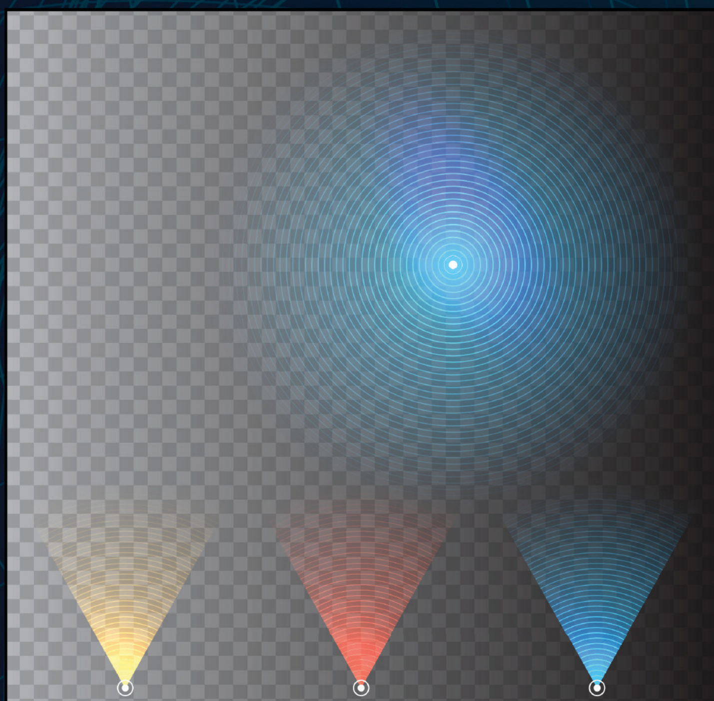
EMERGING MATERIALS AND TECHNOLOGIES

EMERGING NANOMATERIALS FOR CATALYSIS AND SENSOR APPLICATIONS



EDITED BY

ANITHA VARGHESE
GURUMURTHY HEGDE

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Emerging Nanomaterials for Catalysis and Sensor Applications

This book reviews emerging nanomaterials in catalysis and sensors. The catalysis section covers the role of nano-photocatalysts in organic synthesis and health care application, oxidation and sulphoxidation reactions, liquid phase oxidation, hydrogen evolution and environmental remediation. It highlights the correlation of surface properties and catalytic activity of the mesoporous materials. The sensor section discusses the fabrication and development of various electrochemical, chemical, and biosensors.

Features:

- Combines catalysis and sensor applications of nanomaterials, including detailed synthesis techniques of these materials.
- Explores methods of designing, engineering, and fabricating nanomaterials.
- Covers material efficiency, their detection limit for sensing different analytes and other properties of the materials.
- Discusses sustainability of nano materials in the industrial sector.
- Includes case studies to address the challenges faced by research and development sectors.

This book is aimed at researchers and graduate students in Chemical Engineering, Nanochemistry, Water Treatment Engineering and Labs, Industries, Research Labs in Catalysis and Sensors, Environmental Engineering, and Process Engineering.

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The *Emerging Materials and Technologies* series is devoted to highlighting publications centered on emerging advanced materials and novel technologies. Attention is paid to those newly discovered or applied materials with potential to solve pressing societal problems and improve quality of life, corresponding to environmental protection, medicine, communications, energy, transportation, advanced manufacturing, and related areas.

The series takes into account that, under present strong demands for energy, material, and cost savings, as well as heavy contamination problems and worldwide pandemic conditions, the area of emerging materials and related scalable technologies is a highly interdisciplinary field, with the need for researchers, professionals, and academics across the spectrum of engineering and technological disciplines. The main objective of this book series is to attract more attention to these materials and technologies and invite conversation among the international R&D community.

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Section I

Emerging Materials in Nanocatalysis

This section is dedicated to explaining the important role of nanomaterials in the area of catalysis. Here, various kinds of catalysts were used, ranging from photocatalysts, nanocatalysts, metal nanocatalysts, and so forth. Using such nanocatalysts, different kinds of innovative applications were highlighted and explained, such as healthcare, oxidation, and sulphoxidation reactions, the catalytic activity of mesoporous metal aluminophosphates, liquid-phase oxidation, visible light photocatalysis, hydrogen evolution, and environmental remediation, and so forth. This section also provides information about recent trends in this area of research.

