Nano Material in Biosensor

Abstract:

A biosensor device is defined by its biological or bio inspired receptor unit with unique specificities toward corresponding analytes. Bioinspired receptor unit with unique specificities toward corresponding analytes. These analytes are often of biological origin like DNAs of bacteria or viruses, or proteins which are generated from the immune system (antibodies, antigens) of infected or contaminated living organisms. Such analytes can also be simple molecules like glucose or pollutants when a biological receptor unit with specificity is available. The use of these nanomaterials has allowed the introduction of many new signal transduction technologies in biosensors. Because of their submicron dimensions, nano sensors, nanoprobes and other nano systems have allowed simple and rapid analyses in vivo. Portable instruments capable of analyzing multiple components are becoming available. This work reviews the status of the various nanostructure-based biosensors. In order to increase sensitivities and to lower detection limits down to even individual molecules, nanomaterials are promising candidates due to the possibility to immobilize an enhanced quantity of bioreceptor units at reduced volumes and even to act itself as transduction element. Among such nanomaterials, gold nano particles, semi-conductor quantum dots, polymer nanoparticles, carbon nanotubes, nano diamonds, and graphene are intensively studied.

Introduction:

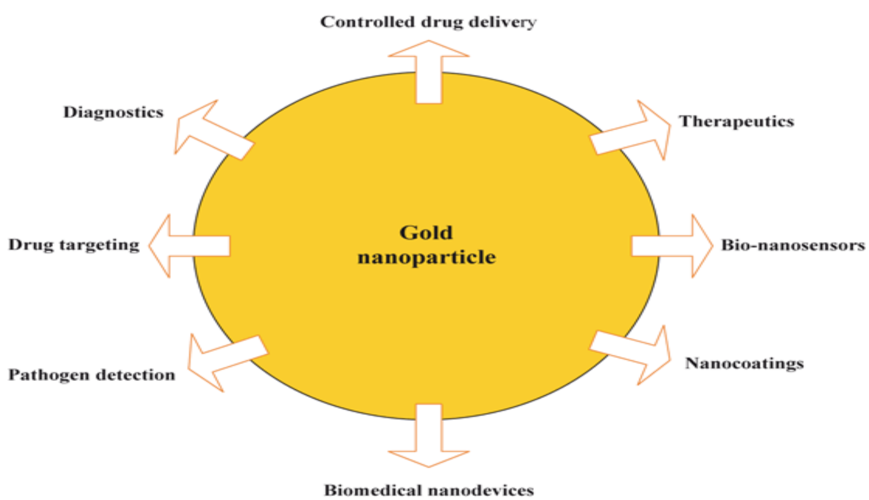
As in many different technological sections, nanomaterials have demonstrated their appropriateness for biosensing applications. The intelligent use of such nano-objects led to clearly enhanced performances with increased sensitivities and lowered detection limits of several orders of magnitudes. The advantage of such systems, compared to the other immobilization methods, is the reversibility, enabling the possibility to regenerate the transducer element. Furthermore, all components like the functionalized transducer surface and the modified bio-receptor can be characterized individually assuring the reproducibility of the constructed biosensor. This is the case for affinity biosensors like the immunoreaction between an antigen and its antibody or the hybridization of corresponding DNA strands. The specific properties of some nanomaterials clearly contributed to the development of “label free” transduction techniques or contribute to clear signal amplifications when used as labels.

GOLD NANOPARTICLES

The group of noble metal nanoparticles, gold nanoparticles are mostly used for biosensor application due to their biocompatibility, their optical and electronic properties, and their relatively simple production and modification. Gold nanoparticles have also demonstrated their advantages in bioanalysis using SPR transduction. This method is usually based on the change of the dielectric constant of propagating surface plasmons’ environment of gold films where the detection of the analyte can be recorded in different ways like the changes of the angle, intensity, or phase of the reflected light.

At particle sizes smaller than the excitation wavelength, the oscillating electrons (surface plasmons) cannot propagate along the gold surface leading to a polarization of the electron cloud at one side of the particle. SPR transduction replacing the gold film. The optimal configuration of this approach was determined for gold nanoparticles smaller than 40 nm at a distance to the gold film surface of 5 nm as illustrated. Gold nanoparticles have also shown their ability to form a powerful transduction platform for single molecule detection. By refractive index sensing of localized surface plasmon resonance (LSPR) coupled with enzyme linked immunosorbent assay (ELISA) using isolated gold nanoparticles of 60 nm sizes.

The properties of such gold nanoparticles can be tuned and adjusted. Whatever the desired application, almost any desired shape or size can be obtained using the appropriate synthesis technique. These different morphologies result in different optical, catalytic, and electronic behavior of these gold nanoparticles.



QUANTUM DOTS

Another prominent example of nanomaterials used for bio analytics are luminescent semiconducting nanocrystals called quantum dots (QDs). The most studied colloidal QDs are based on cadmium chalcogenides (S, Se, Te). Which provide a very large absorption spectrum with a size-dependent narrow emission spectrum. This phenomenon is due to the varying band gaps of the semiconductor material for different nanocrystal sizes (the bigger the particle the lower the band gap) which leads to distinct emission wavelengths from the recombination of the electron-hole exit on.

