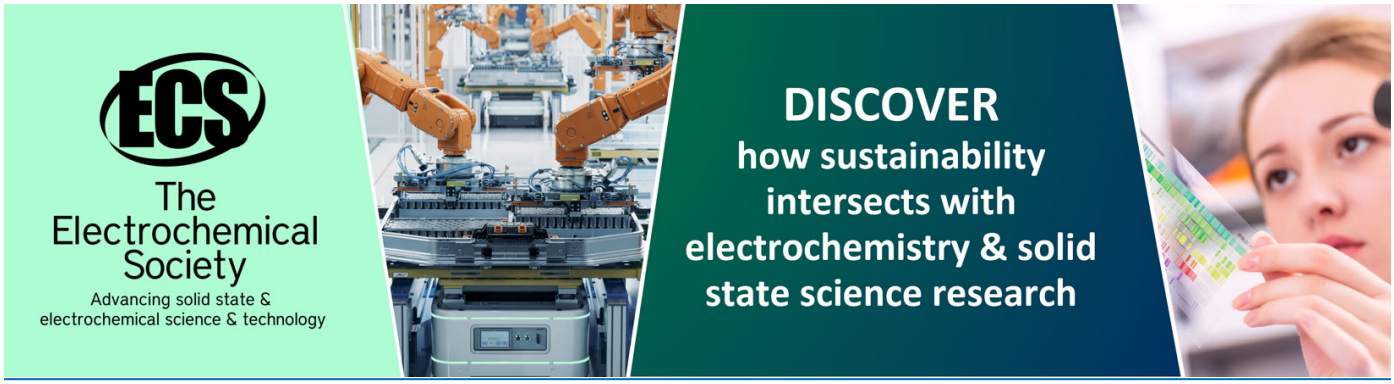
Nanotechnological Nano Noses



Nanotechnological Nano Noses

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Abstract. Nano-biosensors surely have their place in the modern universe of the nanotechnologies. The most recent age of electronic noses is nano biosensor clusters dependent on the electrical properties of olfactory receptors from well-evolved creatures, which are proteins arranged in the olfactory epithelium inside the nasal pits. The e-noses accompany various likely applications in sanitation and quality control (poisonous mixes, corruption, immaculateness), beauty care products, assurance of the earth (air and water quality, contaminants, smoke investigation), on-line observing of modern or natural procedures (aging, maturation), security controls (location of risky or harmful substances, explosives, drugs), as a guide while scanning for covered casualties, clinical diagnostics (diabetes, schizophrenia, malignant growth, and so on.), and so forth. These e-noses have been utilized for quite a long time in the research centers of numerous associations. Notwithstanding, as of not long ago they have been unreasonable for use in reality. E-noses have needed versatility, taken too long to even think about producing valuable outcomes, and have just had the option to break down lab arranged examples. The Nano-Nose will upset the electronic nose industry with its minimized size and down to earth pertinence. The lightweight gadget is handheld and can identify and measure analytes quickly. The Nano-Nose is likewise one of a kind in its capacity to break down gushing air instead of just lab controlled air tests, enhancing its true ease of use.

Keywords: Nano- noses, olfactory, biosensor

1. Introduction

Nanotechnology is the perception and regulation of the problem at dimensions varying from about 1 to 100 nanometers, where one of a kind marvels allow modern applications [1-5].The imaginative component of these nanomaterials is their size; when the size of materials is obliged into the nanoscale measurements they get novel physical and substance properties. Nanomaterials can work all alone or can be incorporated into progressively complex gadgets. A gadget with coordinated nano-highlights can play out some specific activities solely because of the fuse of specific nonmaterial [6-9]. If those materials were not in the nano go, the gadget would not work at all or would work unexpectedly. In straightforward words, we can say that the properties of such fabricated items rely upon how its particles are masterminded. On the off chance that we revise the iotas in coal, [10-15] we can make precious stones. On the off chance that we modify the molecules in the sand (and include a couple of other minor components), we can make PC chips. On the off chance that we revise the molecules in the earth, water, and the air we can make potatoes. A nanometer is a one-billionth of a meter [16-19]. One piece of paper has a thickness of about 100,000 nanometers: a single gold particle has a width of around 33 percent. Nanotechnology has a wide scope of uses and this examination essentially centers

around nano-biosensors [20-26]. A nano-biosensor is a gadget that joins a natural marker with an electrical, mechanical, or compound detecting framework on the nanoscale.

