Synthesis, Characterization, and Antifungal Activity of Cd_2SnO_4 Nanoparticles Prepared by Sol-Gel Technique

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Abstract

In this study, Cd_2SnO_4 nanoparticles were produced using a sol-gel technique. X-ray diffraction was used to investigate the Cd_2SnO_4 nanoparticles. Transmission electron microscope (TEM) with Fourier transform infrared spectrophotometer (FTIR), FE-SEM images show that manufactured Cd_2SnO_4 nanoparticles have cubic structures with some irregular cubic shaped nanoparticles. XRD patterns of the prepared thin films showed that the nanoparticles have a polycrystalline structure. The wide bands between 551 and 854 cm^{-1} are attributable to the framework vibrations of the Sn-O bond in SnO_2, and the band at 551 cm^{-1} is also due to cadmium and oxygen in this area, according to the FTIR analysis. The TEM result shows the presence of cubic shaped nanoparticles. The interaction between the cadmium nanoparticles and the cellular contents of the fungi may be the reason for the antifungal effectiveness of Cd_2SnO_4 nanocomposites.

Key Words: Cd_2SnO_4, Nanoparticles, Sol-gel, Fungi, XRD.

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Introduction

Materials with a unique combination of high transparency and electrical conductivity, particularly thin films, offer a wide variety of uses. Transparent electrodes and conductors, as well as solar heat collectors, are among their applications. SnO_2, ZnO, and In_2O_3:Sn are the most often utilized transparent conducting oxides (TCO_s), and they have been extensively studied and employed in a various applications. The development of TCO_s with low electrical resistivities does not require larger carrier concentrations; instead, it can be accomplished by keeping a reasonable carrier density while increasing mobility. In recent years, ternary oxides such as $CdIn_2O_4$ (Mamazza et al., 2002), Zn_2SnO_4 (Coutts et al., 2000, Wu et al., 2001), $ZnGa_2O_4$ (Pandey et al., 1999), and $Cd_2 SnO_4$ have gotten a lot of attention. (Bel-Hadj-Tahar et al., 2015). Among these compounds, CTO offers numerous notable, compared to other transparent conducting materials, this material has a number of advantages, which was explored in the 1970s in the form of powders and films and is now attracting fresh interest for use as TCO for CdTe solar cells to attain optimum efficiency (Bel-Hadj-Tahar et al., 2015). This material differs from a simple combination of CdO and SnO_2 as a result of the structural differences between both the bulk as well as the film. The formation of pure spinel phase is frequently related with the manufacture of CTO layers with better characteristics than standard TCO materials.

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$CdSnO_3$ is another ternary oxide that may be made with Cd and Sn (Al-Mashhadani et al., 2021, Radhi et al., 2020, AlMashhadani and saleh, 2020). This substance crystallizes into two distinct phases, a cubic perovskite lattice with a conductance much lower than those of Cd_2SnO_4 and a gas sensing field (Bel-Hadj-Tahar et al., 2015). Molds, yeasts, yeast-like fungi, and dimorphic fungi are eukaryotic, heterotrophic organisms that lack chlorophyll and have a strong cell wall. In damp and wet conditions, fungi grow quickly and reproduce by generating spores and mycotoxins. Inf inflammation, allergies, and infections can cause respiratory issues, eye discomfort, headaches, coughing, nose or throat irritation, and skin rashes (Saadullah, 2020). In the present work, A simple procedure for producing Cd_2SnO_4 nanoparticles using the sol-gel technique is described, as well as physical properties and medical applications.

