio-nano generator.However, this estimate is only true if all food was converted to electricity, and the human body needs some energy consistently, so possible power generated is likely much lower. The electricity generated by such a device could power devices embedded in the body (such as pacemakers), or sugar-fed nanorobots. Much of the research done on bio-nano generators is still experimental.

MEDICAL DIAGNOSTICS

Constructing nanoelectronic devices that could detect the concentrations of biomoleculesin real time for use as medical diagnostics,thus falling into the category of nanomedicine. A parallel line of research seeks to create nanoelectronic devices which could interact with single cells for use in basic biological research. These devices are called nanosensors. Such miniaturization on nanoelectronics towards in vivo proteomic sensing should enable new approaches for health monitoring, surveillance, and defense technology.

NANO-ELECTRO-MECHANICAL SYSTEMS (NEMS)

All electronic tools have one thing in common: an integrated circuit (IC) acting as their “brain”. The extent to which this “brain” has influenced our lives has already been tremendous but what if its decision-making capability is augmented by “eyes” and "arms"? Nano-electro-mechanical systems have evolved during the last 10 years to make this dream come true by creating sensors ("eyes") and actuators ("arms") at the same scale as the accompanying nanoelectronics. Recent developments in synthesis of nanomaterials with excellent electrical and mechanical properties have extended the boundaries of NEMS applications to include more advanced devices such as the non-volatile nanoelectro-mechanical memory, where information is transferred and stored through a series of electrical and mechanical actions at the nanoscale.

C. Contacted CNTs represents a '1' state.A carbon based nano-electro-mechanical nonvolatile memory;

A. Separated CNTs represents a '0' state.

B. CNTs are brought into contact by applying a voltage between them.

D. Applying a relatively large voltage across the junction generates CNT phonon excitations with sufficient energy to cause their separation leading to the RESET operation.

CONCLUSION

The proposed nanotechnology could allow the development of a new generation of integrated self contained nanofunctional devices incorporating multiple end-point sensing elements,optical quantum detectors and integrated electro-optic molecular switching capability. The obvious challenges are reducing the cost of materials and devices, improving reliability and packing the devices into useful products.It is expected by compounding nano sensors and motivation in feature to make intelligent materials which present a great role in production process of complicating systems. And plane other new technology. Although restriction such as: high price; assurance of their effecting and also assurance of applying them in peaceful fields must be removed.

REFERENCES

Xiang, Jie; Lu, Wei; Hu, Yongjie; Wu, Yue; Yan; Hao & Lieber, Charles M. (2006). "Ge/Si nanowire heterostructures as highperformance field-effect transistors". *Nature* **441** (7092): 489–493.

Waldner, Jean-Baptiste (2007). *Nanocomputers and Swarm Intelligence*. London: ISTE. p. 26. ISBN 1-84704-002-0.

Jensen, K.; Jensen, K.; Weldon, J.; Garcia, H. & Zettl A. (2007). "Nanotube Radio". *Nano Lett.* **7** (11): 3508–3511.Bibcode:2007NanoL...7.3508J.

1. Tian, Bozhi; Zheng, Xiaolin; Kempa, Thomas J.; Fang, Ying;Yu, Nanfang; Yu, Guihua; Huang, Jinlin & Lieber, Charles M. (2007). "Coaxial silicon nanowires as solar cells and nanoelectronic power sources". *Nature* **449**(7164): 885–889. Bibcode:2007Natur.449..885T.doi:10.1038/nature06181

2. Grace, D. (2008). "Special Feature: Emerging Technologies". *Medical Product Manufacturing News*.**12**: 22–23.

Saito, S. (1997). "Carbon Nanotubes for Next-Generation Electronics Devices". *Science* **278** (5335): 77–78.doi:10.1126/science.278.5335.77.

3. Cavalcanti, A.; Shirinzadeh, B.; Freitas Jr, Robert A. & Hogg, Tad (2008). "Nanorobot architecture for medical target identification". *Nanotechnology* **19** (1):

4. Cheng, Mark Ming-Cheng; Cuda, Giovanni; Bunimovich, Yuri L; Gaspari, Marco; Heath, James R; Hill, Haley D; Mirkin,Chad A; Nijdam, A Jasper; Terracciano, Rosa; Thundat, Thomas & Ferrari, Mauro (2006). "Nanotechnologies for biomolecular detection and medical diagnostics". *Current Opinion in Chemical Biology* **10** (1):

5. Patolsky, F.; Timko, B.P.; Yu, G.; Fang, Y.; Greytak, A.B.; Zheng, G. & Lieber, C.M. (2006). "Detection, stimulation, and inhibition of neuronal signals with high-density nanowire transistor arrays". *Science* **313** (5790): 1100–1104.

6. Frist, W.H. (2005). "Health care in the 21st century".*N. Engl. J. Med.* **352** (3): 267–272.

7. Cavalcanti, A.; Shirinzadeh, B.; Zhang, M. & Kretly, L.C. (2008). "Nanorobot Hardware Architecture for Medical Defense". *Sensors* **8** (5): 2932–2958.

8. Couvreur, P. & Vauthier, C. (2006). "Nanotechnology: intelligent design to treat complex disease". *Pharm. Res.***23** (7): 1417–1450.