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ABSTRACT

The recent developments in the Nano scale systems promise to be a harbinger for scientific and technological advancements initiating a fundamental understanding and quest of novel physical, chemical, and biological characteristics of systems in nano material dimensions. The latest architectures in nanostructures and nano systems are representative of improved functionalities. The nano structured materials have future applications for chem.-bio sensors, medical therapies and potential applications in security and environment safety. (Merkle, R.C.1993)

INTRODUCTION

The intentional or unintentional contamination of the environment, food items and the agricultural products has been increased due to certain local and global threats of poisonous gases and terrorism. This situation makes the decentralized sensing a core issue for several international bodies. A nanotechnology based sensor platform makes the direct electrical detection of biological and chemical agents possible in a highly multiplexed format over a vast dynamic range during clinical testing. Nucleic acid layers can be combined with nanomaterials-based electrochemical which produce affinity biosensors such as the “DNA Biosensor” or “Genosensor”. Such devices are used for converting the hybridization event into an analytical signal for obtaining sequence specific information, which are beneficial for clinical, environmental, or forensic investigations.

CURRENT STATUS OF THE FIELD

Medical nanotechnology is a branch of nanotechnology which practically applies its principles and findings in the field of health care and maintenance issues. Nanotechnology is a broad field of knowledge which includes scientific endeavors involving manufacturing and machining which occurs on a molecular scale. There are a number of applications of medical nanotechnology in the practical field and in its early phases, people had raised higher hopes about the radical changes which will transform the medical world with the assistance of medical technology and the nano devices. (Merkle, R.C.1994)

Nanotechnology currently operates on a smaller scale. It is precisely targeted to develop the surgical instruments, the drug delivery systems, and the implants. Nanobots are used to perform a medical imaging study inside the human body and perform surgical procedures. Nanomaterials can also be implanted into the body of some patient with a badly damaged bone or joint

This technology is suitable to monitor and minimize environmental pollution, the root cause of many chronic and deadly health disorders and diseases, maligning millions of people due to its ill effects. Due to the nanotechnology based portable, wireless and web-based gas sensors, the pollution can now be monitored at several ground stations.

These systems, when developed on the rational and scientific basis, will have the capability to detect the plight of the biological systems in the living beings. These detections will be made electrically, optically, and magnetically. This will bring transformations not only in physical and chemical world but primarily in the medical and biological world. These nano sensors will sense not only at molecular level in the living cells but at the level of various parallel integrations of multiple signals.

However, there are numerous risks and issues associated with the frequent use of engineered nano materials. The number of nano materials and their wide range of applications are multiplying day by day. Research has been conducted on vast scales regarding the potential dangers of nano particles to biological organisms. These researches have drawn roots from academia, industry, and governmental regulatory agencies all over the world. Conducting reliable biocompatibility studies with nanostructures are highly critical due to the uncertain behavior of matter in biological settings. Besides, making accurate measurements of properties as size, shape and surface chemistry are in themselves quite complicated. Hence, to tackle with this complexity, risk assessment of nano materials demands a close collaboration of experts from various fields such as toxicology, chemistry, medicine and molecular biology.

DISCUSSION

The application of nano-bio sensors is greatly supplemented due to their biocompatibility with the organism, the biological tissues or any fluids being tested. When it comes to invivo system or systems, they have to be non-toxic in the very first place. Moreover, the materials should not exhibit a biological response that mars the purpose of testing. In other cases, like sensors designed for in vitro use, need to be in accordance with the biological fluids under study, particles or components used for measurement purposes. Nano particle mediated sensors, for example, the bio-imaging aids or the drug delivery aids have complexities such as the high dissolution rate, the accumulation and the surface adsorption of biological molecules. Expert’s services are utilized during the measurement of more mature prototypes to guarantee safety and efficacy of the sensor technology.

Nanotechnology has the potential to influence medical diagnosis and therapies. Early detection of cancer is indispensible even before anatomic anomalies appear. The upcoming challenge in cancer diagnosis, during the 21st century, is to be capable of determining the exact relationship between the cancer biomarkers and the clinical pathology and to be able to detect certain life threatening tumors at an early stage for maximum therapeutic advantages. For instance, the goal of molecular imaging is to timely diagnose when the tumor mass has expands to 100-1000 cells resulting in breast cancer as compared to mammography, which require more than one million cells to accurately diagnosis the clinical situation.