Materials and Method

Cd_2SnO_4 nanoparticles with cubic morphology were synthesized by a sol-gel method. This solution was prepared by dissolving Cadmium Nitrate [$Cd(NO_3)_2$ $.4H_2O$], (1 M) which is a powder with molecular weight of 308. 47g/mol, in 100 ml from distilled water and appropriate amount of $SnCl_4.5H_2O$ (0.25M) which is also a powder with molecular weight of 350.58 g/mol, in 100 ml from distilled water. and 0.5 M from Citric acid $C_6H_8O_7$ with molecular weight of 192.123 g/mol. The solutions were mixed with a magnetic stirrer and left for 50 minutes to ensure that no residues remained and that the final solution was homogeneous. Drops of 0.1M aqueous ammonia solution (NH_4OH) were added to the aforesaid solution while stirring as a solvent. To remove water molecules, the gels were filtered and dried for four days at 80° C. To create Cd_2SnO_4 nanoparticles, the powder was annealed in an air environment at 550 oC for two hours and then allowed in the furnace to cool to room temperature after cutting off the furnace. X-ray powder diffraction (XRD) was used to look at the samples that were made. The XPERT PRO used CuK_α, X-ray radiation with a wavelength of 0.15406nm. Each scan took 0.01^o. XRD patterns were taken from 10 to 80^o (2) with a scan speed of 0.01^o spectra.

1. The Biological Efficacy of Cadmium Citrate against some Dermatophyte Pathogenic Fungi (Cd_2SnO_4)

i. **Preparation of fungal isolates:** The laboratories of the Department of Biotechnology/College of Science/University of Diyala isolated and diagnosed some species types of dermatophytes and opportunistic dermatophytes. The species included: Dermatological pathogens: *Microsporum audounii*, *Trichophyton rubrum,* and *Epidermophyton floccosum* Skin opportunistic pathogens; Candida albicans and *Rhodotorula mucillaginosa* (yeasts), in addition to molds that included *Aspergillus nidulans*, A. *Terreus*, *Cladosporium sp., Penicillium sp*. and *Rhizopus arrhizus* (Crespo et al., 1990, Mahmoud et al., 1989, Al-Zuhairi, 2018).

ii. **Study the effect of cadmium oxide on the growth of some pathogenic fungi**. The test was conducted using the agar-well diffusion method, which was as follows: Inoculate the surface of the sabouraud agar with a sterilized swab from cultured fungi containing ($1.5x10^6$) cells/ml by comparing it with a fixed turbidity solution. Then, the plates were left to dry at room temperature. Drills with a diameter of (5) mm were drilled in the middle of the cultured area with a Cork Borer. Concentrations (1 mg/ml) were prepared using sterile distilled water, where (1 g) of the compound was dissolved in (1 ml) of the solvent solution to obtain a concentration of 1 mg/ml. A micropipette was used to add (0.1) ml of the compound to a hole, and sterile distilled water was used to make a control hole. In order to allow the compound to spread through the medium, the dishes were placed in the refrigerator at a temperature of (4) °C for half an hour as described (Mahmoud et al., 1989). The dishes were incubated at (37) C for a period of 3-5 days. The diameter of the Inhibition Zone surrounding each hole was measured to assess the compound's efficiency. For each fungal isolate, the experiment was performed three times.

Discussion of the Results

1. XRD Analysis

The XRD pattern of Cd_2SnO_4 nanoparticles generated by sol-gel technique is shown in Figure 1. The XRD pattern revealed the crystalline nature of Cd_2SnO_4 nanoparticles and showed that the nanoparticles have a polycrystalline structure. Fig.1 shows three sharp peaks about $2\theta = 33.6^o$, 38.3^o and 55.2^o, which corresponds to (222), (400) and (440) crystal planes, which is in agreement with other reports (Wu et al., 1997, Kelkar et al., 2012). No peaks of different impurity crystalline phases have been detected. The fact that the diffraction peaks appear to be broadened indicates the presence of small nanosized particles. The average crystallite size (D_{av}) in nm, using Scherrer's formula, was determined for (020) plane (Farhan et al., 2020, Mohammed et al., 2020):

$$D_{av} = \frac{K\,\lambda}{\beta \cos\theta} \quad (1)$$

Where: (K) is constant and equal 0.9, (λ) is the wavelength of incident X-ray radiation (1.5406 Å for CuK_α), (β) is the full width at half maximum and (θ) is Bragg's diffraction angle of the XRD peak(Farhan et al., 2020, Khodair et al., 2020, Khodair et al., 2019, Abed et al., 2019, Abed et al., 2006). The crystallite size is approximated as stated in Table (1).

