

# *Abstract*

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This thesis deals with the studies based on the synthesis and characterization of metal oxide/sulphide and its polymeric nanocomposites such as ZnO, TiO<sub>2</sub>, Co<sub>3</sub>O<sub>4</sub>, ZnS, g-C<sub>3</sub>N<sub>4</sub>, g-C<sub>3</sub>N<sub>4</sub>@ZnS and ZnO@ZnS using aqueous extracts of *Ipomoea carnea* (morning glory), *Recinus*, *Butea monosperma* plants leaves. The produced nanocomposites were characterized using analytical techniques such as UV-visible spectroscopy, Powder X-Ray Diffraction, TEM, FT-IR spectroscopy, SEM@EDAX, FE-SEM, XPS, BET, and photocurrent response analyses. The green method generated metal oxides are applied for the biochemical application such as micronutrient, antibacterial analysis and anticancer activity. It was also used as a catalyst to perform catalytic transformations of some organic reactions. The sensing and electrochemical property of the fabricated metal oxide/polymeric nanocomposites analysed for the detection of LPG at room temperature.

The biochemical and sensing properties of synthesized metal oxide/polymeric nanocomposites were observed using crop field, cyclic voltammetry, etc. The band gaps of metal oxide/polymeric nanocomposites were computed using Tauc plot method. FT-IR spectra clearly indicated the presence of M-O/S stretching which confirmed the formation of metal oxide/sulphide nanocomposites. The XRD patterns revealed the crystallinity and phase purity of the fabricated metal oxide/polymeric nanocomposites. The shape, size and surface morphology of the nanomaterials were confirmed using SEM, FE-SEM, BET and TEM analysis. EDAX and elemental mapping investigation was performed to confirm the elemental composition of fabricated nanomaterials. The SEAD patterns revealed the polycrystalline nature and phasic purity of green synthesized nanomaterials. The chemical states of elements in fabricated metal oxide/sulphide nanocomposites were confirmed from the XPS analysis. To confirm the electronic sensitivity, photocurrent response of the engineered metal oxide/sulphide nanocomposites was analysed. The biochemical, as well as sensing activity of synthesized metal oxide/sulphide nanocomposites was investigated in the black carrot production, legumes, antimicrobial, antifungal, anticancer and gas sensing application. The reaction parameters like catalyst dose and pH of the medium, concentration, selectivity were also investigated.

In the biochemical analysis of  $\text{Co}_3\text{O}_4$  nanoparticles (NPs) using aqueous extract of leaves of *Ipomoea carnea* plant is used. The produces  $\text{Co}_3\text{O}_4$  NPs has well crystalline, mesoporous very small size (6-10 nm diameter), having very narrow size distribution nanoparticles. Phytotoxicity, antifungal and antibacterial activities, lipid test and protein test have been performed using  $\text{Co}_3\text{O}_4$  NPs. Phytotoxicity results showed the  $14.75 \pm 0.57$  and  $9.11 \pm 0.86$ ,  $7.65 \pm 2.110$  and  $10.6 \pm 1.813$ , and  $6.35 \pm 3.361$  and  $12.8 \pm 1.720$  roots and shoots length of respectively *Vignaradiata*, *Pisumsativum* and *Cicerarietinum* observed using 20 ppm  $\text{Co}_3\text{O}_4$  NPs. Antifungal activity was done against *A. flavus* CR500 while antibacterial activity was performed on *Staphylococcus aureus* and *Shigella flexnerii* using MHA media and inhibition zone was recorded till 17.8 mm and 16.7 mm respectively. 96% yield in catalytic oxidation of benzaldehyde into benzoic acid was found using  $\text{Co}_3\text{O}_4$  NPs as catalyst. The green methods generated  $\text{Co}_3\text{O}_4$  NPs do not show any toxic impact for human at a minimal level.