1.1. NANO NOSES

In this examination, we acquaint with you the current sort after Nano Nose. Since 1982, research has been led to create advances, regularly alluded to as electronic noses that could distinguish and perceive smells and flavors [27-30]. These electronic noses are exceptionally profitable than human sniffers. Human sniffers are expensive when contrasted with an electronic nose. It is because these individuals must be prepared [31-35]. This is a tedious procedure better than that is the development of an electronic nose. Furthermore, for the affirmation of the qualities got from a sniffer, the outcome acquired from the sniffer must be contrasted and some other sniffer's worth. Furthermore, here there are extraordinary odds of distinction in the qualities got by every person [36-40]. The Discovery of risky or toxic gas is beyond the realm of imagination with a human sniffer. Therefore mulling over every one of these cases we can say that the electronic nose is profoundly productive than the human sniffers.

This idea of electronic noses that impersonate the olfactory frameworks of warm-blooded animals and bugs have been charming for the scientists engaged with building better, less expensive, and littler sensor gadgets[41,42]. A superior comprehension of the gathering, signal transduction, and scent acknowledgment components for well-evolved creatures joined with the critical accomplishments in different fields like material science, microelectronics, and software engineering has lead to the improvement of e-noses. Every single piece of the electronic nose is like the human nose. The capacity of breathing is finished by the siphon which drives the gas to the sensors. The gas breathed in by the siphon is separated which in the human is the bodily fluid layer. Next comes the detecting of the sifted gas, which will be finished by the sensors i.e., olfactory epithelium in the human nose. Presently in the electronic nose, the synthetic hold happens which in the human body is a chemical response. After this, the phone layer gets depolarized which is like the electric signs in the electronic nose. This gets moved as nerve motivation through neurons i.e., neural system and electronic hardware.

In any case, one significant point that must be considered is that the olfactory arrangement of even the easiest creepy crawlies is mind-boggling to such an extent that it is as yet difficult to repeat the equivalent at the current degree of innovation. For instance, the organic receptors are consistently supplanted during the life of warm-blooded creatures in an entirely solid manner so the receptor exhibit doesn't require to be adjusted. Presently on account of the current electronic nose gadgets, their presentation is substantially more reliant on the sensor's maturing and particularly the sensor's substitution and they require a much successive recalibration to represent the change. Also, the current electronic nose gadgets dependent on metal oxide semiconductors or leading polymers that explicitly distinguish vaporous odorants are regularly enormous and costly and consequently are not sufficient for use in miniaturized scale or nanoarrays that could mirror the presentation of the characteristic olfactory framework. Nanotechnology is viewed as a key in propelling e-nose gadgets to a level that will coordinate the olfactory frameworks created commonly. The extent of the Nano nose program is to build up a gas sensor - or a "counterfeit nose" given polymer cantilever exhibits and an optical identification framework.

How about we investigate the essential fundamental standard of a nano nose, olfaction, our feeling of smell, relies upon the ability of particular tangible cells in the nose to identify airborne odorant atoms. These olfactory cells contain explicit protein atoms that go about as 'olfactory receptors' - they tie just to explicit odorant particles present noticeable all around breathed in through the nose. At the point when such a coupling occasion happens, the olfactory receptors change their shape and this distortion triggers compound and electrical signs which are in the long run transmitted to the cerebrum through neurons. In people, as in numerous different warm-blooded creatures, when gases enter the nose, the natural mixes including the scents diffuse through a slender layer called the epithelium. There are more than 100 million receptors of roughly 1000 sorts situated in this layer. These receptors are delicate by fluctuating degrees to more than one kind of smell atom. A reaction design is in this way delivered decides the capacity of the cerebrum to separate between various scents. Human and

particularly some creature noses (think bomb-sniffing canines) are exceptionally advanced and incredibly delicate gas sensors that can recognize fundamentally the same as gas atoms**.**
The Nano nose gadgets have just settled a significant situation for themselves in the different fields of:

- Medical diagnostics (cancer, asthma).
- Food wellbeing and quality control (harmful mixes, debasement, and immaculateness).
- Protection of the earth (air and water quality, contaminants, smoke investigation).
- Online checking of modern or natural procedures (maturing, maturation).
- Safety controls (identification of harmful or risky substances, explosives, drugs).
- Also as a guide while looking for covered casualties.