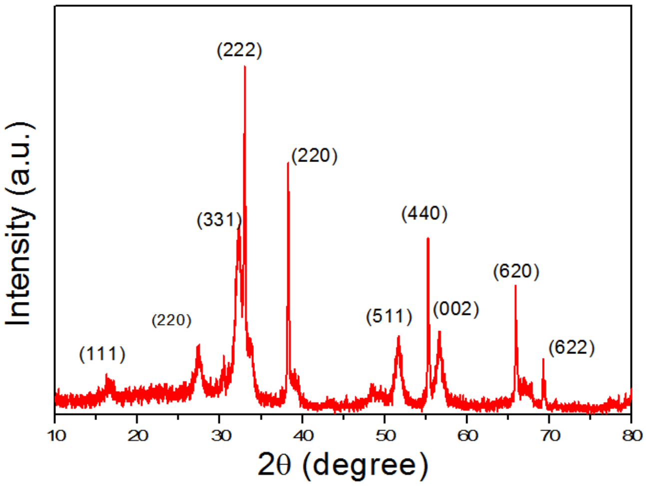

Figure 1. **X-ray diffraction of Cd_2SnO_4 nanoparticles**

The density of dislocation (δ) was estimated using (Farhan et al., 2020, Abed et al., 2006).

$$\boldsymbol{\delta} = \frac{1}{D_{av}^2} \quad (2)$$

The dislocation density (δ) of Cd_2SnO_4 nanoparticles, as shown in the table, has been observed (1).

The number of crystallites (N) was calculated via (Abed et al., 2006, Khodiar et al., 2020, Khodair et al., 2016).

$$N_o = \frac{t}{D_{av}^3} \quad (3)$$

The number of crystallites for Cd_2SnO_4 nanoparticles can be seen in table (1).

Table 1. XRD analysis of Cd_2SnO_4 nanoparticles

2θ (Deg.)	**FWHM (Deg.)**	**d_{hkl} Exp.(Å)**	**G.S (nm)**	***hkl***	**δ (line. nm^{-2}) *10^{+18}**	**N_o (nm^{-2}) *10^{+18}**
16.64	0.14	5.3234	57.3	111	0.0003	0.0016
27.47	0.54	3.2443	15.1	220	0.0044	0.0864
32.34	0.16	2.7660	51.7	311	0.0004	0.0022
33.6	0.2	2.6651	41.5	222	0.0006	0.0042
38.38	0.17	2.3435	49.5	400	0.0004	0.0025
48.62	0.12	1.8711	72.6	422	0.0002	0.0008
51.72	0.16	1.7660	55.2	511	0.0003	0.0018
55.26	0.16	1.6610	56.0	440	0.0003	0.0017
56.58	0.32	1.6253	28.2	002	0.0013	0.0134
65.91	0.16	1.4160	59.2	620	0.0003	0.0014
69.24	0.17	1.3558	56.8	622	0.0003	0.0016

1. FE-SEM Analysis

FE-SEM images (field-emission scanning electron microscopy) of cubic Cd_2SnO_4 nanoparticles prepared by sol-gel technique is shown in Fig. 2. at various magnifications Synthesized Cd_2SnO_4 nanoparticles include cubic structures with some irregular cubic shaped nanoparticles, as shown in the images (Kadhim et al., 2022). where the existence of cubic shaped nanoparticles with an average particle size of 30.8 nm is clearly seen in Fig. 2. The average particle size in the SEM pictures matched the values estimated from the XRD observations in Table, which agrees with previous research (Levinson, 2014). 139