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8 Synthesis of Fluorescent Nanosensor for Biomedical Engineering

Saba Farooq and Zainab Ngaini

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CONTENTS

8.1 INTRODUCTION

Fluorescence sensing materials have gained much attention due to their wide range of applications in nanotechnology biosensors (Tian et al., 2015), aerospace, the food industry (Vyas et al., 2015), agriculture (Guan et al., 2021), military security (Qian et al., 2016) and the biomedical field (Khan et al., 2020). These materials are able to size up to 100 nm (Liu et al., 2016a) with the capability of sensing external changes such as pH, oxygen, temperature, proteins and water (Wu et al., 2021). The fluorescent nanosensor (FNS) is a powerful tool that depicts the advancement in optical-sensor technologies having high selectivity, a wide detection range, low cost and low detection limit (Gong et al., 2015).

The structure of a nanosensor consists of three components, that is: sensor (sensing action, basically analyte, bioreceptor and nanoparticles), transducer (convert I/P to electronic signal) and detector (Figure 8.1A) (García-Añoveros and Corey, 1997). The fluorescent nanosensor contains fluorescent material that is encapsulated or bound with inserted biocompatible materials with a high level of temporal and spatial resolution (Petrakova et al., 2015). FNS is composed of a reference fluorophore, which contributes toward the stable fluorescence emission and analyte-sensitive fluorophore, a dynamic fluorescence emission depending upon the nature or amount of target materials to achieve both high accuracy and ratiometric output (Figure 8.1B) (Desai et al., 2014). The multiple target materials can be detected by the association of multiple analyte-sensitive fluorophores (Qiu et al., 2015).

