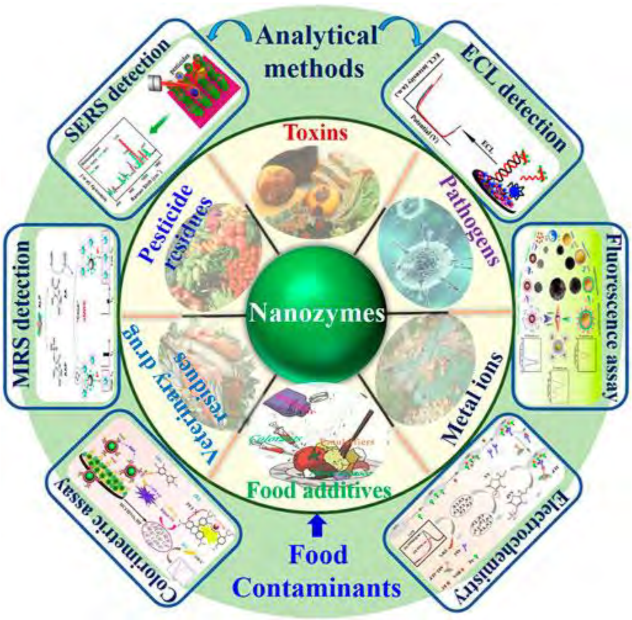
ABSTRACT

By the thesis title, I aim to demonstrate my profound understanding of the fields of their developments of Nano enzyme and diverse applications of nanozyme in different area of human aspect. Since Yan and associates' groundbreaking 2007 paper was published, Nano enzyme has attracted a great deal of attention. The properties of nanomaterials that hinder the activity of enzymes, such as nanozyme, have addressed many of the drawbacks of bio enzymes, such as their high cost, poor stability, difficulty in storage, and low durability under demanding reaction conditions. These drawbacks have seriously limited the widespread application of bio enzymes in analytical and medicinal chemistry. At that point, nanozyme entered the market to address bio enzyme's shortcomings and rose to prominence in the fields of environmental, biological, analytical, and sensing aspects. Since then, a variety of nanomaterials have been extensively studied for their ability to mimic enzymes such as oxidase, peroxidase, superoxide dismutase, and catalase in biomedical, colorimetric sensing, and electro-catalytic applications. These materials include Fe_3O_4 NPs, V_2O_5 NPs, MnO_2 NS, and Co_3O_4 NF, as well as some noble metal nanozymes like Ir, Au, and Ag. Yet, the majority of these nanomaterials catalyzed reactions that mimicked a single enzyme. Multi enzyme mimic nanozymes, in our opinion, have a wide range of uses and superior multifunctionality, including the elimination of ROS, antioxidant, anticancer, and anti-inflammatory properties. Unfortunately, only a few number of nanomaterials and nanocomposites—such as Ni-Pd hollow NPs, Co_3O_4, Mn_3O_4, and porous carbon produced from biomass—have been shown to have multienzyme mimicking capabilities. Therefore, there are still difficulties in developing a robust, highly effective multienzyme mimic nanozyme. Multi-enzyme mimic nanoparticles have many benefits, one of which is that they provide exceptional



defense for biological systems against ROS-mediated oxidative stress while leaving the body's natural antioxidant defenses intact. Many biological systems depend on a specific ROS level, which can be preserved by internal antioxidant defense mechanisms as SOD, CAT, and POD enzyme activity. Therefore, in situations where the body's natural antioxidant defense mechanism is ineffective or excessive ROS generation occurs, multienzyme mimic nanomaterials that particularly catalyze SOD, CAT, and POD may be used as artificial antioxidants. The characterization of nanomaterials involves the determination of size, shape, surface morphology, crystallinity, chemical composition, and other properties. Techniques such as scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), and scanning tunneling microscopy (STM) are commonly used for imaging and determining the morphology and size of nanomaterials with high resolution. X-ray diffraction (XRD) and selected area electron diffraction (SAED) are employed to investigate the crystalline structure and phase purity of nanomaterials. Chemical composition analysis is crucial for understanding the properties and behavior of nanomaterials. Energy-dispersive X-ray spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS) are widely used for elemental analysis and chemical bonding characterization. Spectroscopic techniques such as UV-Vis spectroscopy, Fourier-transform infrared spectroscopy (FTIR), and Raman spectroscopy provide information about electronic transitions, vibrational modes, and chemical functional groups in nanomaterials. Surface properties play a vital role in determining the behavior and applications of nanomaterials. Surface area and porosity analysis can be performed using techniques like Brunauer-Emmett-Teller (BET) analysis and gas adsorption measurements. Zeta potential analysis and dynamic light scattering (DLS) are used to determine the surface charge and size distribution of nanoparticles in suspension. In addition to these techniques, thermal analysis methods such as differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) offer insights into the thermal stability and decomposition behavior of nanomaterials. Magnetic properties can be characterized using superconducting quantum interference device (SQUID) magnetometer. This abstract provides a comprehensive overview of the diverse range of characterization techniques available for nanomaterials. By employing a combination of these techniques, researchers can gain deep insights into the structure, composition, surface properties, and behavior of nanomaterials, thus facilitating their design, optimization, and utilization in various applications.

