Antibacterial Activities of CdO Microplates Synthesized by Hydrothermal Method

K. Karthik[a], S .Dhanuskodi[a*], C. Gopinath[b], S. Sivaramakrishnan[b]

[a] School of Physics, Bharathidasan University, Tiruchirappalli – 620 024, Tamilnadu, India.
[b] Department of Biotechnology and Genetic Engineering , Bharathidasan University, Tiruchirappalli -620 024, Tamilnadu, India. * E-mail: dhanus2k3@yahoo.com.

Abstract— **CdO microplates were synthesized (hydrothermal) with cadmium chloride and ammonium hydroxide as starting materials and characterized by XRD, FE-SEM with EDS and FTIR. It exhibits face centred cubic structure with an average crystallite size of 27 nm and the lattice strain (W – H Plot) is 0.0012. The surface morphological image displays microplate like structure with agglomeration. The vibrational stretching mode of Cd-O is 455 cm^{-1}. From the UV- Visible spectra, the optical energy bandgap is estimated as 2.56 eV. The significant antimicrobial activities were studied against gram negative (*Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris)* and gram positive (*Staphylococcus aureus, Enterococcus faecalis, Enterococci spp)* bacteria. The zone of inhibition is found to be more for gram negative than for gram positive bacteria.**

Keywords- **Antibacterial activity, Microplates, Hydrothermal, Structural and FT-IR.**

I. INTRODUCTION

In recent research among the conducting oxides, there exists a promising candidate cadmium oxide (CdO), with specific features of low bandgap (2.2 – 2.7 eV), high conductivity (10^3 $ohm^{-1}cm^{-1}$), high carrier mobility (142 cm^2/Vs) and large linear refractive index (n_o=2.49). CdO has shown applications in the fields of solar cells, photo transistors, transparent electrodes, catalysis and gas sensors [1]. It is an important II – VI semiconductor having NaCl crystal structure with alternating Cd and O atoms located at lattice points [2].

II. EXPERIMENTAL

A. Material synthesis

CdO microplates were synthesized by hydrothermal method with $CdCl_2$ and NH_4OH as starting materials. Cadmium chloride was dissolved in 100 ml of double distilled water and ammonia solution was added dropwise into the above solution and was maintained at pH = 10. Then the solution was transferred to a stainless steel autoclave bottle kept at 150°C for 10 h in the hot air oven. The resulting solid product was washed with ethanol and double distilled water repeatedly and dried in air resulting with a solid powder and was sintered at 873 K for 6 h. Finally, it was grounded to get brown CdO powder.

B. Instrumentation

X-ray powder diffraction (XRD) studies were carried out to affirm the crystal structure using XPERT – PRO X-ray Diffractometer with Cu K_α radiation (1.5406Å) in the range of 10-70° in steps of 0.0025 at a scan speed of 2°/min. The morphology of the synthesized powder was examined by FE-SEM (JEOL – JSM – 6301 FE-SEM) and the chemical composition was investigated by EDAX (Bruker). The molecular structure was confirmed by JASCO 460 PLUS FTIR spectrometer (400-4000 cm^{-1}). The linear optical absorption characteristics were recorded using Shimadzu UV-1800 spectrophotometer (200-800 nm).

III. RESULT AND DISCUSSION

A. Structural and morphological characteristics

Fig. 1 shows the X-ray diffraction pattern of CdO microplates and the cell parameters are in good agreement with the JCPDS (75-0592) with a=0.469 nm for cubic phase. The broadened peaks reveal the synthesized microplates are of higher order of crystallinity and purity [3]. The crystallite size (D) is calculated using Scherrer's formula

$$D= k\lambda/\beta\cos\theta \qquad (1)$$

Where k is a constant (0.94), λ is the wavelength of X-ray (1.5406 Å), θ is the peak position and β is the full width at half maximum (FWHM). The average crystallite size (D) of CdO microplates is 27 nm. The Willamson – Hall method was followed to find the lattice strain using the modified Scherrer equation

$$\beta\cos\theta = (k\lambda/D)+(4\varepsilon\sin\theta) \qquad (2)$$

W-H plot of βcosθ against 4sinθ provides the information about the microstrain. The W – H plot is expected to be a horizontal line, parallel to the sinθ axis, whereas in the presence of strain, it has a non-zero slope. The calculated value of the microstrain for the synthesized CdO microplates is 0.0012.

