United Journal of Quality and Validation

Opinion on Development of Nano materials as Biosensors

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Research Areas

1-Material Science

2- Catalysis

3- Bio-Inorganic Chemistry

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Article Information

Article Type: Opinion Article
Article Received: 01-24-2021
Article Accepted: 02-06-2021
Article Published: 02-09-2021
Vol:2, Issue:1

OPEN ACCESS

INTRODUCTION

The demand for highly sensitive and selective optical sensors without the need for complex instrumentation and processing has driven the development of novel nanomaterials for optical sensing applications. Nanoparticles have the potential to be used for biosensing in a diversity of fields and could be further developed into multifunctional sensors able to offer sensitive, specific, rapid, and cost-effective solutions for modern biological research and clinical practice. By utilizing the unique properties of a variety of nanoparticles for biosensing functions, effective biosensors have been developed and applied. 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 nanoparticles, semiconductor quantum dots, polymer nanoparticles, carbon nanotubes, Nano diamonds, and graphene are intensively studied[1,2]. As an attractive alternative to conventional dyes, fluorescent nanoparticles have greatly increased the sensitivity in a variety of biosensor formats[3].

Nanoparticle-based sensing is an emerging field, and the further development of nanomaterials for sensor applications will provide numerous advanced tools with both increased sensitivity and improved capability for unique applications in molecular biology, drug discovery, and clinical diagnosis.

Although nanoparticle-based optical sensors have made advances in high-throughput molecular screening and detecting, they have not yet been practically useful in complex biological systems and clinical fields[4,5]. Most of the high-throughput multiplex bioanalyses using nanomaterials are still in the stage of demonstrating the principles. There are quite a few technical and environmental hurdles to overcome before these nanomaterials and nanotechnologies can be used effectively in real life. For example, in spite of the efforts in nanoparticle surface modification to render them water-soluble, chemically stable, and biocompatible in physiological media, strategies are needed to improve the properties of the nanoparticle support matrices and surfaces

Citetion: Ahmed M. Abu-Dief / United Journal of Quality and Validation 1(2021): 1-2

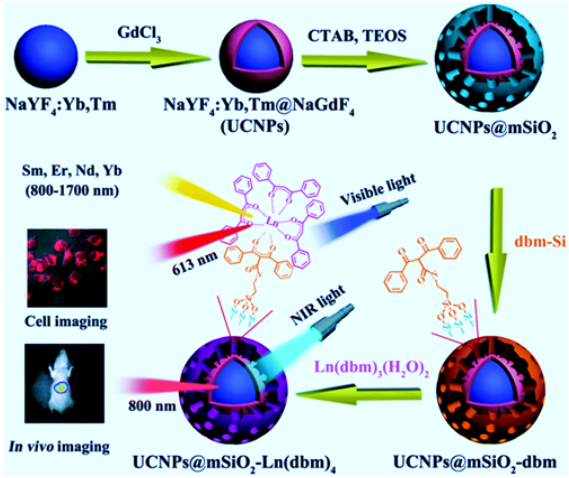

Figure. 1: Schematic of the preparation and structure of multifunctional mesoporous NPs containing both upconversion and magnetic nanophosphors (with an architecture of the type NaYF4:Yb,Tm@ NaGdF4) and covered with a conventional luminescent lanthanide complex (Ln-dbm) for use in upconversion and downconversion luminescence imaging and as T1-weighed MRI contrast agents. From ref. 3

Surface modification can help reduce non-specific binding and facilitate the subsequent attachment of biological moieties, which will improve the binding kinetics and affinities of the nanoparticles for their target molecules. Non-specific binding and nanoparticle aggregation are still major issues blocking or slowing our progress in realizing the power of nanomaterials for ultrasensitive, multiplexed bioanalysis. Total elimination of non-specific binding is a difficult or probably impossible task, especially when the nanoparticles are used in a biological milieu. This problem demands that the scientific community design new strategies to reduce nanoparticle background signal due to non-specific binding. Additionally, the capacity to attach multiple functional groups to nanomaterials and to manipulate the matrix itself is necessary for diagnostics and therapeutics. Although researchers have demonstrated interesting applications of biocompatible nanoparticles in clinical use[6,10], there is a huge gap between the results obtained in research labs and the requirements of real-life and clinical applications. It is necessary to push the limits in low-cost, large-scale nanoparticle production and portable detection systems to rapidly and automatically decode the optical signals from nanoparticles. These requirements, in addition to the cost of the technologies, will probably determine which candidate will be broadly useful and feasible for commercial applications. Today's signaling instrumentation and imaging facilities may not be capable of simultaneously detecting and decoding the multiplex information. Instrumentation to acquire and process a large amount of information is necessary. Large data storage and imaging analysis are a must for simultaneous imaging of a few analytes. Both call for novel technological developments from molecular imaging, signal processing, electrical and computer engineering, informatics, and other instrumentation and data analysis-related fields. Finally, future applications of optical biosensors will emphasize the development of in vivo sensors for multiplex bioassays. While microbeads are generally useful for in vitro multiplex bioassays, they are not suitable for the staining or labeling of subcellular components or intracellular measurements as they are relatively large in size. Nanosized devices are envisaged to be ingested or injected into the body, where they could act as reporters for diseased tissues and organs in the human body. Before this happens, detailed studies need to be performed on the in vivo behavior of such probes, including their bio distribution, non-specific uptake, cellular toxicity, and pharmacokinetics. To use nanoparticles for encoding cellular assays, the nanoparticles tested must not interfere with normal cell processes such as signal transduction, receptor trafficking, and membrane function. When these nanoparticles are better integrated into the complex biological system, we will witness an explosion in the use of nanoparticle-based multiplex assays for faster, more sensitive, and accurate disease detection- first in laboratory tests and then in the patients. While we should be optimistic about the future of nanotechnology-based optical biosensing and imaging, a significant uncertainty and many technical challenges are still there.

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