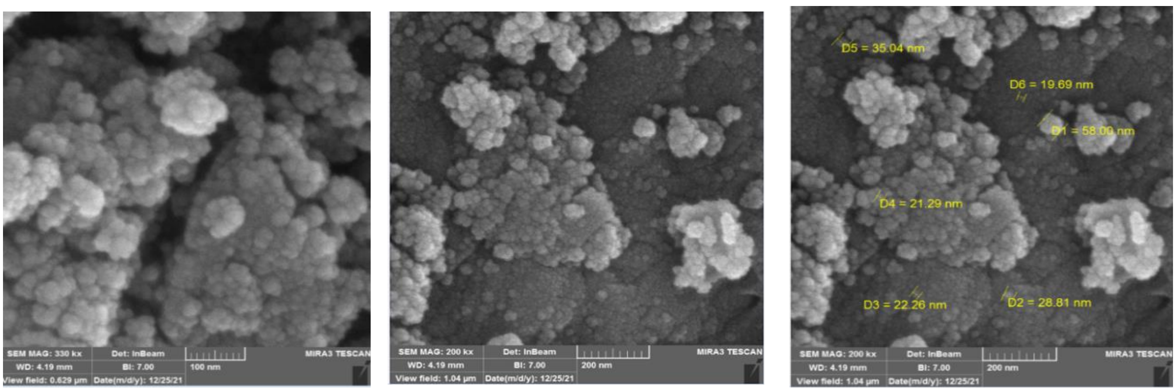

Figure 2. FE-SEM image of Cd_2SnO_4 nanoparticles at different magnifications

2. TEM Analysis

Transmission electron microscopy (TEM) analysis was used to learn more about the structure of the prepared Cd_2SnO_4 nanoparticles. Fig. 3a & b explains the TEM images at 30 and 80 nm respectively, where the presence of cubic shaped nanoparticles is easily seen in Fig. 2a. It shows that spherical nanoparticles are homogenous and well-distributed, with some partially aggregated into irregularly shaped tin oxide nanoparticles. The average particle size is about 22 nm. Moreover, the presence of spherically elongate crystals indicates that the SnO_2 and Cd crystals grew in response to the grain coalescence process was triggered by grain rotation. The anisotropic growth tendency of the spherical and some aggregated SnO2 nanoparticles is readily seen when comparing the TEM patterns. (Al-Zuhairi, 2018, Wu et al., 1997).

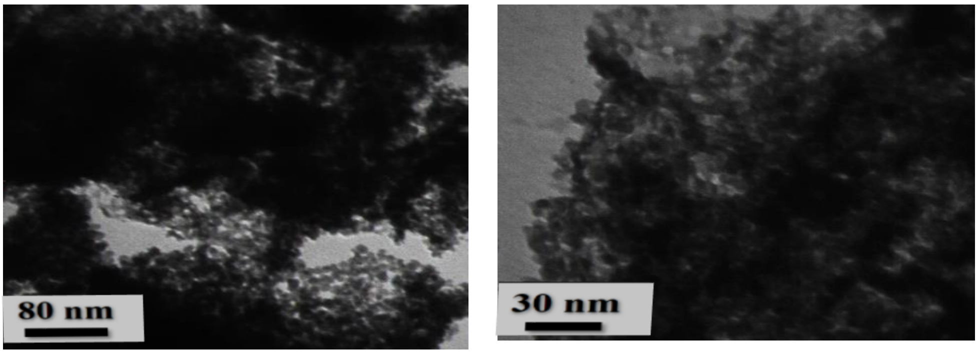

Figure 3. TEM image of Cd_2SnO_4 nanoparticles

3. FTIR Analysis

The FTIR transmittance (4000–400 cm^{-1}) spectral range of Cd_2SnO_4 nanoparticles is shown in Fig. 4. The spectrum and the bands are approximately presented at 551, 854, 1519 and 3527 cm^{-1}. The broad bands at 1519 and 3527 cm^{-1} can be attributed to the O–H vibrations in absorbed water on the sample surface. The wide bands between 551 and 854, cm^{-1} are ascribed to Sn–O bond framework vibrations in SnO_2 (Khodair et al., 2016), and the band at 551 cm^{-1} is also due to cadmium and oxygen in this region. Most of the metal compounds should be present in the region (Levinson, 2014).