As already described, gold nanoparticles are excellent acceptors and are highly efficient QD quenchers. Due to the more favorable hybridization kinetics of the analyte DNA, the short sequence with the gold nanoparticle is released and the QDs' fluorescence reappears where its intensity is correlated to the analyte concentration. Another use of non-radiative energy transfer provoking QD fluorescence is called Bioluminescence Resonance Energy Transfer (BRET). Here, a light-emitting protein label transfers the energy to QDs and eliminates the necessity of an external excitation light source.

Magnetic nano particles:

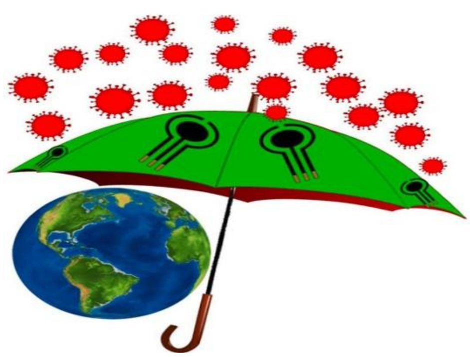
Magnetic nanoparticles are promising alternatives to fluorescent labels in biosensor devices. Nanosized magnetic nanoparticles show different magnetic behaviors compared to its bulk material due to the reduced number of magnetic domains (regions of parallel oriented magnetic moments caused by interacting unpaired electrons of an atom) leading to so called superparamagnetic behavior. Such superparamagnetic behavior prevents therefore from attractive or repulsive forces between the magnetic nanoparticles as long as no external magnetic field is applied. Beside a wide range of ferromagnetic materials, iron oxide is mostly used for bioanalytical applications.

Carbon Nano structures

The beneficial properties of nanostructured carbons such as carbon nanotubes or graphene made them a widely used material as electronic or electrochemical transducer in biosensor devices. In Carbon nanotubes possess the outstanding combination of nanowire morphology, biocompatibility and electronic properties. Therefore, carbon nanotube interfaces present clearly enhanced capacities, e.g., to approach the active sites of a redox enzyme and to wire it to the bulk electrode. Moreover, CNT films exhibit a high electroactive surface areas due to the natural formation of highly porous three-dimensional networks, suitable for the anchoring of a high amount of bioreceptor units, leading consequently to high sensitivities.

These materials are mostly obtained after mechanic exfoliation or chemical oxidation of graphite based on the Hummers and Offeman method. This initially called graphitic oxide is now generally known as graphene oxide and allows obtaining soluble carbon oxide sheets of undefined layer composition and sizes. The electric conductivity of this isolating material can be reestablished by chemical, thermal, or electrochemical reduction.

Prospects of nanomaterials-enabled biosensors for COVID-19 detection:



We are currently facing the COVID-19 pandemic which is the consequence of severe acute respiratory syndrome coronavirus (SARS-CoV-2). Since no specific vaccines or drugs have been developed till date for the treatment of SARS-CoV-2 infection, early diagnosis is essential to further combat this pandemic. In this context, the reliable, rapid, and low-cost technique for SARS-CoV-2 diagnosis is the foremost priority. At present reverse transcription polymerase chain reaction (RT-PCR) is the reference technique presently being used for the detection of SARS-CoV-2 infection.

However, in a number of cases, false results have been noticed in COVID-19 diagnosis. To develop advanced techniques, researchers are continuously working and in the series of constant efforts, nanomaterials-enabled biosensing approaches can be a hope to offer novel techniques that may perhaps meet the current demand of fast and early diagnosis of COVID-19 cases.

It is reviewed those nanomaterials e.g. gold nanostructures, lanthanide-doped polysterene nanoparticles (NPs), graphene and iron oxide NPs can be potentially used to develop advanced techniques offered by colorimetric, amperometric, impedimetric, fluorescence, and optomagnetic based biosensing of SARS-CoV-2. Finally, critical issues that are likely to accelerate the development of nanomaterials-enabled biosensing for SARS-CoV-2 infection have been discussed in detail. This review may serve as a guide for the development of advanced techniques for nanomaterials enabled biosensing to fulfill the present demand of low-cost, rapid and early diagnosis of COVID-19 infection. At present, the reliable, rapid, and low-cost technique for SARS-CoV-2 diagnosis is the foremost priority. In this context, nanomaterials enabled based biosensors can be a hope to offer novel techniques that may perhaps meet the current demand for early and rapid diagnosis of SARS-CoV-2 infections.

Conclusion:

Nanomaterials became important components in bioanalytical devices since they clearly enhance the performances in terms of sensitivity and detection limits down to single molecules detection. The specific properties of such nano objects also offer alternatives to classic transduction methods. Furthermore, the combination of different nanomaterials, each with its characteristics, to increase even more the performances of biosensors is a well-accepted strategy. Nanomaterials became important components in bioanalytical devices since they clearly enhance the performances in terms of sensitivity and detection limits down to single molecules detection.

Reference Books

1. BIO SENSOR -RAJMOHAN JOSHI-2006.

2. Biosensor principles and application -Pierre R. Coulet, Loïc J. Blum,2019.

3. Biosensor Nanomaterials -Songjun Li, Jagdish Singh, He Li, 2011.

4. Advance in biosensor: Perspectives in biosensor -Bansi Dhar Malhotra, Anthony Turner, 2003.

5. Biosensor application in healthcare diagnosis -Zeynep Altintas, 2017