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Antibacterial Activity of Cadmium Stannate Nanoparticles Synthesized by Chemical Precipitation Method

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Abstract:

The removal of bacteria from water is an extremely important process for drinking and sanitation systems, especially against bacteria and fungi. Cadmium Stannate (Cd_2SnO_4) is a peculiar and promising material, that received much attention from scientific perspectives and industries for its excellent structural, optical and electrical properties. In this present work, cubic phase Cd_2SnO_4 nanoparticles have been synthesized by the chemical precipitation method. XRD, FESEM, EDAX, FTIR, PL and UV analysis have been performed to study the structural, surface morphological, elemental composition and optical properties. The antibacterial activities of the nanoparticles were carried out for Staphylococcus aureus (gram-positive) and Escherichia coli (gram-negative) by using zone inhibition method. The XRD results confirm the formation of a cubic structure with a particle size of 46 nm. FESEM image shows the cubic-like structure of the nanoparticle. The absorbed peaks from EDAX spectrum confirm the presence of Cd, Sn and O elements. The formation of absorption bands in the range of 500–1200 cm^{-1} is attributed to the metal-oxygen stretching of Cd-O and O-Sn-O. The transmittance value was measured as 76% from the UV graph. The optical band gap was measured as 2.4 eV from Tauc's plot. The photoluminescence spectrum reveals the presence of multiple emission bands in the UV-Vis region. The antibacterial activities confirm Cd_2SnO_4 nanoparticles have great potential against gram-positive and gram-negative bacteria and can be used effectively to remove pathogens and bacteria from contaminated water.

***Key Words**:Cd_2SnO_4 nanoparticles, XRD, FESEM, EDAX, FTIR, Antibacterial activity.*

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I. INTRODUCTION

The application of nanomaterials in water and wastewater treatment has drawn wide attention, due to their small sizes and large specific surface areas, nanomaterials have high mobility [1], strong adsorption capacities, and reactivity [2]. In addition, heavy metals [3], organic pollutants [4], inorganic anions [5], and bacteria [6] have been reported to be successfully removed by various kinds of nanomaterials. The antimicrobial efficiency of metal oxide nanoparticles depends on the particle size, presence of light, the composition of the aqueous medium used in assay *etc*. Metal oxide nanoparticles are found to be the good inhibitors to bacterial strains [7]. One of the members of the ternary oxide family, Cadmium Stannate (Cd_2SnO_4) is an n-type semiconductor with bandgap values around 2.6 - 3.2 eV, high carrier density (~$10^{21} cm^{-3}$), high mobility (~$100 cm^2V^{-1}s^{-1}$) and low absorption, these impressive optical and electronic properties mold them to use in several applications, such as lithium-ion batteries, solar cell and photocatalysis, water splitting, gas sensor, *etc*.. [8-12]. Cd_2SnO_4 forms two different crystal structures, the cubic phase at low temperature (up to 750 °C) and the orthorhombic phase at high temperature *i.e*., above 1000°C [12]. Cd_2SnO_4 nanoparticles were synthesized using several methods such as solution combustion method [11], hydrothermal [10], and chemical precipitation method [13] sol-gel [14] *etc*.

Hence, in this present work, we have made an attempt to develop cubic phase Cd_2SnO_4 nanoparticles by the chemical precipitation method. Further, the antibacterial activities of the nanoparticles were carried out against gram-positive *Staphylococcus aureus*and gram-negative *Escherichia coli* by using the Zone inhibition method. To the best of my knowledge, no reports were available in the literature which explores the antibacterial activity of Cd_2SnO_4 nanoparticles against gram-positive *Staphylococcus aureus*and gram-negative *Escherichia coli* for wastewater treatment.

