# Quantum Dots

## 2.3 Quantum Dots (QDs)

QDs are inorganic nanocrystals, approximately 1–10 nm in size, with unique optical properties of broad excitation, narrow size-tunable emission spectra, high photochemical stability, and negligible photobleaching. They have been widely used, mainly as alternatives to fluorophores, for the development of optical biosensors to detect ions, organic compounds, pharmaceutical analytes, and biomolecules such as nucleic acids, proteins, amino acids, enzymes, carbohydrates, and neurotransmitters. They have also been employed for the in vivo detection of target sites in cancer. In fact, they are the ideal candidates for multiplexed optical bioanalysis due to their ultra-high sensitivity, high specificity, cost effectiveness, miniaturized size, size-dependent emission wavelength, and rapid analyte detection

## 2.4 Nanoparticles (NPs)

NPs have also been extensively used in various bio-analytical applications, especially for the development of biosensors, diagnostics, imaging, drug delivery, and therapy, due to their unique optical and other properties. They change color in response to the binding of molecules to their surface. The change in the properties of nanoparticles by varying their size or shape has been exploited for various bioanalytical applications. The most widely used NPs are GNPs, which have a non- toxic, biocompatible, and inert core. The prominent plasmon absorption and scattering properties of GNPs are highly useful for the early stage detection and photothermal therapy of cancer and other diseases. They have been used for the development of immunoassays, diagnostics, and biosensors for various analytes. Based on their preferential accumulation at the tumor sites, they have been used for the therapy of cancer and other diseases by acting as nano-carriers for the delivery of drugs, DNA, and genes. The multivalent GNPs facilitate efficient drug delivery to the target sites by shielding the unstable drugs, while their strongly enhanced surface plasmon resonance absorption enables the photothermal therapy of cancer. They have been extensively used in imaging due to their enhancement of the Raman and Rayleigh signals that provide greater chemical information. Therefore, it will be highly useful to combine all the benefits of GNPs, such as diagnostic, specific targeting, and therapeutic, into a single multifunctional GNPs- based platform, which can be chemically tailored for a particular disease.

*Magnetic NPs* are the second most widely used NPs, which have been extensively employed in biosensors and diagnostics for the detection of proteins, enzymes, DNA, mRNA, drugs, metabolites, pathogens, and tumor cells. Various types of magnetic sensors based on different signal transduction mechanisms, such as magnetic relaxation switch assay sensors, magnetic particle relaxation sensors, and magnetoresistive sensors, have been developed. The diagnostic magnetic resonance (DMR) technology has also been employed extensively for magnetic biosensing. The development of miniaturized chip-based nuclear magnetic resonance detector (µNMR) has further enhanced the capabilities of DMR for the highly sensitive analyte detection in microliter sample volumes, multiplex analysis, and development of cost-effective, portable, and high- throughput platforms for point-of-care diagnostics. The magnetic NPs are being extensively used by industries such as Phillips Research, Eindhoven, Netherlands for the development of immunoassays and rapid integrated biosensor for multiplexed immunoassays.

### 2.5 Dendrimers

Dendrimers are hyperbranched, monodispersed, star-shaped, and nanometer-scale three-dimensional macromolecules with a very high density of surface functional groups. They are composed of three distinct components, i.e., the core, the interior dendron, and the exterior surface with terminal functional groups. They have been used extensively in various biosensors and diagnostics, such as those based on electrochemistry, fluorescence, surface enhanced Raman scattering, impedimetry, and surface plasmon resonance, mainly as they increase the analytical sensitivity, stability, and reproducibility but reduce the non-specific interactions. They have also been used for other bioanalytical applications such as drug delivery, gene transfection, and catalysis.