SUMMARY OF THE WORKS

CHAPTER I

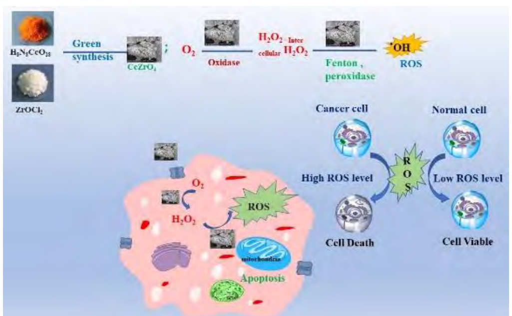
A thorough explanation of the research effort, its scope, and its relevance to contemporary science are provided in this chapter. It also discusses the significance of carbon and metal oxide-based nanomaterials, as well as the reasoning for nanozyme. All things considered, nanozymes have enormous potential in a variety of sectors, providing creative answers to problems with food safety, energy, healthcare, and environmental sustainability. Continuous investigation keeps examining and broadening their uses, propelling additional developments in nanotechnology and catalysis. This chapter contains a summary of every investigation technique employed in the research project.

CHAPTER II

This chapter reviews the previous research on this subject, which was done by various scientists and researchers all around the world. This chapter also offers a thorough discussion of the results and covers the several synthetic techniques used to create the nanomaterials, such as the hydrothermal, reduction, co-precipitation, and sol gel methods. This thesis delves into the theory that underpins various investigation techniques, including FTIR, UV-visible, Differential Scanning Calorimetry, Powder XRD, Scanning Electron Microscopy, Antimicrobial study, and Cytotoxicity study. Additionally, the significance of applying these techniques to the research described is discussed.

CHAPTER III

This study design to explore the anticancer potential and behavior of cerium-based nanomaterials mimicking enzymes since cerium-based materials have great stability, nontoxicity, and a strong redox capacity. Using β-cyclodextrin as a stabilizer and neem leaf extract as a reducing agent, our research synthesized $CeZrO_4$ nanoparticles using a green technique that demonstrated dual enzyme activity similar to those of oxidase and peroxidase. The greatest catalytic



activity of the enzyme was observed at pH = 4, which suggests that the tumor microenvironment is acidic and generates a lot of ROS. This is further corroborated by the Fenton-like behavior of the $CeZrO_4$ nanoparticles.

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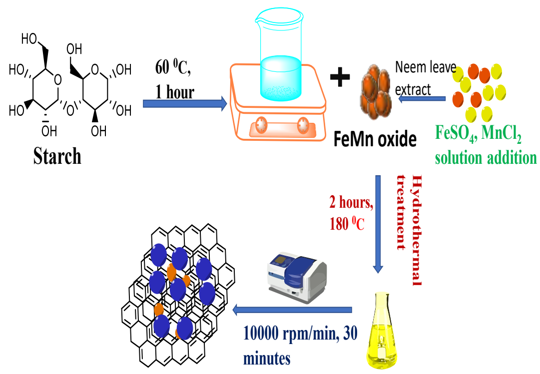
CHAPTER IV

In the current study, we have designed a visual colorimetric chemo sensor assay using the brilliant oxidase mimicking activity of biosynthesized $FeMnO_4$@GQD Nanocomposite.$FeMnO_4$@GQD nanocomposites showed excellent mimicking activity in mild acid medium pH-5, and obtained a Vmax value of 1.71603×10^{-6} and an important Km value of 0.0684 mM based on Hanes-Woolf kinetics. The robust nanocomposites were shown to be significant stability for detecting oxidases in a variety of conditions. As a consequence, oxidase-like activity was inhibited in the presence of fluoride ions. A linear correlation was established by the development of blue color with fluoride ions concentration and appeared at a low limit of detection of 1.2 µg/ml without interfering with other common ions.