II. MATERIAL AND METHODS

Synthesis of Cd_2SnO_4 nanoparticles: Cd_2SnO_4 nanoparticles were synthesized by the chemical precipitation method. Analytical grade high purity chemicals were used for synthesis process The stoichiometric amount of cadmium acetate dihydrate $(CH_3OO)_2Cd.2H_2O$ and tin chloride dihydrate $SnCl_2.2H_2O$ were taken in the molar ratios of 2:1 and dissolved separately in 100 ml of deionized water under constant stirring of 1 hour at room temperature for complete dissolution. These solutions were mixed in a beaker under constant stirring of 2 hours for complete mixing at room temperature. Simultaneously, 1M of KOH solution was added drop wise into the solution until a cloud colour mixer was formed. The precipitation was cleaned several times using deionized water and dried in the air using a heating mantle. The dried nanoparticle was annealed at 600^{o}C for one hour to obtain the required structure of the nanoparticles.

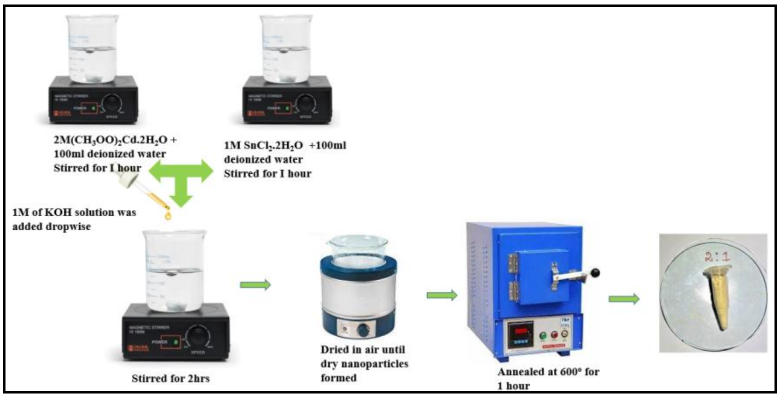

Fig.1. Graphicalillustration for the synthesisofCd_2SnO_4nanoparticles

Instrumentation: The crystal structure of the prepared Cd_2SnO_4 nanoparticles were analyzed by X-ray diffraction using PAN analytical X'Pert PRO powder X-ray diffractometer (λ=1.5406 Å). Field Emission Scanning Electron Microscope (FESEM) with EDAX was recorded on Carl Zeiss, SUPRA 55VP instruments. Optical absorption spectra of the synthesized nanoparticles were recorded on Thermo fisher Evaluation 220 spectrometer. Photoluminescence studies were carried out by a Varian Cary Eclipse Photo Luminescence Spectrophotometer. Fourier transform infrared was done by Thermo Nicolet 380 FTIR. The antimicrobial activity of Cd_2SnO_4 nanoparticles was tested using the Zone inhibition method. Water is used as control, and *Gentamicin* as standard drug.

III. RESULTS ANDDISCUSSION

XRD analysis: To investigate the structural properties of Cd_2SnO_4 nanoparticles, X-ray diffraction (XRD) analysis were carried out. The XRD pattern of the synthesized nanoparticles was shown in Figure.2.

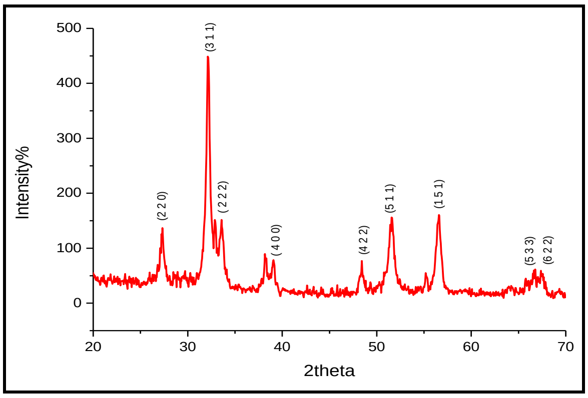

Fig. 2. Powder XRD pattern of the synthesized Cd_2SnO_4 nanoparticles

The XRD pattern of nanoparticles calcinated at 600$_o$ C shows the cubic structure, with prominent peaks at 27.37^o (2 2 0), 32.25^o (3 1 1), 33.83^o (2 2 2), 39.23^o (4 0 0), 48.60^o(4 2 2), 51.68^o (5 1 1), 56.66^o (1 5 1), 66.79^o (5 3 3), 67.66^o (6 2 2) are well indexed with standard JCPDS data # 80-1469 [10].

