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Biosynthesis of CdO-MgO Nanocomposite using Tinospora cordifolia Leaf Extract: Optical, Morphological, and Elemental Composition Studies

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Abstract. *In this study, Tinospora cordifolia leaf extract was used to synthesis the CdO-MgO nanocomposite through the co-precipitation. UV-visible spectrophotometer, FESEM, and EDAX characterizations were employed to study the optical, morphological, and elemental compositions of the Tinospora cordifolia-derived CdO-MgO nanocomposite (TC CdO-MgO NC). The absorbance peaks of 214 nm and 261 nm for MgO and CdO nanoparticles respectively, confirming the formation of TC CdO-MgO NC. The direct and indirect band gap of TC CdO-MgO NC are 5.248 eV and 4.849 eV. FESEM images shows synthesized nanocomposite has mixture of nearly spherical and cuboid shape with different sizes. The Mg, Cd, and O elements are present in the EDAX spectrum, confirming the formation of TC CdO-MgO NC. Hence, TC CdO-MgO nanocomposite might be suggested to the applications of optical devices.*

Introduction

Oxidative stress in the human body is caused by the excess free radicals prone to severe health diseases. Free radicals are volatile molecules with unpaired electrons in their outermost orbit. Antioxidants can reduce the risk of the onset of degenerative diseases by donating electrons to the free radicals [1]. Incorporating plant-based resources like fruits and vegetables into your diet is essential, as they are packed with antioxidants that effectively neutralize free radicals by donating electrons, promoting better health and well-being. Plant-based resources such as fruits and vegetables are particularly rich in antioxidants that can neutralize the activity of free radicals by donating electrons [2]. Tinospora cordifolia (TC) is a deciduous climbing shrub from Menispermaceae family, commonly known as Guduchi in Sanskrit and Teppatige in Telugu [3]. The plant contains a diverse array of phytochemicals, including alkaloids, steroids, phenolics, glycosides, flavonoids, diterpenoids lactones, sesquiterpenoids, polysaccharides, and aliphatic compounds [4]. The leaf extract of TC has demonstrated various medical properties, including antidiabetic, antioxidant, antiperiodic, anti-inflammatory, antimicrobial, anti-arthritic, anti-allergic, antistress, antileprotic, antineoplastic, hepatoprotective, and immunomodulatory activities [5,6].

Nanocomposite is a material that consists of two phases, and at least one phase has dimensions in the nanometer range. Nanocomposites possess remarkable properties, including a high melting point, low density, low coefficient of thermal expansion, high thermal conductivity, and high hardness. They also exhibit good chemical stability and enhanced mechanical properties, such as greater specific strength, improved wear resistance, and specific modulus. These characteristics make nanocomposites promising candidates for various industrial applications [7]. Cadmium oxide (CdO) is an outstanding n-type semiconductor, featuring a bandgap of 2.2 to 2.5 eV. Its remarkably low electrical resistivity of 10^{-4} Ω cm and exceptional electrical conductivity make it an ideal choice for various electronic applications [8]. It finds increased applications such as solar cells, photo diodes, transparent electrodes, gas sensors, etc [9]. Magnesium oxide (MgO) is a versatile oxide material with a large band gap (7.8 eV) [1]. MgO plays a vital role in various applications, including photocatalysis, electronics, refractory materials, pharmaceuticals, and wastewater treatment. Its remarkable non-toxic nature makes it particularly appealing for biological applications, capturing significant interest for its safety and effectiveness in diverse fields. Magnesium oxide (MgO) is one of the important applications in the field of photocatalysis, electronics, refractory materials, pharmaceuticals, and wastewater degradation. MgO has attracted major interest in biological applications due to its non-toxic nature [10,11]. As per our knowledge, biosynthesis of CdO-MgO nanocomposite using Tinospora cordifolia leaf extract is the first of its kind. The structural morphological, and elemental composition studies were carried out using XRD, FESEM and EDAX characterization techniques.

MATERIALS AND METHODS

All analytical grade chemical reagents were used in this study, procured from SRL, Chemicals Pvt. Ltd, India. The preparation of TC leaf extract was followed according to the literature [1]. 10 ml of TC leaf extract was added to the 100 ml of 0.1 M Cadmium acetate monohydrate, kept on magnetic stirrer for 4 hrs at 60^0 C. 3.5 g of Mg $(NO_3)_2 \cdot 6 H_2O$ was mixed with above solution mixture, maintained for 2 hrs at the same reaction temperature. 0.5 M NaOH was added to the solution to get the precipitation for 2 hrs. The resultant solution was centrifuge at rate of 4000 rpm to get the precipitate. The precipitate was washed three times with the distilled water to get rid off impurities. The resultant precipitate was heated at 100^0 C for 2 hrs, then calcinated it in muffle furnace for 4 hrs at 700^0 C. The nano-powder was obtained by grinding using mortar and pestle.

RESULTS AND DISCUSSIONS

UV-visible analysis

TheUV-visible spectrophotometer was used to study the optical properties of prepared nanocomposite. Fig. 1 illustrates the absorbance peaks at 214 nm and 261 nm for MgO and CdO nanoparticles respectively, confirming the formation of TC CdO-MgO NC.

The optical band gaps (direct and indirect band gaps) of TC CdO-MgO NC was analysed through the Tauc plot relation (1), Fig. 2.

$$(\alpha h\vartheta)^n = k\left(h\vartheta - E_g\right) \qquad (1)$$

Where, α is the absorption coefficient (cm^{-1}), $h\vartheta$ is the photon energy (eV), k is the proportionality constant, and E_g is optical band gap energy (eV). The direct and indirect band gap of TC CdO-MgO NC are 5.248 eV and 4.849 eV.