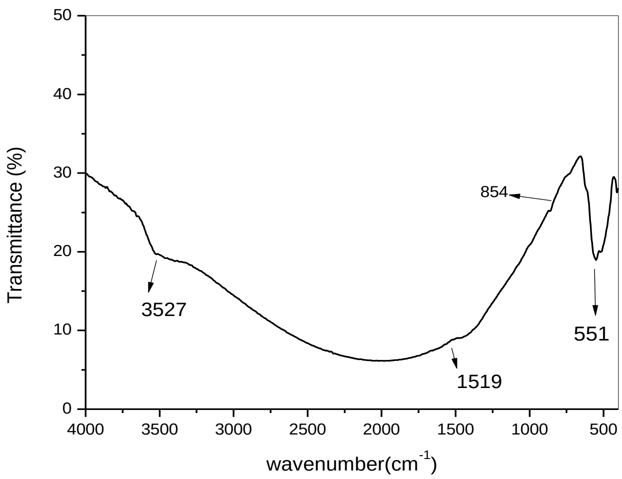

Figure 4. FTIR spectrum of Cd_2SnO_4 nanoparticles

4. Result of Fungal Isolates

Antifungals in general have different mechanisms of action against pathogenic fungi, depending on the chemical structure of the antifungal. The effect may be on the contents of the cell wall of the fungus, the plasma membrane, the nuclear content (DNA, RNA) or the fungal enzymes (Shivashankarappa and Sanjay, 2015). According to previous studies presented by Shivashankarappa and Sanjay, and Sandhiyapriya et al., (Sandhiyapriya et al., 2021, Webster and Weber, 2007), Cd_2SnO_4 nanoparticles are an effective anti-fungal, as shown in Fig. 5 and table 2..The reason for the effectiveness, as mentioned above, maybe due to the interaction between cadmium nanoparticles and the cellular contents of the fungi, where the cell wall of the fungi consists of chitin layers. These components are not found in human cells, and fungi's cell membranes contain the compound ergo sterol instead of the cholesterol found in human cells (Kidd et al., 2016). This makes the compound safe for biological use. The difference in natural compound results (Cd_2SnO_4) is due to the genetic makeup of the species, the genetic content of the cell, the chemical composition of the cell, yeast *Rhodotorulla mucilaginosa*) for example containing polysaccharides (contains a polysaccharide extracellular matrix (capsule).