The average crystalline size (D) of Cd_2SnO_4 nanoparticles was calculated using Debye–Scherrer's formula

$$D = \frac{k\lambda}{\beta \cos\theta} \tag{1}$$

Where D - average crystallite size, λ-wavelength of radiation(1.5406Å), k-Constant (0.94), β-Full width half maximum andθ-Bragg's diffraction angle respectively.Theaverageparticlesizeofthe nanoparticles wasmeasuredas 46nm.Thedislocationdensity(δ)andmicrostrain(ε)werealsodeterminedusingtheEquations(2)& (3) as:

$$\delta = \frac{1}{D^2} \tag{2}$$

$$\varepsilon = \frac{\beta \cos\theta}{4} \tag{3}$$

The dislocation density of the nanoparticle was calculated as 0.0557×10^{15} lines/m^2,andthemicrostrain was0.836×10^{-3}.

SEM with EDAX analysis: The SEM study reveals the surface morphology of the nanoparticles. Fig. 3(a) indicates the SEM image of Cd_2SnO_4 nanoparticles. It is clearly seen from the figure that the homogeneity in shape and size of the nanoparticles with cubic structure [15]. The observed particle size was well-matched with the results obtained from XRD studies. The chemical composition of Cd_2SnO_4 nanoparticles was extracted from the energy-dispersive X-ray spectrum (EDAX) which is shown in Figure 3(b). The EDAX analysis exhibits clear peaks of Cd, Sn and O elements.

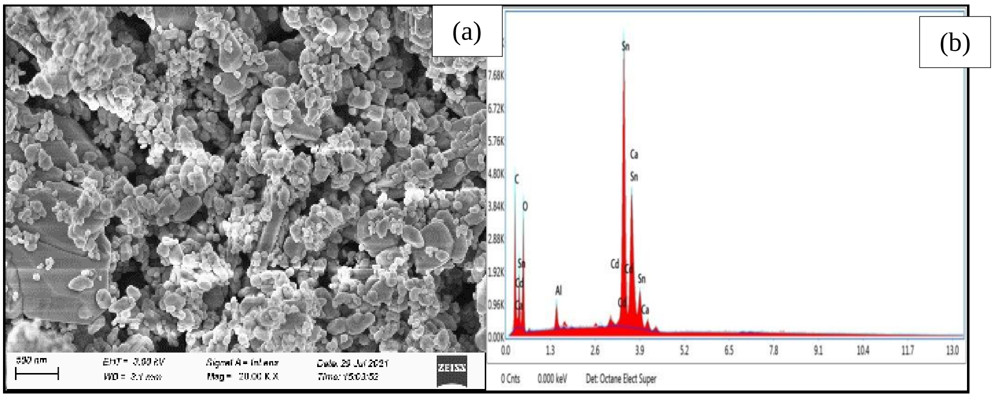

Fig.3.(a)FESEMimageand(b)EDXspectrum ofCd_2SnO_4nanoparticles.

UV-Visible analysis:The optical absorption, transmittance and direct bandgap of the Cd_2SnO_4 nanoparticle were shown in Figure 4(a),(b) and (c). The transmittance is measured as 76%. Theopticalenergybandgapwascalculatedusing the formula

$$(\alpha hv) = A(hv - E_g)^n \tag{4}$$

Where, *α*is the absorption coefficient, *hv*is photon energy, $E_g$is the bandgap of the material and the exponent *n*dependson the type of transition. The parameter *n* got the value 2 for direct allowed transition. Tauc'splot between $(\alpha hv)^2$ and *E*(eV) are plotted and the linear portion of the graph has beenextrapolated to meet the energy axis to determine the energy band gap as shown in Figure 4(c).Theoptical bandgap valueof Cd_2SnO_4nanoparticleis 2.4 eV. Similar result was observed by Dinesh *et al* [10].