2. Principle

Olfaction, our feeling of smell, relies upon the ability of specific tangible cells in the nose to identify airborne odorant atoms. These olfactory cells contain explicit protein particles that go about as 'olfactory receptors' - they tie just to explicit odorant atoms present noticeable all around breathed in through the nose. At the point when such a coupling occasion happens, the olfactory receptors change their shape and this disfigurement triggers synthetic and electrical signs which are at the end transmitted to the cerebrum through neurons. In people, as in numerous different warm-blooded creatures, when gases enter the nose, the natural mixes involving the scents diffuse through a slight layer called the epithelium. There are more than 100 million receptors of around 1000 kinds situated in this layer. These receptors are touchy by shifting degrees to more than one kind of scent particle. A reaction design is along these lines delivered that decides the capacity of the cerebrum to separate between various smells. Human and particularly some creature noses (think bomb-sniffing canines) are complex and incredibly touchy gas sensors that can recognize fundamentally the same as gas atoms. The electronic nose is a gadget that utilizes a variety of synthetic sensors attached to an information handling framework that emulates how a nose works. The sensors each produce autonomous reactions to the distinctive compound components inside a given example and the whole of the considerable number of sensors' reactions is a 'design relating to that smell. To distinguish an obscure example, the information handling framework thinks about its reactions to a library of beforehand estimated designs. In any case, these electronic noses are not convenient and not proficient. Nano nose could beat these impediments.

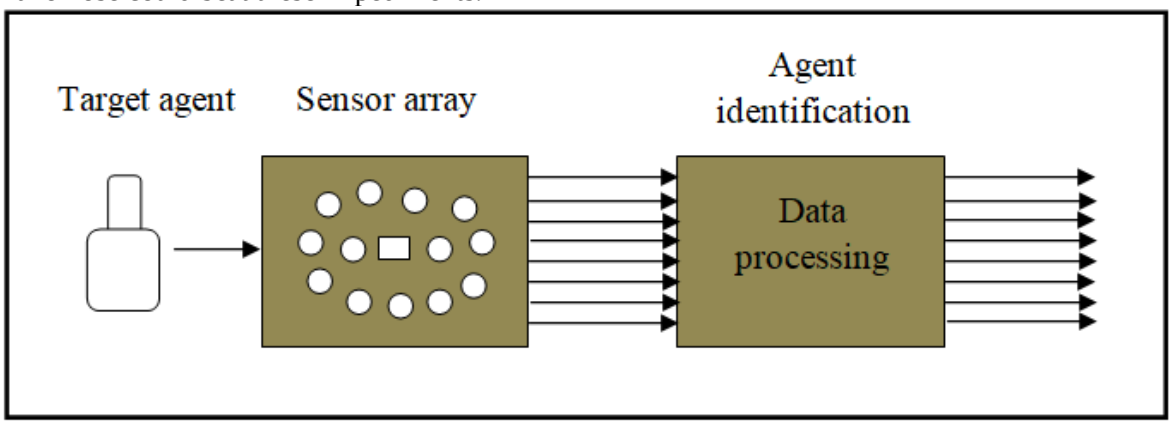

Figure 1. Artificial noses make use of the key principles of olfaction

The extent of the Nano nose program is to build up a gas sensor - or a fake nose" in light of polymer cantilever exhibits and an optical identification framework. The rule is that atoms adsorbed on a micrometer-sized cantilever will make the cantilever divert because of changes in surface pressure. On the other hand, a mass change can be distinguished by checking a move in the resounding recurrence of the cantilever. For the mass location, the cantilever ought to be as little as could reasonably be expected (nanometer measurements) to expand the mass affectability. The counterfeit nose will be prepared to do precisely perceiving and measuring various distinctive airborne synthetic substances present at amazingly low fixations all the while.