Many counter cancer drugs are designed to target cancer cells. The distribution of anticancer drugs in healthy body organs or body tissues is extremely undesirable. It happens that the systemic application of these drugs often causes severe side effects in tissues found in bone marrow, cardiac region, and nervous system. To launch an effective war against cancer, there is a need to selectively attack the cancer cells, and at the same time saving the healthy tissues from the excessive burdens of drug toxicity and side effects. Furthermore, the rapid elimination and pervasive distribution into non-targeted organs and tissues often needs the extensive administration of a drug, which is uneconomical and risky. This concurrent toxicity is a serious limitation of the current cancer therapies which cause the patient to fall a prey to the ill effects of the drug toxicity far earlier than the tumor viciousness.

Nano material can contribute greatly in medical field in general and cancer therapy in particular. Nano science holds bright prospects to augment medical therapy, particularly in safer drugs' delivery to the critical targeted points, as claimed by the Nobel Laureate Robert Curl.

Curl, in one of the sessions of 95th Indian Science Congress, emphasized that non-particles, which would act as the capsules carrying drugs can be biodegradables and safer; thus, preventing harmful effects upon the human body and organs. Besides these, there are various perspectives where nanoscience offers its salubrious services like the creation of enzymes synthesizing molecules, and producing the required enzymes at the stable rate required by the body. The process of enzymes' production has the potential to become the reality in near future, in contrast to the production of enzymes without any controllable factors in the present times.

There is another way aspect where nano materials can confer their benign advantages. For instance, the problem of drugs transportation to the cell layers in retina of the eye. It is difficult for the fluid eye ball to accept the medicine. The nano capsule eases the direct drug carriage to the retinal cell layers. J.K. Viswanath, who worked in the Graduate School of Biomedical Sciences, located in Texas, envisages that the US Food and Drugs Administration has considerd Poly DL Lactide C-glyolide as an effective, trustworthy, stable and biodegradable vehicle to deliver drugs.

According to eminent scientists, Nano science can be deployed to treat prostrate cancer, malign diseases and cellular mitigation. The second generation of nano particles to be developed would target nano therapeutics related to antibodies and peptides. Nano materials for applied drugs can be both viral and non-viral constructs.

Another scientist has illustrated the miracles of ancient civilization in this context. Persian Khanjar and the Damascus steel were materialized by unconsciously applying the nano technology. The iron ore was utilized in India and went through a process in traditional way at requisite temperatures to produce these fruitful items. If these ancient products are keenly examined, it is found out that there is the existence of carbon nano tubes in them. Nano technology ensures environmental protection if deployed in the stages of manufacturing, disposal, transportation and exposure.

Researchers from MIT are of the view that tiny particles containing a killer gene can effectively mitigate ovarian tumor growth in mice. Findings in this regard could lead to a satisfactory treatment of ovarian cancer causing more than 15,000 deaths every year in the United States. It is because, it usually is diagnosed at a relatively later stage making ovarian cancer one of the deadliest forms of the disease.

Anderson and other researchers from MIT claim that the gene-therapy treatment is equally as effective as the traditional chemotherapy. Furthermore, the accompaniment of Nan materials reduce the harmful side effects of chemotherapy because the gene are programmed to be expressed in the ovarian cells but remain inactive in other types of cell. Furthermore, to observe the tumor-related effects, the nanoparticles were administered by injection into the peritoneal cavity, where the abdominal organs such as the stomach, liver, ovaries and uterus are encased. Here, also nano materials justify their benefits.

The recently developed nanoparticles, made up of the positively charged biodegradable polymers, are known as poly beta-amino esters. When combined together, these polymers spontaneously assemble with DNA to generate nanoparticles. This polymer-DNA nanoparticle then delivers the functional DNA, when injected into the target tissue. For a couple of years, MIT-Lankenau team has been engaged in developing these nanoparticles as an alternative to viruses since these nano materials have exhibited their potential to treat ovarian cancer, a variety of other diseases, including prostate cancer and viral infections. It is also expected that nanoparticle-delivered genes help in mitigating the forms of cancers, including brain, lungs and the liver cancers.