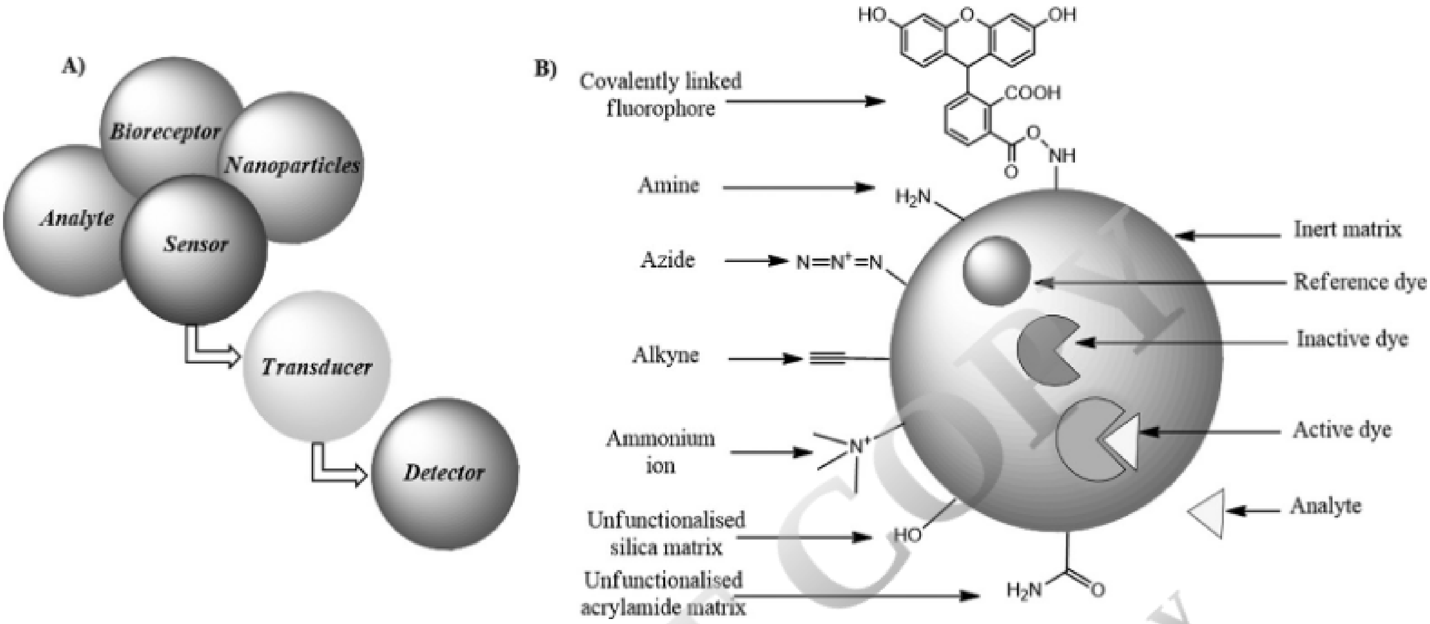

FIGURE 8.1 A and 8.1B General components of nanosensor (A) and Functionalized FNSs (B).

Investigation of biological processes is laborious – for example, gene regulation, DNA repair mechanisms, single-cell activity and diagnosis of disease (Francis and Rajith, 2021). Numerous probe sensors are actively used by researchers for disease diagnostic techniques reported in Table 8.1 (Chakraborty et al., 2020). The fluorescent sensor is not, however, straightforward functioning like a naked-eye detected nanosensor. The UV lamp is required for the excitation of fluorophore and the detection of signals. Another drawback encountered by the fluorescent nanosensor is the quenching procedure during the emission of several fluorophores by numerous external factors (i.e., oxygen, light). Quenching of fluorescence can be overcome by doping (Yuan et al., 2016). To date, the development of recyclable, efficient, good stability and sensitivity (Xie et al., 2015), metal-free, eco-friendly and inexpensive high-performance sensors still constitute a challenging process (Wang et al., 2015a). This chapter highlights the fluorescent nanosensor fabrications techniques, response to external stimuli, and applications in the biomedical engineering field. It also attributes the structural attributed significance for sensitive and efficient fluorescence nanomaterials.

TABLE 8.1
Fluorescent Probes for Intracellular Imaging

Types of Fluorescent Probe (size)	Intracellular Imaging Application	Advantages	Limitations
Fluorescent carbon dots (2–10 nm)	Intracellular organelle, amino acid, RNA, metal ion, redox state	Bright and tunable emission, nontoxic	Larger size, broad emission
Doped semiconductor nanoparticle-based (5–50 nm)	Glucose, drug	Low background fluorescence	Larger size
Quantum dot-based (5–50	Protein, lipid droplet,	Bright, narrow and tunable	Larger size,

nm)	nucleus, mitochondria	emission, single light for exciting multiple colors	cytotoxicity due to Cd
Dye-based (< 2 nm)	Nucleus, mitochondria, lysosome	< 2 nm size for easier cytosolic entry	Photobleaching
Upconversion nanoparticle-based (5–100 nm)	TK1 mRNA and pH detection	Low background noise	Larger size
Aggregation-induced emission active dye-based (< 2 nm)	Mitochondria, lysosome	< 2 nm size for easer cytosolic entry, low photobleaching	Elective chemical structure

(Source: Ali et al., 2020)

8.2 PREPARATION OF FLUORESCENT NANOSENSOR

The fluorescent nanosensor can be naturally present in banana (De and Karak, 2013), sweet potato (Shen et al., 2017), lemon (Das et al., 2019), chitosan (Caprifico et al., 2020), palm kernel shell (Monday et al., 2021)) or created synthetically (i.e., CQDs-RhB (Fu et al., 2017), RbH-CD (Ma et al., 2018)) through various methods, that is, hydrothermal (Shi et al., 2015), microemulsion (Amjadi et al., 2016), solvent displacement (Xie et al., 2016), thermolitic methods (Saenwong et al., 2018), precipitation method (Cun et al., 2016), reverse micelles and arrested precipitates (Zuo et al., 2016). Traditional top-down methods (Farooq et al., 2020) require multisteps that are tedious and