The surface morphological image is shown in Fig. 2 and EDS data is (Cd: 42.30% and O: 57.70%).

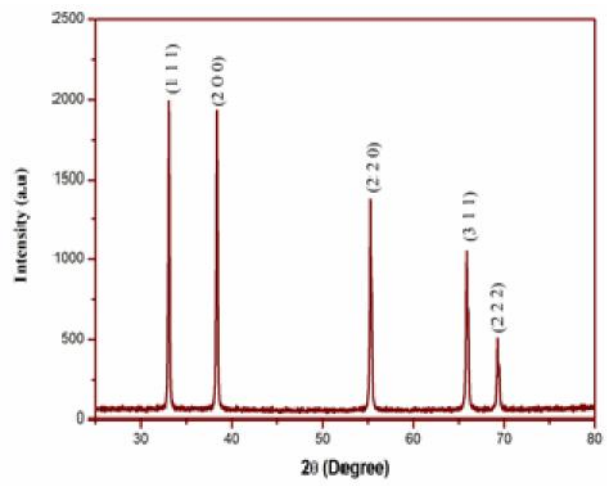

Fig.1 XRD pattern of CdO microplates

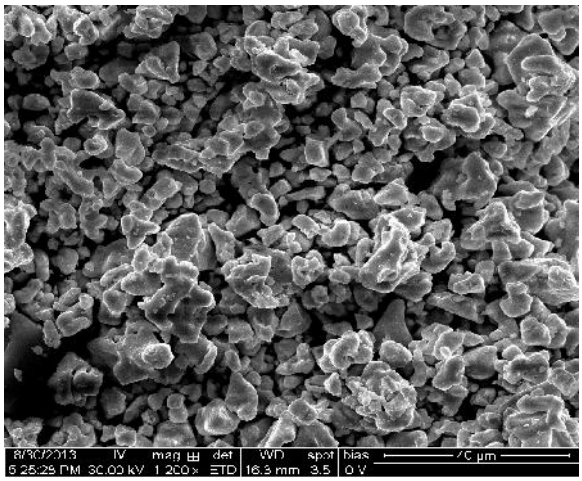

Fig.2 SEM image of CdO microplates

A. FT-IR analysis

The molecular structure was confirmed by FT-IR spectra. A strong band at 3440 cm^{-1} is assigned to O-H stretching vibration of surface hydroxyl groups. A peak at 1645 cm^{-1} is due to the deformative vibration of water molecule. The band at 914 cm^{-1} is the overtone of the stretching modes of Cd-O. The formation of Cd-O bond is described by the peak at 455 cm^{-1} (Fig. 3) [1].

B. Linear optical studies

In the present work, in order to record the UV-Vis spectrum, CdO were firstly dispersed in double distilled water by ultrasonication. It shows a near band edge absorption at 225 nm. The optical bandgap is calculated by the relation

$$\alpha h\upsilon = A\,(h\upsilon - E_g)^n \qquad (3)$$

Where A is the characteristic parameter, h is Planck's constant, υ is the frequency of light, E_g is the optical energy bandgap and n is the parameter which characterizes the transition process involved. The parameter n = 2 for direct allowed electron transition and ½ for indirect allowed electron transition. The plot of $(\alpha h\upsilon)^2$ Vs hυ is shown in Fig. 4, from which the optical energy bandgap (E_g) is estimated by extrapolating the linear part up to zero on the energy axis. The optical direct bandgap is estimated as 2.56 eV [4].