Also, Regenerative medical therapy, which is based on the self-repairing potential of patients, has been medically tested in order to induce tissue regeneration in lost or seriously impaired tissues in the treatment of diseases. Recently, biology and medicine have been researched upon, to produce molecular mechanisms of tissue development to repair the chronic fibrosis. When a fibrotic tissue is degraded, it is regenerated by the neighboring healthy tissue, which is capable to introduce gene growth.

Molecular nanotechnology is one of the speculative subfields of nanotechnology pertaining to the possibility of engineering molecular assemblers and the machines which have the ability to re-order matter at atomic and molecular scale. Dr. Gregory. F describes Living organisms as existing naturally and fabulously complex systems of molecular nanotechnology. This statement portrays the amazing possibility that the human body can be cured of diseases by the machines constructed at the molecular level (nanomachines). This application of nanotechnology, to the branch of medicine, is commonly known as nanomedicine. In simpler words, nanomedicine is actually the medical application of nanotechnology. (Drexler K.E. 1981).

The applications and utility of nanomedicine range from the efficient medical use of nanomaterials, to nanoelectronic biosensors. It has possible future uses of molecular nanotechnology. Current problems exist for the nanomedicine, that relate to the understanding of the issues of toxicity, treatment, even research and the environmental impact of nanoscale materials.

Imagine a situation where one needs to go to the medical doctor in order to get the treatment for a chronic fever. Instead of giving a pill or prescription, the doctor advises him to an expert medical team to implant a tiny robot into his bloodstream. The robot is there to detect the root cause of your fever, travels to the target system and provides the needed medication directly to the infected region. The time is near when this will be used actually in medical procedures. They're called nano-robots. It is also speculated that using nanorobots in medicine would totally transform the world of medicine once it is materialized. Nanomedicine shall introduce the nanorobots into the body, to detect damages and to repair infections. The size of the typical and common blood borne nano robot would be between 0.5-3 micrometers, since it is the size possible due to capillary passage requirements. (Klafter, R.D., and Negin M., 1989)

New nanoparticle-based signal amplification and the coding strategies for bioaffinity are much in discussion. There is also focus on carbon-nanotube molecular wires for achieving efficient electrical communication with redox enzyme and nanowire-based DNA sensors. The question is often raised: Why nanomaterials? The buzzword ‘‘nanotechnology or the nano sensors’’ is now heard everywhere. Nanotechnology has recently become one of the most revolutionary fields in biology and analytical chemistry. Nanotechnology is usually defined as the creation of the materials or devices and systems by controlling of matter at the 1 to100 nm scale. These Nanodevices can be observed working inside the human body using MRI, this is particularly easy when the components are processed using mostly ^{13}C atom/atoms insteand of the naturally occuring ^{12}C carbon isotope. It is to be remembered that the ^{13}C is a nonzero nuclear magnetic moment.

In order to build these nano robots, Carbon would be the primary element used, due to the inherent strength and the other attributes of carbon. Nanorobots would be developed in desktop nanofactories specialized for this particular purpose. To avoid being attacked by the inner immune system, passive diamond coating is not only the best but also a secure choice for the exterior coating. All depends upon the smoother and flawless coating, which ensures the minimal reaction from the immune system. These devices have been designed in recent years but a working model has not been built so far.

After injecting such nano materials in the human body, the doctor will monitor their progress and will follow that the nanodevices have reached to the correct target treatment region. In this way, the doctors will be able to scan the desired sections of the body, and observe the nano-devices congregated neatly around their target tumor masses. To empower the nanorobots, there is a procedure to metabolize local glucose and oxygen for energy. For this purpose, communication with and monitoring the device can be attained by a broadcast type acoustic signaling. A navigational network installed in the body, will support the keeping of navigational elements also indicating high positional accuracy for the passing nanorobots that monitor information and want to know their location.

This shall help the physician to keep accurate track of the instruments in the body.