3. Applications

3.1. MEDICAL DIAGNOSTICS

The SPOT-NOSED (Single Protein Nano-biosensor Grid Array) venture brought about "electronic noses" to assist specialists in recognizing and distinguish issues by smell. The nano biosensors are built by putting a layer of olfactory receptor proteins from creature noses on a microelectrode; by estimating the response when the proteins interact with odorant atoms, the framework can recognize odorants in fixations that people would miss through and through. A nano biosensor-based electronic nose would require, at least, a few hundred unique proteins; various proteins respond to various odorants. The human nose, for instance, utilizes about 1.000 various proteins to permit the mind to decide 10,000 unique scents. This strategy could prompt another and snappier approach to test for the nearness of ailment forms in pee, blood, discharge or other real discharges from patients. Likewise, smell innovation could detect spoiled food, explosives, or medications.

CANCER: Nano noses could prompt clinical applications to analyze organ disappointment, bacterial contamination, or infections, for example, the disease being made economically accessible inside a couple of years, just as gadgets that would majorly affect different areas. A definitive objective of a nano nose is to recognize sickness at the most punctual stage conceivable, in a perfect world at the degree of a solitary cell or different cells of disease stages.

As per Vince Rotello from the University of Massachusetts, the human nose has a progression of receptors, which respond distinctively to various mixes. Therefore it's anything but a particular smell that the receptors respond to, however it is a summed up reaction delivered by the receptors, which makes the smell. Collaborated with his associates from the college and with researchers from the Georgia Institute of Technology, Vince Rotello applied the equivalent 'nose-guideline' to recognize proteins.

The 'nano nose' utilizes an arrangement of six receptors, every one comprising of an answer with gold nanoparticles not bigger than 2 nanometers, everyone having an alternate covering as well. Nitrogen particles from the natural atoms which make up the covering of the nanoparticles, various kinds of proteins have various highlights, along these lines having a property to join to different receptors, through authoritative with certain receptors more than with others. The group's errand was to recognize those properties of authoritative for various proteins. For this reason, the group utilized an atom radiating a fluorescent sign. The atom appended to the receptor particles and afterward, it was supplanted by a protein particle when the last bound to the receptor. Thusly, the more the fluorescent particle was uprooted, the more light delivered. The outcomes were along these lines examined by the PC. During the analyses, the researchers ran tests with 56 distinct proteins and demonstrated that the signs delivered by the receptors could be then used to recognize among different proteins. The 'nano-nose' was precise in 96 of 100 cases during these tests.

ASTHMA: Nano noses can likewise be of extraordinary guide to asthma patients. Explorers have just actualized nano hubs which could tell the asthma patients the dangers of assaults. The watch would go about as a sort of mechanical nose, checking the degrees of specific gases which are referred to aggravate the aviation routes, for example, ozone, unburnt hydrocarbons from petroleum, and the oxides of nitrogen. It would give wearers an admonition that would permit them to make precaution strides, for example, withdrawing inside or ensuring they had an inhaler to hand. The minuscule sensor would work by estimating the electric flow moving through gas particles caught in a chip. A voltage is applied over the chip and afterward the gas streams in and changes the current. What's more, as it examines the voltage, it will show a range that unveils the available gases.

3.2. ENVIRONMENT

Specialists in California have found that the tube-shaped forms of buck balls can be utilized to recognize the poisonous gases nitrogen dioxide and alkali. Both nitrogen dioxide and smelling salts add to nursery warming and corrosive downpour, so levels in the climate must be continually

observed. Specialists likewise need to gauge groupings of these gases at, for example, coal-consuming plants to check the effectiveness of scouring frameworks that expel contaminations.
Existing estimation methods are tormented by significant expense, an absence of movability of necessities. The nanotube sensors, which have been created by a group of scientists at Stanford University drove by Hongjie Dai, are viewed as ready to tackle these current issues.
These sensors comprise nanotubes with metallic leads associated at either end. In contrast to current sensors, they work at room temperature and are modest to deliver. They are likewise small enough only 3 micrometers 105 to be utilized in a "lab-on-a-chip", a microchip-based apparatus for performing compound investigations [43]. The gathering specialists are making changes to these nanotubes considering different applications and have just had some achievement in making nanotubes that can be utilized for distinguishing carbon monoxide [44].

