7.1 Summary

We have successfully synthesized and characterized different nanomaterials and their composite with improved optical and chemiluminescence properties and capitalized them for the sensing of various biomolecules, and a portable test kit was designed. The performance of the sensors in terms of their catalytic activity is greatly improved by the use of nanomaterials. The thesis explains the synthesis and efficacious use of several nanomaterials, including molybdenum disulfide (MoS_2), 2D carbon, carbon nitride (C_3N_4), and gold nanoparticle (GNP), and their functionalization with metal nanoparticles as composite for the improvement of their catalytic and optical properties with enhanced stability like iron functionalized MoS_2, Platinum decorated C_3N_4 nanosheet, and PDT cross-linked GNPs.

Further, the optical (colorimetric and chemiluminescence) and enzyme-mimicking properties of the synthesized nanomaterials has been investigated for developing the sensors of some important chemical and biological species such as glutathione, ascorbic acid, and glucose. This thesis is well-structured and focused on the fabrication of metal nanoparticles, nanocomposites, and their use in sensing. The following chapters provide an overview of the thesis.

Chapter 1 elucidates the general idea and an introduction to some fundamental concepts about sensors, components, types of sensors, the importance of nanomaterials, their composites, carbon and metal nanomaterials for catalysis and sensing, nanomaterials and carbon materials are used as artificial enzymes that replace natural enzymes and catalyst that enhance the chemiluminescence signals, and the need to develop sensitive and selective sensor 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 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 deals with 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 induces the oxidation of chromogenic substrate to produce a blue color charge transfer product, which exhibits excellent peroxidase mimicking activity. 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. The developed sensor for glutathione detection exhibits good linearity in the range of 1-30 μM with a lower detection limit (0.577 μM).

Chapter 4 deals with a colorimetric sensor for ascorbic acid detection based on 2 D carbon material obtained from bio-waste water hyacinth. Such 2D carbon has a high surface area (781 m^2g^{-1}) with self-doped O, N heteroatom, which gives unique electronic or redox properties. The presented colorimetric method exhibits an excellent dynamic range from 1 to 70 μM with a 0.26 μM detection limit. This chapter offers an upfront method for making a complete, metal-free, and effective nanozyme, and it investigates ascorbic acid detection in oranges, grapes, lemons, and human serum. It also provides a fresh route for developing a long-lasting mimic substrate and a roadmap for converting bio-waste into technology.

Chapter 5 reports 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. Graphitic carbon nitride (g-C_3N_4) has been synthesized by a facile one-step thermal polymerization technique, while surface reduction of platinum ions yields Pt-g-C_3N_4. The proposed colorimetric sensing platform is easy to use, highly sensitive, cost-effective, and selective for sensing AsA in real samples. Moreover, the synthesized Pt@g-C_3N_4 nanocomposite being eco-friendly will benefit human society to use it for AsA sensing. This sensor evinces good linearity for AsA sensing in the concentration range of 1-100 μM having a significant detection limit of 0.45 μM. Additionally; we have also developed a paper-based assay for the on-site naked-eye detection of ascorbic acid.

Chapter 6 deals with smartphones for imaging and quantifying stable and enhanced chemiluminescence (eCL) for the non-invasive detection of glucose concentrations in a biological fluid (urine). This technique is reliable as well as beneficial over the invasive method (blood sample) for diabetic patients, which is painful. Hence, we can monitor the glucose level easily without piercing the injection. Under the optimized conditions, the sensor is developed for glucose sensing in a dynamic range from 0 to 2 mM (R^2=0.98) with a detection limit of 0.36 mM. 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.

7.2 Future work

In the thesis, we synthesize nanocomposites with enhanced optical and catalytic properties. The issue with their stability has been attempted to address by functionalizing the nanoparticles' surfaces. In the case in point of nanozyme, we have shown the formation of nanoparticles with inherent enzyme mimicking properties and also examined induced mimicking properties that can be obtained through surface modification. We have exemplified colorimetric and chemiluminescence sensors based on modified nanomaterials for antioxidants, glucose identification, and regular health check-up. Nowadays, people are suffering from heart and kidney-related health problems, so the fabrication of commercial Colorimetric and Chemiluminescence devices based on catalytic materials for designing sensors will be our main focus. We will also explore the design of a handheld device for knowing diabetic and kidney status using a non-invasive method.