In order to investigate the next biochemical analysis of green method generated ZnO and  $\text{TiO}_2$  nanomaterials, black carrot production have been done. Since, nano fertilizers (NFs) are now becoming an important tool for plant nutrient management having capabilities to improve soil fertility, crop productivity and quality of agricultural products. Since, they are needed in very small amount, thus, reduces cost of crop production. Among different essential or beneficial plant nutrients, Zn and Ti are important micro nutrients having number of beneficial effect on crop growth, yield, quality and post-harvest life. Present experiment was carried out to prepare ZnO and  $\text{TiO}_2$  nanoparticles (NPs) through green technology by using aqueous extract of *Ipomoea carnea* (morning glory) leaves. Subsequently, the effect of foliar spray of ZnO and  $\text{TiO}_2$  NPs were evaluated in respect of vegetative growth, yield and quality of black carrot (*Daucus carota* L.) cv. Pusa Asita in presence of 50% Recommended dose of fertilizer (RDF) to assess their effect on fertilizer use efficiency also. There were 8 treatments viz. Control (no fertilizer), recommended dose of fertilizer (RDF),  $\text{TiO}_2$  (5, 10 and 15 ppm along with 50 % RDF), ZnO (50, 75 and 100 ppm along with 50% RDF)] with 3 replications following Randomised Block Design having 24 plots (1 m x 1 m). The observations were taken for vegetative growth, edible root yield and root quality parameters. Although, the growth, yield and quality parameters were found superior (root yield 43.84 g/plant) under conventional system of recommended dose of fertilizers (RDF) of NPK, however,  $\text{TiO}_2$  NPs also showed very promising result close to RDF as compared to ZnO NPs. Among them, 5 ppm  $\text{TiO}_2$  foliar application along with 50%

NPK was found to be the best in terms of vegetative growth, root yield (38.73 g/plant) and quality of black carrot. It was also found that higher concentration of TiO<sub>2</sub> and ZnO NPs had adverse effect on the plant performance. Therefore, it can be concluded that 5 ppm TiO<sub>2</sub> NPs along with 50 % RDF was good for black carrot production and by applying this process for the production of black carrot RDF quantity can be minimized and crop soil and contaminations can be improved.

*Recinus* plant leaves have been used to produce ZnS@g-C<sub>3</sub>N<sub>4</sub> nanocomposite (NC) which exhibited the wonderful sensitivity, reliability and selectivity of piezo-nanogenerator which acts as a self-powered gas sensor (SPGS) for sensing liquefied petroleum gas (LPG) at room temperature (RT). The sensitivity for each sample has been estimated by measuring the slopes of the curves. It was found that, sample ZnS, ZnS@ g-C<sub>3</sub>N<sub>4</sub> and g-C<sub>3</sub>N<sub>4</sub> possess sensitivity ~0.65, 15.86 and 3.71 sensor response/vol.% respectively. Overall, the sample ZnS@g-C<sub>3</sub>N<sub>4</sub> has exhibited the best sensing performance in terms of maximum sensor response, sensitivity, and minimum response/recovery times. The synthesized separate and composite materials have shown lesser sensitivity against NH<sub>3</sub>, CO<sub>2</sub>, C<sub>2</sub>H<sub>5</sub>OH, acetone and saturated water vapour than LPG, but good selectivity for detecting LPG. Such piezo- LPG detection at room temperature can be utilized to the new piezo-surface coupling effect of ZnS@ g-C<sub>3</sub>N<sub>4</sub> nanocomposites. The practical application of the device can be motivated by humanoid force. This effort offers an innovative idea to engineer RT- LPG sensors and encourages the advancement of self-powered sensing system. The practical application of the device can also be simply demonstrated by sticking a device on the door. Our results point out a new way for realizing LPG sensing at RT.

In order to investigate the next biochemical analysis of different nanostructured materials like ZnO, ZnS and ZnO@ZnS binary nanocomposite, have been produced using *Butea monosperma* plant leaves extract. Various physio-chemical and spectral investigations such as UV-visible, XRD, TEM, XPS, FTIR, and BET have been performed to observe the morphology, size, crystal structure, porosity and optical properties of the nanoparticles. The data indicated formation of very small size, well crystalline, mesoporous ZnO@ZnS nanocomposite. The anticancer activity of the synthesized ZnS, ZnO and ZnO@ZnS nanomaterials was examined against four cancer cell lines (MCF-7, MDA-MB-231, HeLa and SKOV-3). The ZnO@ZnS composite demonstrated high anticancer activity against all four cancer cell lines, with IC<sub>50</sub> values of 35.46±2.45, 52.42±1.36, 32.45±2.41 and 56.42±2.47 µg/mL against MCF-7, MDA-MB-231, HeLa and SKOV-3,

respectively after 72 hours. Moreover, ZnO@ZnS nanocomposite has shown cytotoxic effect against normal human embryonic kidney cells (HEK- 293). In this experiment, it also suggests that ZnO@ZnS nanocomposite can be used as an antibacterial reagent for the treatment of wastewater. They can particularly be applied as a complementary method with UV disinfection. Thus, these nanocomposites can be advanced as antibacterial agents to advance waste water quality. The best antibacterial performance has been observed by ZnO@ZnS nanocomposite in 24 h. The zone of growth inhibition was referenced by the known antibacterial drug Vancomycin. This investigation will be help in the very dangerous cancer treatment and waste water treatments.

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