Abstract

With technological advancement and global competition, the threat to human lives and the environment has risen to the top of the priority list. There is a decrease in life expectancy due to environmental health hazards, imbalanced diet, sedentary lifestyle, random physical exercise, deficiency of nutrients, and pandemics. As a consequence, mankind is suffering from diabetes, cholesterol, blood pressure, obesity, and many health-related problems. Therefore, regular monitoring of biomolecules (which are indicators for health conditions) like glucose, cholesterol, glutathione, ascorbic acid, etc., is crucial. Further, for remote areas where medical infrastructure is poorly developed, and health awareness is lacking, there is an instant need for the development of portable sensor devices that can quickly move and meet their demands. The main technological advancement of sensor devices demanding for monitoring nutrients and biomolecules in the body are miniaturization and the development of cost-effective devices with minimum energy usage. The use of a wide range of sensors significantly impacts daily living. Sensors can enable bedside, regular, and remote monitoring of vital signs and other health parameters, as well as boost the intelligence of medical devices such as life-supporting implants.

Sensors are analytical tools that sense physical and chemical changes in their environment and transfer them into readable signals. The human body is the best example of a complex system with numerous sensors capable of selectively sensing a wide range of physical, chemical, and biological characteristics. In this century, there is an urgent need to develop a modern and comprehensive sensor that can detect the disease at a preliminary stage and can do regular health monitoring. The necessity for low costs and the ability for real-time monitoring, particularly for point-of-care applications, are fundamental concerns with the integration of sensing platforms.

Abstract

To improve device performance, more work must be put into designing and creating nanoscale sensing materials. Nanomaterial-based sensing signal amplifications have a huge potential to increase the sensitivity and selectivity of sensors because of the outstanding advancements in nanotechnology and nanoscience. Due to its vast surface area, which makes it simple to functionalize and improves biocompatibility, selectivity, and sensitivity, improved sensors with low detection limits for analytes have been designed with the help of nanotechnology.

We are concentrating on the levels of biomolecules in the body, specifically antioxidants (glutathione, ascorbic acid, L-cysteine) and glucose, whose alterations could lead to a number of health issues. Therefore, it is essential to monitor both the in-vitro and its level in the human body (in-vivo) for analyzing health issues. For instance, antioxidants protect our bodies against free radicals, which are a major factor in the development of cancer, heart disease, and other disorders. Our bodies use glucose as their primary fuel source to produce energy. In order to protect human health from many diseases like cancer, cardiovascular, diabetes, etc., the amount of antioxidants and blood sugar is crucial.

The thesis entitled "Field deployable sensors for health monitoring using colorimetric and chemiluminescence techniques" comprise the development of nanomaterials that are made of Transition Metal Dichalcogenides (TMDCs) such as Molybdenum Disulphide (MoS_2), and their composites e.g., Iron doped MoS_2 (Fe-MoS_2) composite, graphitic Carbon nitride (C_3N_4) and their composites i.e., Platinum decorated graphitic Carbon nitride (Pt-g-C_3N_4), 2D carbon material derived from water hyacinth, gold nanoparticles (GNPs) and 1,3-Propane dithiane (PDT) cross-linked GNPs (PDT-GNPs). The pristine nanomaterials lack catalytic performances. So, the surface modifications of nanomaterials as nanocomposites boost the surface charge ratio and show excellent catalytic activity for the sensing of antioxidants and glucose. The performance of the sensors in terms of their catalytic activity is greatly improved by the use of nanomaterials in nanotechnology. The thesis has been divided into seven chapters based on the findings.

Chapter 1 elucidates the extensive idea and lead-in to some fundamental concepts about sensors, types of sensors, components, the significance of nanomaterials, their composites, carbon and metal nanomaterials for catalysis and sensing, the use of nanomaterials and carbon materials as artificial enzymes that replace natural enzymes. The nanomaterials as catalysts enhance the chemiluminescence signals, and the need to develop sensitive and selective sensors is covered. Detailed information on the proposed research topic is presented in the review of the literature.

Chapter 2 explains many experimental methods that have been utilized to characterize developing materials. Scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffractometer (XRD), energy dispersive spectroscopy (EDX), X-ray photoelectron spectroscopy (XPS), and Fourier transform infrared spectroscopy (FTIR) are the main techniques that have been used for characterizing materials. For the spectroscopic characterizations and optical sensing of various analytes, UV-Visible spectrometers have been employed. For electrochemical characterization, cyclic voltammetry (CV) setup has been utilized.

Chapter 3 presents a colorimetric probe for a glutathione sensor based on Iron doped molybdenum disulfide (Fe-MoS_2) nanosheet. Fe-MoS_2 has been synthesized, and it persuades the oxidation of chromogenic substrate to produce a blue color charge transfer product, which exhibits outstanding peroxidase mimicking activity. This nanomaterial's capacity to follow steady-state kinetics for peroxidase mimetic activity and display durability in adverse environmental circumstances is used for the effective detection of glutathione levels in buffer and blood samples. Fe-doped MoS_2, which has good mimetic activity, is used to develop high-performance, low-cost peroxidase mimics for on-site glutathione detection in real samples.

Chapter 4 talks about a colorimetric sensor for ascorbic acid detection based on 2 D carbon material obtained from bio-waste water hyacinth. The production of 2D carbon has been achieved by carbonization at 800 ^{o}C with inert N_2 conditions, followed by an acid-base-water washing procedure. The carbon obtained has been kept at R.T. for future application. Since 2D carbon has a large surface area and N, O doped hierarchical pores, it has more catalytic active sites and can quickly oxidize the chromogenic substrate 3,3,5,5-Tetramethylbenzidine (TMB).

In **Chapter 5**, we are reporting a highly sensitive Pt-decorated graphitic carbon nitride nanocomposite (Pt-g-C_3N_4) based colorimetric sensor to detect ascorbic acid (AsA) in real samples. The thermal polymerization method has been used to easily synthesize graphitic carbon nitride (g-C_3N_4), while surface reduction of platinum ions results in Pt-g-C_3N_4. The nanocomposite's fabrication has been confirmed by a number of characterization approaches. Its oxidase behaviour was also investigated towards the oxidation of the chromogenic substrate 3,3',5,5'-tetramethylbenzidine (TMB) and found to be possessing enhanced mimic activity. Further, we have also developed a paper-based assay for the on-site naked-eye detection of ascorbic acid.

Chapter 6 is dedicated to employ smartphones for imaging and quantifying stable and enhanced chemiluminescence (eCL) for the non-invasive sensing of glucose concentrations in a biological fluid (mainly urine). The evaluation of analyte (glucose) concentration in urine is achieved by introducing 1,3-Propane Dithiol cross-linked

Gold nanoparticles (GNPs-PDT) in the chemiluminescence system (Luminol-O_2) to enhance the chemiluminescence imaging. The GNPs-PDT plays a dual role as an oxidase mimetic and catalyst for the dissolved oxygen, which acts as a co-substrate for glucose oxidation reactions as well as a co-reactant (oxygen-free radical) for luminol eCL emission. The proposed facile cost-effective sensor reveals good stability, sensitivity, and selectivity. Further, our concept can be used for sensing other biomarkers and clinically essential biomolecules and can be miniaturized into a portable sensor.

Chapter 7 covers the thesis's concluding remarks and potential future developments. Overall, this thesis work is the domain of potential nanomaterials for antioxidants and glucose sensing along with various biomolecules.