3.3. NANO NOSES IN SPACE PROGRAMS

There are numerous riddles in innovation that presently can't seem to be unwound. One such secret that is found in space stations is the point at which the commencement stops the spaceship doesn't dispatch and even the best space travelers a hindered when this occurs. One little glitch in the detecting gadget can mean a huge number of dollars lost.
Boeing, a provider of rocket motors for NASA, moved toward a group of experts in the year 2007 with a critical requirement for a minimal and solid hydrogen sensor. Their primary inspiration to imagine a nano nose that recognizes numerous gases was because occasionally they needed to drop rocket dispatches on account of bogus alerts from the prior utilized hydrogen sensors. Not just that hydrogen is a generally utilized concoction in numerous enterprises so a modest and dependable hydrogen sensor will assist these businesses with handling hydrogen all the more securely and effectively.
Basically, the gadget comprises numerous silicon nanowires on a solitary chip. These are small silicon wires that can restrict and manage light fundamentally the same as how metal wires control power. The nanowires are covered with material delicate to hydrogen. The nearness of hydrogen changes the measure of light coming out of the nanowires. Since they are so little there can be several them on a solitary chip and recognizing a wide range of gases by a similar chip is conceivable.

SPACE STATION: Nano nose can be utilized in the space stations to track down possible contaminants. As of now, an Electronic nose is being utilized around there. The E-Nose examined the air with 32 sensors that can identify different scents and pinpoint which ones are risky to people. The smooth, shoebox-sized E-Nose, the third era of its sort, observed the air for 10 contaminants persistently. The E-Nose distinguished formaldehyde, Freon 218, methanol, and ethanol, however, every one of them was at innocuous levels, An instrument like this would one be able to day stay on the Space Station and screen air quality progressively Some of the applications incorporate sensors for identifying risky materials, the screening of new aroma elements for the beautifying agent's industry, or creating counterfeit noses for old individuals to recapture their lost feeling of smell. Nano nose is versatile and lighter than an electronic nose. What's more, it has preferable effectiveness over E-nose to smell the contaminants. Later on, the Nano nose could be utilized in checking team lodges for vehicles to the moon and different goals or be positioned on a moon base. Other potential applications incorporate distinguishing a seething fire before it emits, sniffing for unexploded land mines, and checking for substance spills in a work zone.

3.4. FOR FOOD ANALYSIS, SAFETY AND QUALITY CONTROL

Sanitation is a basic issue for local and universal shoppers. Identification of sullying in bundled meat will be useful in cautioning customers from wellbeing perils. The most dependable, non-dangerous, and fast procedure is to utilize a counterfeit olfactory framework, which has likely applications in the food and meat businesses.
The gadget which was created by researchers Yang Liu, Shantanu Chakrabartty, and Evangelyn Alocilja at Michigan State University, can quantify the measure of microorganism pollution on a specific food or machine. Giving processors more information to decide the degree of an issue their exploration was distributed in the 24 October issue of the Nanotechnology diary. Their paper depicts

how the nano-biosensor fills in as an atomic transistor. Activated by the nearness of explicit microorganisms on an insusceptible sensor,

The transistor works by handling information through crucial rationale doors. The rationale doors work by restricting occasions between an antigen and an immune response into a quantifiable electrical sign utilizing polyaniline nanowires as the transducer. The rationale doors are made by designing antibodies at various spatial areas in an insusceptible sensor test. Immunosensors are biosensors that utilization antibodies to perceive the nearness of a microorganism. In their examination, B. cereus and E. coli were utilized as model microorganisms. Their tests were approved by taking estimations with various microbe focuses.

Other new developments are equipped for identifying different perilous microorganisms. The US Department of Agriculture's Research Service has been fruitful in making a nano biosensor that recognizes Salmonella microbes. This newly discovered innovation could upgrade sanitation and security guarantees a group of researchers. As per the US Department of Agriculture's Research Service ARS), cooperation between its specialists at the Quality and Safety Assessment Research Unit and researchers at the University of Georgia has brought about a nanorod-based biosensor that empowers fast location of the Salmonella microbe with high affectability.