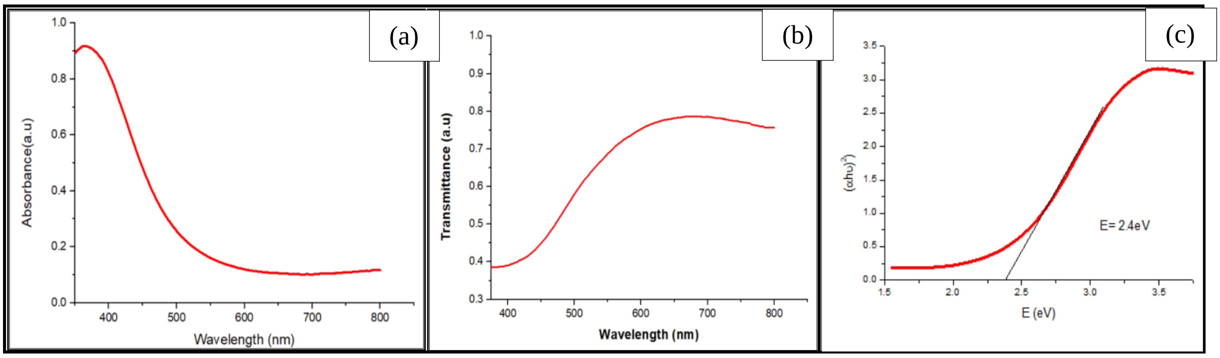

Fig.4(a)Opticalabsorbance(b)Transmittanceand (c)Tauc'splot of Cd_2SnO_4 nanoparticles

PL analysis: PL spectra have been recorded at room temperature with an excitation wavelength of 420 nm. Figure.5. shows the photoluminescence spectra (PL) of the Cd_2SnO_4 nanoparticles. The strong broad peak centered at 361 nm, 411nm can be ascribed near band edge emission of SnO_2 nanostructure which originates from recombination of the hole in the valence band and electron in the conduction band [16]. The nanoparticles exhibited a strong narrow emission band at 489 nm, ascribed to the near band edge emission of Cd_2SnO_4 nanoparticles. The green emission PL peak obtained at 520 nm corresponds to the recombination of holes with the ionized oxygen vacancies, called as deep level or trap state emission [9].

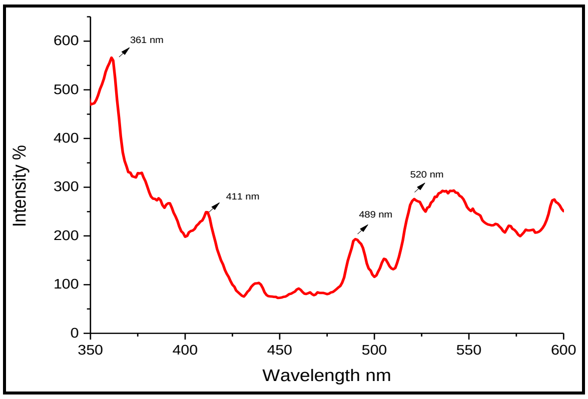

Fig. 5. Photoluminescence spectra of Cd_2SnO_4 nanoparticles.

FTIR analysis:Figure.6. shows the FTIR spectra of the prepared Cd_2SnO_4 nanoparticles. The formation ofCd-O bondisat477 cm^{-1}.The additionalbandcenteredat1200cm^{-1}isrelatedtothestretching mode of Cd-O [17].