Another feature of the nanorobots will be the capacity to differentiate between cell types by checking surface antigens. It will be accomplished by the placement of chemotactic sensors in the specific antigens on the target cells. If the nanorobots become a reality, they can be retrieved by eliminating themselves through the human excretory system. Some possible applications using nanorobots are mentioned below:

Nano materials and nano science can initiate a revolution in the medical science, for example, in curing skin diseases. For this purpose, a cream having nanorobots may be used. It will shed off the right amount of dead skin, reduce excess oils, provide missing oils, nourish the right amounts by providing moisturizing elements, and even attain the elusive goal of deep pore purification by actually reaching down into the deep pores and cleaning them. Nevertheless, the cream should be a safe material with smooth-on and peel-off convenience.

Furthermore, a mouthwash full of efficiently placed nanomachines can aid in the identification and destruction of pathogenic bacteria, while at the same times allowing the benign flora of the mouth to thrive in a fruitful and healthy ecosystem. Moreover, the devices will be able to identify the particles of food, plaque or tartar, and uproot them from teeth to be rinsed away with water. It will be done very conveniently by floating in liquid and swimming freely, these devices would be able to reach the regions beyond the access of the ordinary and commonplace toothbrush bristles.

Medical nanodevices can also ensure the secure immune system by locating and nullifying unwanted bacteria and various viruses. It will achieve this by pin pointing the invader, and then puncturing it. Afterwards, by letting its contents spill out, the nano sensors will clean the internal systems of the body.

Such devices, working in the bloodstream of the living organisms, could nibble away the arteriosclerosis deposits; thus, widening the affected blood vessels for a smoother flow of blood. Cell herding instruments could restore artery walls and linings to health which will ensure that the cells and supporting structures are in their right places. Nanorobot must be small and active enough to navigate through the circulatory system and the intricate network of veins and arteries. In this way, the greater risks involved in heart attacks can be reduced.

Computer artwork of a medical nanorobot also can be beneficial in holding a sperm cell. Microscopic robot technology, if developed, will treat disorders pertaining to infertility. This machine will indicate a suitable sperm cell and will carry medication or miniature tools to enhance their fertility rate.

These materials are of different sizes, shapes and compositions which are easily available. The profound interest in such nanomaterials is due to their desirable properties. In particular, there is a great possibility to tailor their sizes and structures according to the requirements. Therefore, such properties of nanomaterials promise excellent prospects for designing newer sensing systems and enriching the performance levels of the bioanalytical assay.

There are other nano applications. Like, Enzyme electrodes are being extensively used to monitor a wide range of clinically or environmentally important substrates. The amperometric enzyme electrodes are the establishment of satisfactory electrical communication between the active site of the enzyme and the electrode surface. The redox center is electrically insulated by a protein shell. Due to this shell, the enzyme cannot be oxidized at an electrode at any potential. The chances of direct electron transfer between enzymes and electrode surfaces smoothes out the way for superior biosensing devices.

The nano science and the biological science go hand in hand. In fact, the primary functional units of the biological systems and sub-systems like, the membranes, enzymes, the motors and the nucleic acids are all easily influenced by the nano technology. This technology ranges from the preparation of polymers, dendrimers and other artificial organic nano structures.

Colloidal quantum dots, robust and stable light emitters, can be adjusted throght size variation. These bio-conjugating colloidal quantum dots are seen in diverse areas of application ranging from cell tracking to cell labeling, from vivo imaging to DNA detection and multiplexed beads. It is also demonstrated that Colloidal quantum dots have a greater linear absorption , cross section for excitation in comparison to the phycoerithrin. Colloidal quantum dots along with a vast range of bio-conjugation and optimal yield are commercially available.

Colloquially, numerous terms are used to describe nano science in medicine as biomedical nanotechnology, nano-biotechnology, and nano-medicine are some of the commonly used expressions. The integration of nano-materials to the biological sciences has led to the advancement of diagnostic devices, the contrast agents and analytical tools and the physical therapy application.