4. Future Perspectives

The future possibilities of the nano nose are various in numerous fields. These nano noses can be utilized in the food business for keen bundling innovation, can be utilized for the identification of microorganisms in food and refreshments just as for nanoscale newness pointers. These nano noses can likewise be utilized in the field of medication to analyze individuals who are experiencing diabetes. Go food shopping, or out to a café, and you could convey your nano-nose, an individual tasting sensor modified to test nourishment for things you don't care for or synthetic concoctions and allergens which may make you sick. In the interim, nano-sized scanner tags will empower arbitrary particles of an animal's meat to be labeled and observed from homestead to each final result

5. References

[1] W. Gardner Julian, N. Bartlett Philip, *A Brief History of Electronic Noses, Sensors and Actuators B, Vol: 18, no. 19, pp. 211-220, 1994.*

[2] W. Gardner Julian, N. Bartlett Philip, *Electronic Noses: Principles and Applications, 1999.*

[3] Jayendra K Amamcharla, SuranjanPanigrahi: Metalloporphyrin Based Opto-electronic Nose for Sensing Acetic Acid as an Indicator Compound of Meat Contamination, Published by the *American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org.*

[4] Scientists Create Nano Nose Aimed At Sniffing Out Diseased Cells ScienceDaily (Apr. 26, 2007) From the University of Massachusetts Amherst by Vincent Rotello and Uwe Bunz

[5] Electronic Nose To Return From Space Station ScienceDaily (Sep. 11, 2009) - From the NASA's Jet Propulsion Laboratory, http://enose.jpl.nasa.gov.

[6] Smell Of Success For Nanobiosensors ScienceDaily (May 15, 2006) - SPOT-NOSED Project

[7] M. Su. S. Li, V.P. Dravid: "Smart Miniaturized Chemical Multiplexed Sensor Array," *J. Am. Chem. Soc. 2003, 125(33). 9930-9931.*

[8] U.S. Patent Application, "Miniaturized Semiconductor Sensors Fabricated by DPN Using Sol-Inks, "filed 2/18/04. NU 22101, V.P. Dravid, M. Su.

[9] http://cordis.europa.eu/nanotechnology/nanomedicine.htm

[10] Artificial Nano Nose Sniffs out Cancer Cells by Lucian Dorneanu, *Science Editor, 23rd April 2007*

[11] Amalia Z Berna, Alisha R Anderson, Stephen C Trowell. Bio-benchmarking of electronic nose sensors. *PLOS ONE. DOI: 10.1371/journal.pone.0006406*

[12] Bell, G.A. (1996) Molecular mechanisms of olfactory perception: Their potential for future technologies. *Trends in Food Science &Technolgy, 7, 425 – 431*

[13] Srivastava. A.K. and Levy, D.C. (2002) Gas sensor monitoring of environmental air quality. *ChemoSense, 4(3), 8-10*