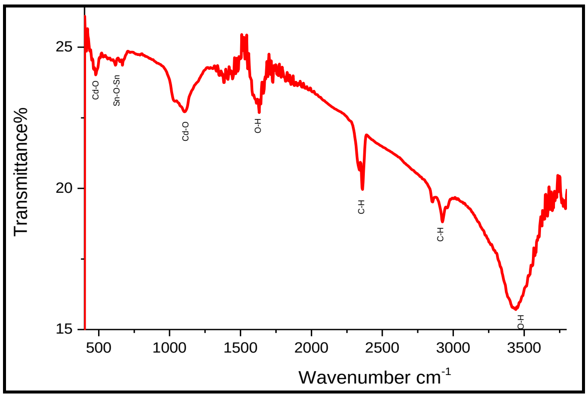

Fig. 6. FTIR spectrum of Cd_2SnO_4 nanoparticles

From this spectrum, it can be observed apparently at 663 cm^{-1}that a strong band is associated with the antisymmetricSn–O–Sn stretching mode [18]. Thepeaksaround1,645cm^{-1} and3,421cm^{-1}correspondtothebendingvibrationsofabsorbedmolecular water and the stretching vibrations of –OH groups respectively. The peaksabsorbedat 2,367and 2,907 cm^{-1}belongto thestretchingvibrations of–C–H[19].

Antimicrobial activity: The effect of Cd_2SnO_4 nanoparticles on the growth of some common food and water poisoning pathogens was studied. In this investigation, we have tested the effectiveness of one disinfectant (Cd_2SnO_4 nanoparticles in solution) on the growth of bacteria (*E.Coli and Staphylococcus Aureus*). 20 µl of Cd_2SnO_4 nanoparticles diluted solution was used disinfectant, water as control, and *Gentamicin* as standard drug. The Petri dish was placed at 37^o C in the incubator for 48 hours. After 48 hours of incubation, the zones of inhibition around each drop were measured in millimeters. Zone of inhibition is the area around a paper disk of bacteria or mold where no other organisms are growing. The larger this zone of inhibition, the more effective that antibiotic is against that specific type of bacteria [20]. For *Staphylococcus aureus*, Cd_2SnO_4 nanoparticles had a higher inhibition zone of 10mm, for *Escherichia coli*, it had an inhibition zone of 9 mm. Figure 7 shows a photograph antibacterial test of Cd_2SnO_4 nanoparticles. This is a significant response when compared to the standard drug Gentamicin.

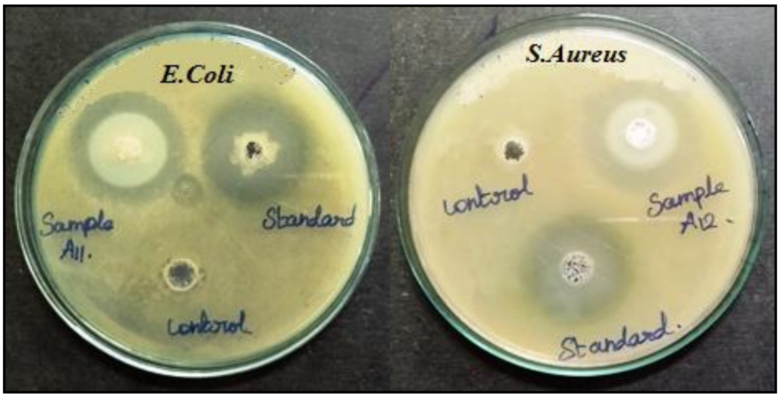

Fig.7. Photographs of antibacterial test of Cd_2SnO_4 nanoparticles

IV. CONCLUSION

ThecubicphaseCd$_2$SnO$_4$nanoparticlesweresynthesizedsuccessfullyusingthechemicalsynthesismethod.TheXRDresultsconfirmtheformationof a cubicphase with high crystalline nature, and the average particle size was measured as46 nm. TheFESEMresult shows the homogeneity of Cd_2SnO_4 nanoparticles and the elemental composition of the nanoparticles was confirmed by EDAX. From the optical studies,the transmittance was calculated as 76% and the optical bandgap wasmeasuredas 2.4 eV.The antibacterial activities confirm Cd_2SnO_4 nanoparticles have great potential against gram-positive and gram-negative bacteria and can be used effectively to remove water poisoning pathogens andbacteria from contaminated water.

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