Among so many recent developments, Nanotechnology “on a chip” is one more dimension of lab on a chip technology. When magnetic nano-particles are bound to a suitable antibody, it is called the label of specific molecules, structures or microorganisms. There are also Gold nanoparticles tagged with short segments of DNA, which are used to identify genetic sequence of the sample under study.

Nanotechnology has caused a colossal boom in the medical field. The overall drug consumption and the ill-effects can be reduced to a greater extent by depositing the agile agent in the morbid region or regions. This highly sensitive technology reduces the costs in financial terms and the human sufferings as well. The dendrimers and nanoporous materials are fine examples of the previous statement. Then, there are block co-polymers forming the micelles for drug encapsulation. They work by holding small drug molecules and help them deliver to the desired location.

Another variation is based on the electromechanical systems abbreviated as NEMS, these are being researched upon for the active release of drugs. The personalized medicine eliminates the excessive drug consumption and treatment expenditures resulting in the societal benefits and welfare in general by uplifting the standard of public health system. Nanotechnology now also offers new opportunities in implantations, which are preferable over the use of injected drugs, since the latter usually displays the first-order kinetics. (Merkle, R.C.1993)

Nanotechnology is being utilized to reproduce or to treat the damaged or badly hurt tissues. Tissue engineering, as commonly known, makes extensive use of artificially stimulated cell proliferation with the help of nanomaterial-based scaffolds. For instance, bones can be treated to make them fully grown on carbon nanotube scaffolds or aides. This tissue engineering has the possibilities to replace the conventional modes of treatment like organ transplants or artificial implantations. It can be rightly said, that advanced forms of tissue engineering would lead to life extension one day.

Chemical catalysis and the process of filtration are two prominent methods where nanotechnology is playing a crucial role. The nano science provides novel materials with suitable features and appropriate chemical properties. In this sense, chemistry and biology are, indeed, the basic nanosciences.

The Rice University, in Texas, there is an instrument named as the “flesh welder,” is made use of to fuse two pieces of chicken meat together. After that, there is a green liquid with gold-coated nanoshells, that is spread along the seam at the point where the two pieces are joined together. Then the infrared laser is used to weld the two sides to each other. Optimistically speaking, this will help treat the blood leaks in surgical operations. Kidney or heart transplant can really benefit where there is a chance of huge blood loss. It suggests that the flesh welder would seal the artery to avoid blood loss.

Kidney diseases may find a solution in the Nanoparticles, and this concept is being studied along with the creation and implementation of molecular and atomic materials and instruments to diagnose and treat renal maladies. Nanonephrology provides nano-scale knowledge on the cellular molecular systems, normal and pathological states of the kidney functioning.

The diagnostic nanomachines, becoming very popular, could be used to detect the bodily internal chemistry. The Nano-robots carrying wireless transmitters, move around in the blood and lymph systems, and would inform when they deyecy any malfunctioning.
In a similar way, immobile nano devices can be placed in the nervous system to trace the function as the pulse rate and the brainwave activities. Implanted nanotechnology instruments will dispense drugs to treat chronic chemical imbalances. The highly advanced nanomedicine acknowledged nowadays, involves utilizing nanorobots in the form of minscule surgeons to repair injured cells or replace damaged cellular formations. Such Nanomachines might even replicate themselves or rectify genetic deficiencies by transforming DNA molecules.

The experts, scientists and the learned believe that the profound research is required regarding the possible risks of nanotechnology to human health, mind and body. Immobilized nanostructures or medical devices as surgical implants are not expected to pose any severe risks till the time they are stationary. Nevertheless, possible release or movement may cause irrevocable problems. For medical applications, where nanoparticles or nanostructures are extensively used, the specific toxicological properties need to be undertaken and studied deeply.

Metabolic support in the context of impaired circulation, poor blood flow, serious tissue damage especially due to inadequate transportation of oxygen can be dealt with nano science. An easier way to improve the concentration of available oxygen, despite the reduction of blood flow, would be to implant an artificial red blood cell. For instance, a sphere of internal diameter of 0.1 microns is typically filled with high pressure oxygen at 1,000 atmospheres. The oxygen is allowed to be released from the sphere at a stable rate. Oxygen can be released from the internal resource into the external world/environment at the desired rate, which however, will sufficiently fulfill human requirements. Technology will improve making systems more sophisticated, helping to release oxygen only when the external pressure of oxygen falls below the threshold level. So, oxygen could be used during an emergency, otherwise it will remain in reserve that would come to rescue only when normal circulation fluctuates.