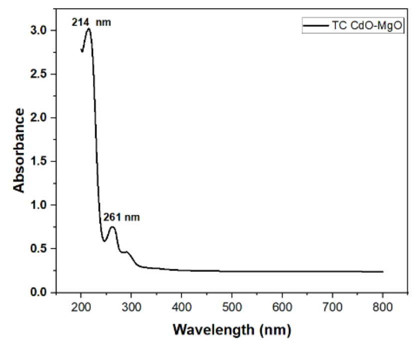

Fig. 1 Absorbance spectrum of TC CdO-MgO nanocomposite.

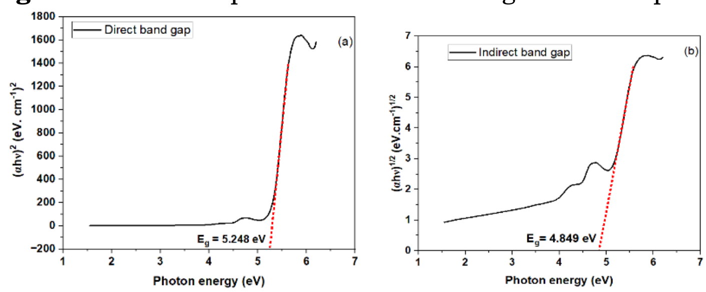

Fig. 2 Optical band gap: a) direct band gap, and b) indirect band gap of TC CdO-MgO nanocomposite.

FESEM analysis

Field Emission Scanning Electron Microscopy (FESEM) was employed to know the morphology of TC CdO-MgO NC. Fig. 3 represents the FESEM micrographs of TC CdO-MgO NC. The synthesized nanocomposite has mixture of nearly spherical and cuboid shape with different sizes.

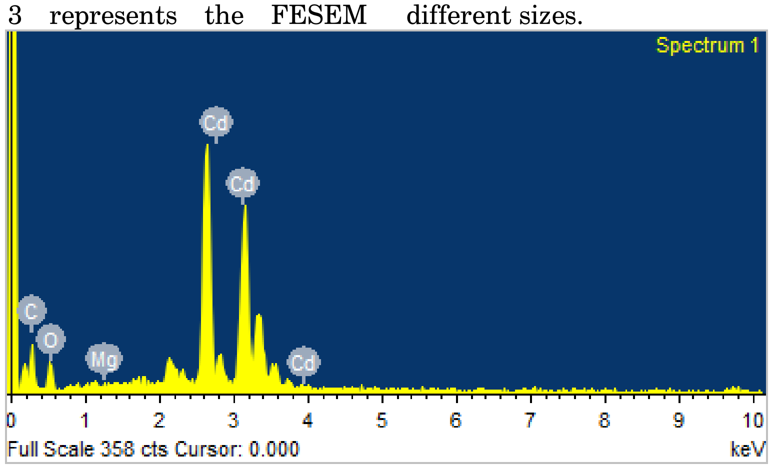

Fig. 3 FESEM images of TC CdO-MgO nanocomposites.

EDAX analysis

Energy Dispersive X-ray (EDAX) is a characterization technique that demonstrates the elemental composition in the TC CdO-MgO NC Fig. 4. The elemental compositions in the synthesized nanocomposite were reported in Table. 1. The existence of Mg, Cd, and O elements in the EDAX spectrum, confirming the formation of TC CdO-MgO NC.

Element	Weight%	Atomic%
C K	9.90	31.43
O K	18.33	43.71
Mg K	0.40	0.63
Cd L	71.37	24.23
Total	100.00	

Table. 1 Elemental compositions of TC CdO-MgO nanocomposites in weight and atomic percentages.

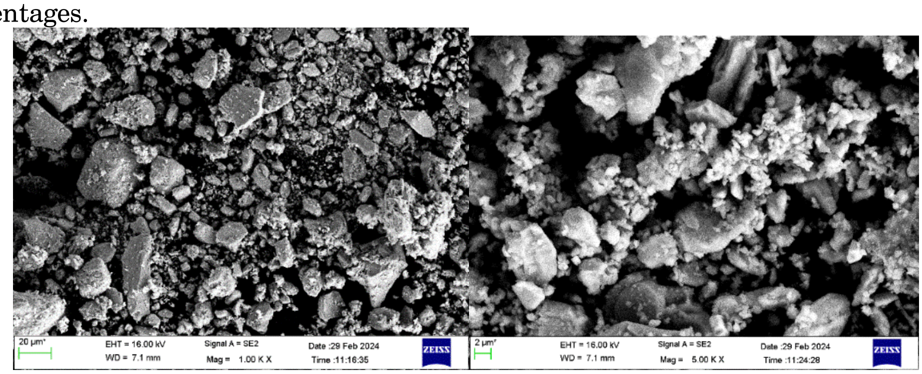

Fig. 4 EDAX spectrum of TC CdO-MgO nanocomposites.

Conclusion

CdO-MgO nanocomposite was prepared using Tinospora cordifolia leaf extract through the co-precipitation method. UV-visible spectrum confirms the formation of TC CdO-MgO nanocomposite. The direct and indirect band gaps of TC CdO-MgO NC was analysed through the Tauc plot method. FESEM images of TC CdO-MgO NC has mixture of nearly spherical and cuboid shape. The presence of Mg, Cd, and O elements in the EDAX spectrum, confirming the formation of TC CdO-MgO NC.

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