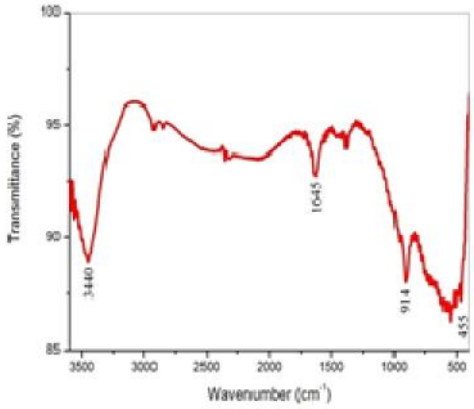

Fig. 3 FT-IR spectra of CdO microplates

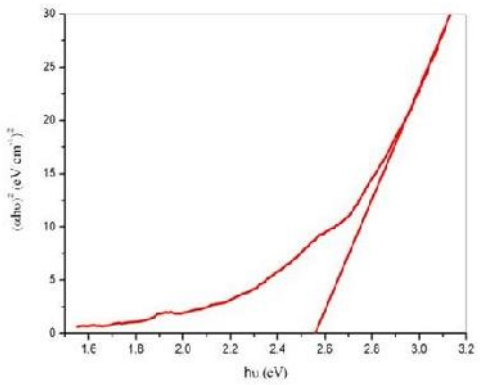

Fig. 4 Bandgap of CdO microplates

C. Antibacterial studies

The antibacterial effects of CdO microplates showed a level of inhibitory effects against the tested pathogenic organisms in impregnated discs. Maximum zone of inhibitory action (ZOI) appeared in all the test organisms such as gram negative (*Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris)* and gram positive (*Staphylococcus aureus, Enterococcus faecalis, Enterococci spp)* bacteria. Interestingly in the present study CdO microplates have shown more prominent cell inhibition of 18 mm for *Enterococci spp* when compared to the standard antibiotics (Ampicillin). The zone of inhibition is found to be more for gram negative bacteria than gram positive bacteria because CdO powder damages the structure of bacteria cell membrane and depresses the activity of some membranous enzymes which cause gram negative bacteria to die eventually [4]. The commonly accepted mechanism of antibacterial action of the material states that the production of reactive oxygen species (ROS) on the surface of these nanoparticles in light causes oxidative stress in bacterial cell, eventually leading to the death of the cells. ROS contain the most reactive hydroxyl radical (OH), the less toxic super oxide anion radical (O_2^-). This can damage DNA, cell membranes etc., leading to cell death. The attachment of the nanoparticles to the bacteria has also been demonstrated. This is attributed to the electrostatic attraction between the negatively charged bacteria and the positively charged nanoparticles. Such a contact may not only inhibit bacterial growth, but the generated ROS may also kill the cell [5]. The zone of inhibition values are presented in Table 1.

Table 1. Antimicrobial activity of CdO microplates against bacterial pathogenic organisms

S.No	Bacterial pathogenic organism	Zone of inhibition (mm)	
		Standard antibiotics (Ampicillin)	CdO
1	*Escherichia coli*	34.6	21
2	*Staphylococcus aureus*	23	20
3	*Pseudomonas aeruginosa*	36.6	20
4	*Enterococcus faecalis*	16	11
5	*Proteus vulgaris*	34.6	20
6	*Enterococci spp*	12.3	18

IV. CONCLUSION

In the present work, CdO microplates were synthesized by hydrothermal method. XRD results indicate the formation of cubic structure. FE-SEM image shows a plate like structure and the presence of Cd and O atoms are confirmed by EDS analysis. The FT-IR spectrum exhibits the characteristics vibration mode of Cd-O. The optical energy bandgap is found to be 2.56 eV from UV-Vis absorption spectrum. The biological activities of the synthesized CdO microplates showed fast and strong antibacterial activity against six pathogenic organisms than the standard antibiotics.

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