Likewise, full replacement of red blood cells encompasses the design of devices capable to absorb and compress oxygen, especially in the situation when the pressure is above the level or has a high threshold. Human lungs often have oxygen in excess. And it will release the required amount when the partial pressure falls down to a lower threshold as this may happen in tissues using oxygen. In such cases, nanotechnology makes the selective transport of oxygen into an inner reservoir, a reality.

Sometimes a single stage does not provide an adequately selective transport system. In such situations, a multi-staged or cascaded system should be made use of. A strong power system is required to compress the oxygen, which might take energy from the burning process of glucose and oxygen. Now, release of the compressed oxygen will allow the energy to be recovered that was used to compress it. Meaning thereby, the sum total of the power consumed by such an instrument not be great. (Eigler, D.M., and Schweizer, E.K.1990)

If any instrument simultaneously absorbs carbon dioxide, when it is faced with high concentrations e.g in the tissues and then releases this gas when it is found at low concentrations e.g in the lungs, then the nano device will provide a solution to remove one of the primary products of metabolic activity. Studies similar to the ones mentioned above refer to the fact that a human being's oxygen intake and carbon dioxide exhale could both be managed for a period of approximately a day by this nano mechanism.

Now, when oxygen is taken in by the artificial red blood cells present in the lungs, at the same time the carbon dioxide is exhaled out. In contrast, the oxygen when it is being released in the tissues then carbon dioxide is being taken in. Compression of first gas can be provided only by decompressing the second and this process utilizes energy. It happens sometimes, that a failure of a 0.1 micron sphere leads to the creation of a bubble of oxygen which is less than a 1 micron in diameter. Failures of minimal intensity can be tolerated. However, in extreme cases the solution lies in nanotechnology: which makes such sudden shifts very infrequent.

Particularly, the mitochondria at some point, will fail due to the malfunctioning and the non-availability of oxygen. Now in extreme cases, the increased oxygen input in the presence of nonfunctional or semi-functional mitochondria, proves to be ineffective in saving the tissue's condition. Therefore, more direct metabolic support is urgently needed. The direct release of ATP is effective in restoring cellular functions and normal order especially when mitochondria's functions are compromised. Nano devices not only restore metabolite levels, by injecting them into the body, but also operate autonomously for many hours till the level of the energy stored in them is exhausted.

The levels of critical metabolites have to be restored, while at the same time the damages during the ischemic event should also be dealt with at the same time. Specifically, there can be several significant and radical problems which happen to various molecular structures within the cell or the tissues, including their DNA. The significant restoring of metabolite levels would be inadequate, when done by itself, to regenerate the cells to their normal state. There are numerous options which could be pursued at this stage. When the cellular condition deteriorates, some efficient and general method of stopping further deterioration is highly desirable. Cooling process of the tissue and the input of the necessary compounds that will block deteriorative processes is the dire need. It is clear, that this factor should be able to counter substantially before any greater damages or losses play havoc. A primary reason in this regard is that the self sufficient molecular machines or nano devices using externally provided power will operate even if the tissues themselves were no longer functional. Doctors will finally have the skill to heal injured cells and improving human life and body sustainability.

FURTHER DIRECTION

Advances in medical technology are only possible when they are founded on the grounds of understanding the reality living systems. With the devices discussed earlier, a better analysis of living systems and organisms together with their environment will become a reality.

CONCLUSION

Thus, Medical nanotechnology has numerous advantages and disadvantages. It can make wonders from cell repair on a molecular level to the most complicated medication administration. Medical nanotechnology but the important fact is to use the findings and research in the right direction. Nano materials should be used to improve the physical, chemical and biological environment of the living beings. It should be kept in mind that concerted efforts must be launched to minimize the evils and maximize the positive aspects of the nano technology. If this technology is utilized in the fullest measures, it is hoped that the humanity would lead a better life ahead.

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