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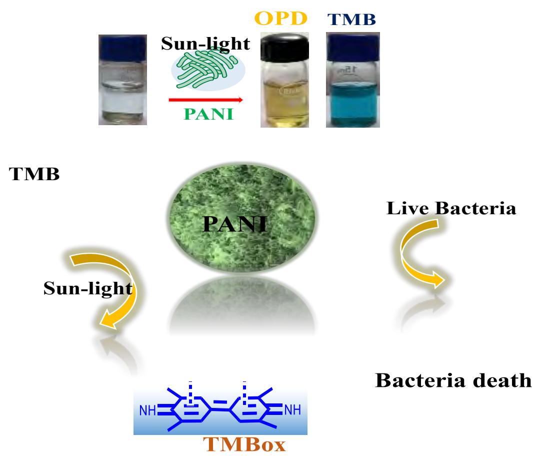
CHAPTER V

Here, we discovered that a conducting polymer called Polyaniline Nanofibers (PANI NFs) mimics the action of light-activated oxidase. According to Hanes-Woodf kinetics, PANI-NFs have a unique Km = 0.087 mM and a high Vmax = 2.32 mMmin-1 value. They can also catalyze the colorless (tetra methyl benzidine) TMB to create a blue product, TMBox. These characteristics are indicative of intrinsic light-activated brilliant oxidase-like activity. In addition, we present here the comparison of PANI-NFs with the light-activated oxidase activity of two other well-known carbo catalysts



graphene oxide (GO) and graphitic carbon nitride (g-C_3N_4). It's incredible that the conductive polymer has this kind of behavior. Density functional theory (DFT) is used to confirm the PANI NFs-TMB composite's stability and adsorption mode, which supports the experimental findings. Additionally, the present nanozyme showed a noteworthy capacity to eliminate biofilms and kill both gram-positive and gram-negative bacteria in physiological settings. We think it could serve as inspiration for future work establishing a connection between optoelectronics and biological processes.

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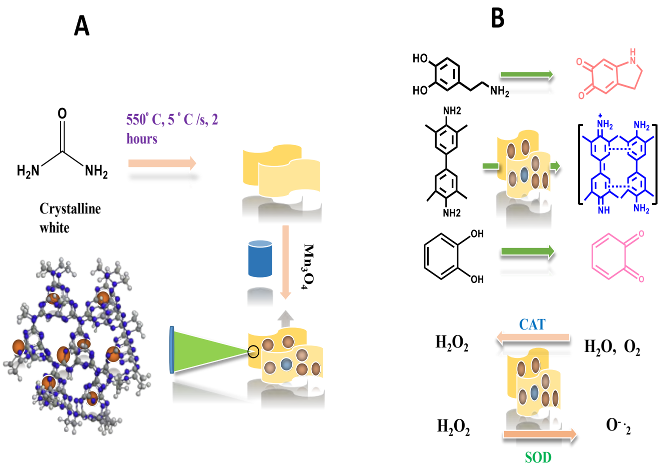
CHAPTER VI

Here, spherical Mn_3O_4 has been grafted onto layered 2D g-C_3N_4 through the use of a solid state mixing technique. Through the use of FT-IR, FE-SEM, and HR-TEM studies, the loading of spherical Mn_3O_4 NPs on the surface of g-C_3N_4 was readily traversed. Tetragonal Mn_3O_4 NPs were formed on the 2D Nano layer g-C_3N_4, and the phases involved were identified using the powder X-ray diffraction (XRD) method. Because of the composites' multi-enzyme mimic activity, which includes catalase (CAT), peroxidase (POD), oxidase (OD), and superoxide dismutase (SOD), they exhibit the fortunate mixed valance state of Mn_3O_4. Mn_3O_4@g-C_3N_4 exhibited good SOD-like enzyme activity, which allowed it to effectively remove the active oxygen (O_2 ·−) from cigarette smoke. A sensitive colorimetric sensor with a low detection limit and a promising linear range has been designed to detect two isomeric phenolic pollutants, hydroquinone (H_2Q) and catechol (CA), by utilizing optimized oxidase activity. The new probe has outstanding sensitivity and selectivity in addition to the ability to visually distinguish between two isomers with the unaided eye.



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