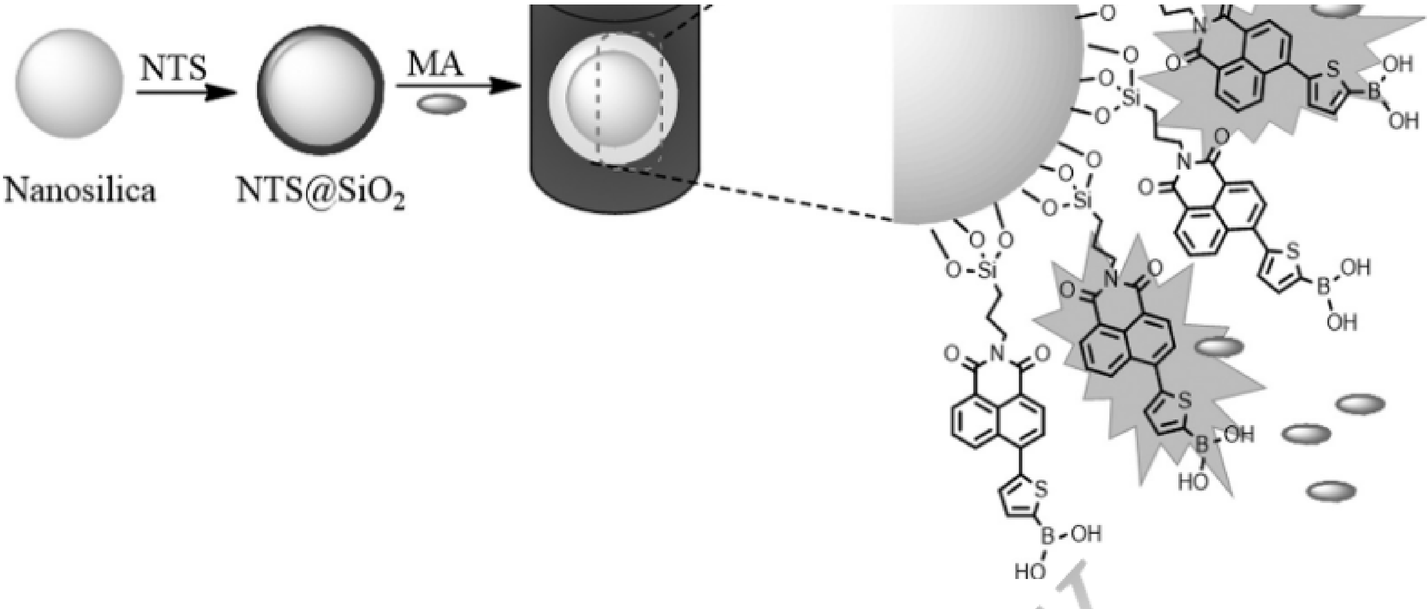

FIGURE 8.16 Methamphetamine detection through nanosensors.

8.5 FUTURE PERSPECTIVES

Fluorescent nanosensors are promising and emerging materials with a desired and distinctive feature that is significant in biomedicinal applications. The forthcoming chances of a fluorescent nanosensor for biomedical applications are auspicious, particularly for disease diagnosis and treatment. The identification of slight disturbance (i.e., pH, temperature, oxygen) in living organisms was a very crucial issue that is overcome by the development of fluorescent nanosensors. In the future, further modification for highly effective and sensitive nanosensors is required with controlled intelligence and mental functioning. However, these fields of research are still in their early stages, and untold efforts are still required for the development of biomedical devices with upgraded characteristics. These research areas need to expand and are expected to provide opportunities for further research and development.

8.6 CONCLUSION

In summary, the latest advances in the synthesis and applications of fluorescent nanosensors are comprehensively presented and discussed in this chapter. Several techniques, such as hydrothermal, photoinduced polymerization, precipitation or reprecipitation and others have been applied for the designing of various fluorescent nanosensor materials. Fluorescent nanosensors size or shape or structure can be adjusted by the fabrication methods and easily characterized by FTIR, SEM, AFM, TEM, and others. Moreover, the synthesized fluorescent nanosensor materials exhibit wide applications in the biomedical field to analyze pH, temperature, oxygen, drugs, or disease and are tremendously beneficial for human health.

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