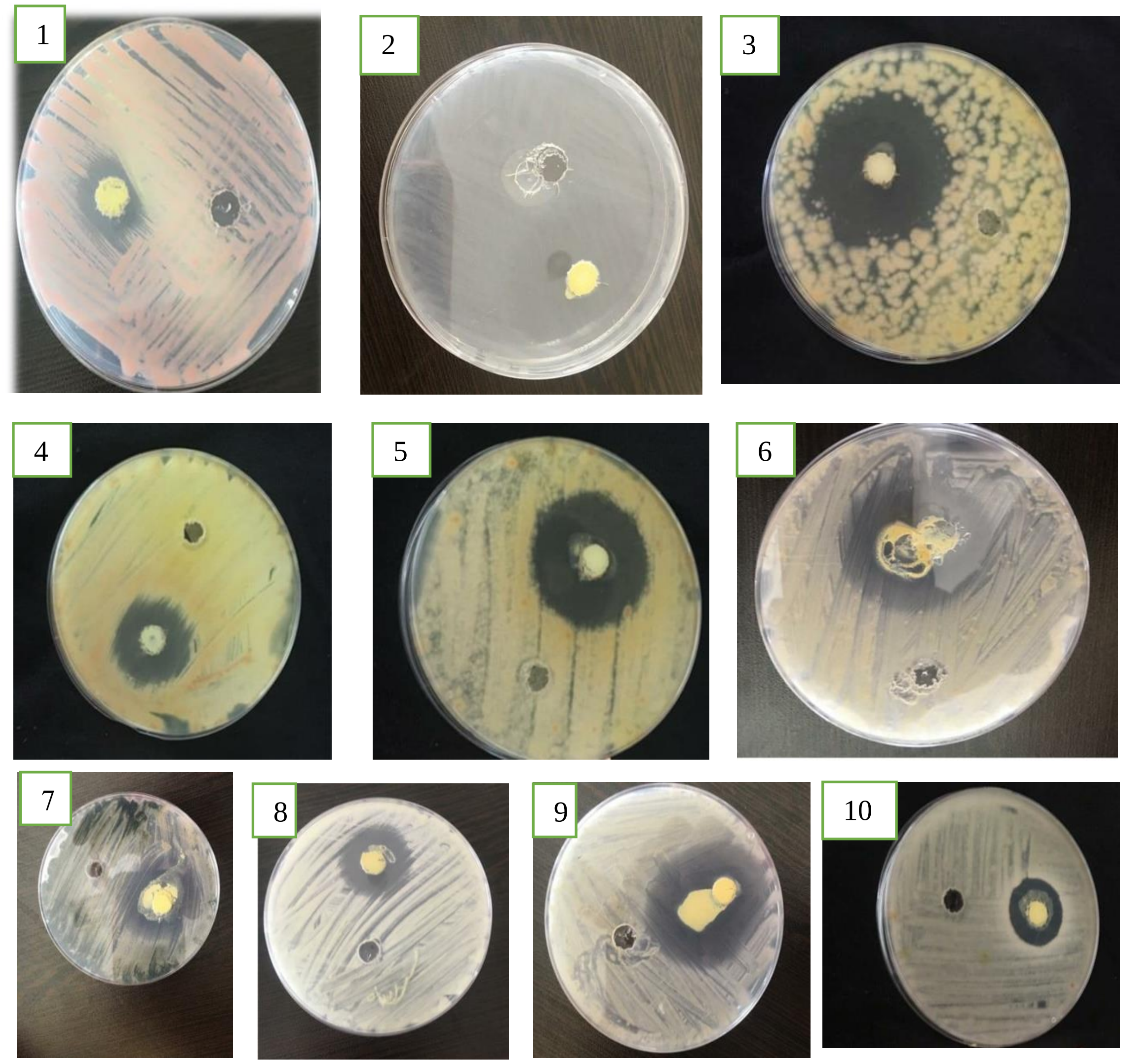

Figure 5. The inhibition zones of fungi by Cd_2SnO_4 nanoparticles

[1. Rhodotorula mucillaginosa (Yeast), 2. Candida albicans (Yeast), 3. Aspergillus nidulans (musty), 4. Aspergillus terreus (musty), 5. Trichophyton rubrum (musty), 6. Epidermophyton floccosum (musty), 7. Cladosporium sp (musty), 8. Penicillium marneffei. (musty), 9. Rhizopus arrhizus (musty), 10. Microsporum audounii (musty)]

Table 2. Average diameter of the compound (Cd2sno4) against fungi

No.	Name of Fungi	Average damping diameter (mm)
1	Rhodotorula mucillaginosa (Yeast)	27.33
2	Candida albicans (Yeast)	24.33
3	Aspergillus nidulans (musty)	42.66
4	Aspergillus terreus (musty)	35.66
5	Trichophyton rubrum (musty)	37.66
6	Epidermophyton floccosum (musty)	40.66
7	Cladosporium sp (musty)	36.33
8	Penicillium marneffei. (musty)	35.33
9	Rhizopus arrhizus (musty)	38.33
10	Microsporum audounii (musty)	25.66

Conclusions

In this study, Cd_2SnO_4 nanoparticles were prepared by a sol-gel technique. X-ray powder diffraction (XRD shows three sharp peaks about $2\theta = 33.6^o$, 38.3^o and 55.2^o which corresponds to (222), (400) and (440) crystal planes. FE-SEM images revealed that the Cd_2SnO_4 have cubic structures with some irregular cubic shaped nanoparticles The FTIR analysis indicate that broad bands between 551 and 854, cm^{-1} are attributed to the framework vibrations of the Sn–O bond in SnO_2 and the band at 551 cm^{-1} is also due to cadmium and oxygen in this region. TEM result shows the presence of cubic shaped nanoparticles. The interaction between the cadmium nanoparticles and the cellular contents of the fungi may explain why Cd_2SnO_4 nanoparticles are effective antifungals.

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