[14] PK Singh, K Sharma, Mechanical and Viscoelastic Properties of In-situ Amine Functionalized Multiple Layer Grpahene/epoxy Nanocomposites, *Current Nanoscience 14 (3), 252-262*
[15] Nanotechnology miracle: "Nano Nose published by *The Viewspaper in the July 8th, 2009 edition*
[16] Vidic, J.M. et al. Quantitative assessment of olfactory receptors activity in immobilized nanosomes: a novel concept for bioelectronic nose. *Lab Chip 6. 1026-1032 (2006).*
[17] PK Singh, K Sharma, A Kumar, M Shukla, Effects of functionalization on the mechanical properties of multiwalled carbon nanotubes: A molecular dynamics approach, *Journal of Composite Materials 51 (5), 671-680*
[18] Hou. Y. et al. A novel detection strategy for odorant molecules based on controlled bioengineering of rate olfactory receptor 17. *BiosensBioelectron (2006).*
[19] Gomila, G., Casuso, I., Errachid, A., Ruiz, O., Pajot, E., Minic, J., Gorojankina, T., Persuy, M.A., Aioun, J., Salesse, R., Bausells, J., Villaneuva, G., Rius, G., Hou, Y., Jaffrezic, N., Pennetta, C., Alfinito, E., Akimov, V., Reggiani, L., Ferrare, G., Fumagalli, L., Sampietro, M., Samitier, J. *Advances in the production, immobilization, and electrical characterization of olfactory receptors for olfactory nanobiosensor development. Sensor actuat B-chem 116, 66-71 (2006).*
[20] The 'e-Nose': Scientists try to develop an electronic sniffer published by ACS' Chemical Reviews
[21] http://met.usc.edu/research_projects_nanoscience.html
[22] P.T. Kissinger, Biosensors—a perspective, *Biosensors and Bioelectronics 20, 251242516, 2005.*
[23] Avraham Rasooly, Guest Editorial, Moving biosensors to point-of-care cancer diagnostics, *Biosensors and Bioelectronics, 21, 1847-1850, 2006.*
[24] Avraham Rasooly, James Jacobson, Development of biosensors for cancer clinical testing, *Biosensors and Bioelectronics 21, 1851-1858, 2006.*
[25] Goyal, M. and B. Gupta, Analysis of shape, size and structure dependent thermodynamic properties of nanowires. *High Temperatures--High Pressures, 2019.*
[26] Massood Z. Atashbar, Bruce Bejcek, Srikanth Singamaneni, and Sandro Santucci, *Carbon Nanotube Based Biosensors, 1048-1051, IEEE, 2004.*
[27] A Yadav, A Kumar, PK Singh, K Sharma, Glass transition temperature of functionalized graphene epoxy composites using molecular dynamics simulation, *Integrated Ferroelectrics 186 (1), 106-114*
[28] Joseph Wang, *Electrochemical biosensors: Towards point-of-care cancer diagnostics, Biosensors and Bioelectronics, 21, 1887–1892, 2006.*
[29] Goyal, M. and B. Gupta, Analysis of shape, size and structure dependent thermodynamic properties of nanowires. *High Temperatures--High Pressures, 2019 48.*
[30] Tuan Vo-Dinh, Paul Kasili, MusundiWabuyele, Nanoprobes and nanobiosensors for monitoring and imaging individual living cells , *Nanomedicine: Nanotechnology, Biology, and Medicine 2, 22– 30, 2006.*
[31] K Sharma, KS Kaushalyayan, M Shukla, Pull-out simulations of interfacial properties of amine functionalized multi-walled carbon nanotube epoxy composites, *Computational Materials Science 99, 232-241*
[32] G. Zheng, F. Patolsky and C.M. Lieber, Nanowire biosensors: a tool for medicine and life science, *Nanomedicine: Nanotechnology, Biology and Medicine, Volume 2, Issue 4, Page 277, 2006.*
[33] ShumingNie, Yun Xing, Gloria J. Kim, and Jonathan W. Simons, Nanotechnology Applications in Cancer, *Annu. Rev. Biomed. Eng., 9, 12.1–12.32, 2007.*
[34] Sterling V.A., Global Nanosensor Market to Reach $17.2 Billion by 2012, Says New Report, According to NANOSENSORS: A MARKET OPPORTUNITY ANALYSIS, December 7, 2004.

[35] Electronic nose sniffs out food aroma quality by Mike Stones , 22 Dec 2009 published in the website www.foodqualitynews.coni
[36] K Sharma, M Shukla, Three-phase carbon fiber amine functionalized carbon nanotubes epoxy composite: processing, characterisation, and multiscale modeling, *Journal of Nanomaterials 2014*
[37] Nano sensors offer rapid detection of Salmonella, claims ARS published by Jane Byrne on 6-Jan-2009 in the website www.foodproductiondaily.com
[38] Nanotech biosensor developed for multipathogen detection published by Ahmed ElAmin on 8-Oct-2007 in the website www.foodproductiondaily.coin
[39] S.Huang, B. Maynor, X. Cai, X J Liu, Ultra long, well aligned singlewalled carbon nanotube architectures. on surfaces, *Adv. Mater. 15, 1651-1655 (2003)*
[40] JN Wohlstader, J L Wilbur, G B Sigal, H A Biebuyck, M A Billadeau, Carbon nanotube based biosensor. *Adv. Mat. 15, 1184-1187 (2003)*
[41] J li, Y J Lu, Q. Ye. M. Cinke. J. Han, M Meyyappan, Carbon nanotube sensors for gas and organic vapour detection, *Nano. Lett. 3, 929-933 (2003).*
[42] A Kumar, K Sharma, AR Dixit A review of the mechanical and thermal properties of graphene and its hybrid polymer nanocomposites for structural applications, *Journal of materials science 54 (8), 5992-6026.*
[43] Nano Biosensors and integrated Microsystems for Intelligent Food packaging from the *IFT Summit Conference: Food packaging Innovations – May 7-9, Baltimore, Maryland*
[44] *Nano noses published in New Scientist by Mark Schrope on 25th December 1999*