## 3. Using Biosensors in Nanotechnology & their applications

There are many potential applications of biosensors of various types. The main requirements for a biosensor approach to be valuable in terms of research and commercial applications are the identification of a target molecule, availability of a suitable biological recognition element, and the potential for disposable portable detection systems to be preferred to sensitive laboratory-based techniques in some situations. Some examples are given below:

- Glucose monitoring in diabetes patients
- Environmental applications e.g. the detection of pesticides and river water contaminants such as heavy metal ions
- Remote sensing of airborne bacteria e.g. in counter-bioterrorist activities
- Protein engineering in biosensors
- Detection of toxic metabolites such as mycotoxins
- Nano/Micro-Electro-Mechanical Systems (N/MEMS) for Sensor Fabrication
- BioMEMS/BioNEMS, Lab-on –Chip, Microfluidic System, Sensor Arrays, Implantable Sensor

## Nanomaterials-Based Biosensors for the Detection of Glucose

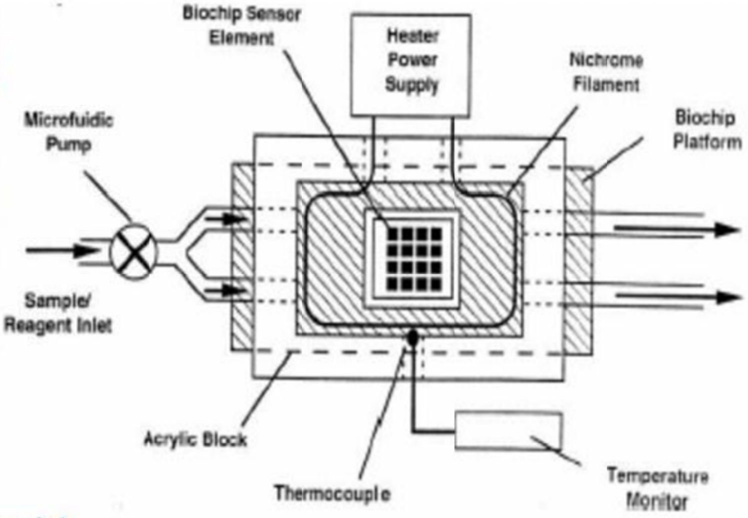
The glucose biosensor has been widely used as a clinical indicator of diabetes. Nanoscale materials such as GNPs, CNTs, magnetic nanoparticles, Pt nanoparticles, Quantum dots, etc. play an important role in glucose sensor performance, fibrous morphology and wrapping of PDDA over MWCNTs result in a high loading of GOx into the electrospun matrix. Pt nanoparticles could be electrodeposited on MWNTs matrix in a simple and robust way. The immobilization of glucose oxidase onto Pt/MWNTs electrode surfaces also could be carried out by chitosan-SiO2 gel. The resulting biosensors could be used to determine the glucose levels of serum samples with high sensitivity.

Integration of nano-scale technologies could lead to tiny, low-power, smart sensors that could be manufactured cheaply in large numbers. Sensing the interaction of a small number of molecules, processing and transmitting the data with a small number of electrons, and storing the information in nanometer-scale structures.

## Military Application:

Using nanotechnology based chemical biosensors in micro UAVs.

SnifferSTAR is a nano-enabled chemical sensor integrated into a micro unmanned aerial vehicle



## 4. Future Prospects and Challenges

In recent years, applications of nanomaterials in biosensors provides novel opportunities for developing a new generation of biosensor technologies. Nanomaterials can improve mechanical, electrochemical, optical and magnetic properties of biosensors, nanomaterial-based biosensors are developing towards single molecule biosensors and high throughput biosensor arrays. However, like any emerging field, they face many challenges. Biological molecules possess special structures and functions, and determining how to fully use the structure and function of nanomaterials and biomolecules to fabricate single molecule multifunctional nanocomposites, nanofilms, and nanoelectrodes, is still a great challenge. The mechanism of interaction between biomolecules and nanomaterials is also not clarified very well yet. How to use these laws and principles of an optimized biosystem for fabricating novel multifunctional or homogenous nanofilms or modifying electrodes is also a great challenge. The processing, characterization, interface problems, availability of high quality nanomaterials, tailoring of nanomaterials, and the mechanisms governing the behavior of these nanoscale composites on the surface of electrodes are also great challenges for the presently existing techniques. For example, how to align nanomaterials such as CNTs in a polymer matrix along identical direction is a great challenge.

How to enhance the signal to noise ratio, how to enhance transduction and amplification of the signals, are also great challenges. Future work should concentrate on further clarifying the mechanism of interaction between nanomaterials and biomolecules on the surface of electrodes or nanofilms and using novel properties to fabricate a new generation of biosensors. Nevertheless, nanomaterial-based biosensors show great attractive prospects, which will be broadly applied in clinical diagnosis, food analysis, process control, and environmental monitoring in the near future.

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