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A STUDY ON STRUCTURAL AND DIELECTRIC PROPERTIES OF CdO_2 Nanoparticles

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Abstract- *Cadmium Oxide (CdO_2) nanoparticles were synthesized by chemical co-precipitation method. The structural studies of CdO_2 nanoparticles (NPs) were characterized by powder X-ray diffraction (XRD) analysis. The XRD results revealed that the sample product was crystalline with a grain size of 34 nm in cubic structure. The functional groups present in the Cadmium Oxide nanoparticles were identified by Fourier transformation infrared spectroscopy (FT-IR) analysis. The surface morphology was characterized by High Resolution Scanning Electron Microscope (HRSEM). The chemical compositions of the CdO_2-NPs were determined using X-ray energy dispersive analysis (EDX). The dielectric properties of cadmium oxide NPs were measured as a function of frequency at different temperatures. The dielectric constant and loss tangent of the sample decreased with an increasing applied frequency signal. The ac conductivity of the prepared sample was found to increase with increase in frequency.*

Key Words: **Cadmium Oxide, Co-precipitation, HRSEM, Dielectric properties, AC conductivity**

1. INTRODUCTION

Now a day's interest in studying nanostructured metal oxide semiconductors have been increased because of quantum size effect associated with low dimensionality, which affects unique size and shape dependent physical and chemical properties. CdO_2 occurs naturally in the rare mineral brown or red monteponite single crystals is an n-type oxide belonging to the II-VI group. They are being used in a diverse of applications such as flat panel displays, LED's, photovoltaic solar cells and biological labels etc. [1]. Several methods have been reported for the synthesis of nano size particles of cadmium oxide. These include co-precipitation [2], chemical vapor deposition [3], sol–gel technique, etc. [4]. Among these synthesize routes co-precipitation method is relatively popular since it is easier, low-cost, environmentally friendly, enormous-scale production, low-temperature process and no catalyst is required [5].

The dielectric constant and loss measurement as a function of frequency and temperature provides information about the polarization mechanism, process of conduction, influence of impurities and phase transition. AC conductivity obtained from the dielectric properties will help to understand the information on defect formation, impurities and nature of conduction of a material [6].

Thus, in the present study, we have successfully synthesized CdO_2 nanoparticles through chemical co-precipitation method. The synthesized nanoparticles were characterized by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), High resolution scanning electron microscopy (HRSEM), Energy dispersive X-ray analysis (EDX) and dielectric studies.

2. EXPERIMENTAL

2.1 Materials and Methods

CdO_2 nanoparticles were synthesized at room temperature by simple and low-cost chemical co-precipitation method using cadmium acetate dehydrate ($Cd(CH_3COO)_2.2H_2O$), and ammonia solution 25% (0.91). For the synthesis of CdO_2 NPs, an aqueous solution of appropriate amount of cadmium acetate dehydrate ($Cd(CH_3COO)_2.2H_2O$) was added in 80 ml deionized water. Then the solution was continuously stirred for half an hour and subsequently ammonia solution was added to the above solution drop by drop until pH was reached as 9. While adding the ammonia, a white colored precipitate was formed. The white precipitate was kept aging for 5 hours. Thereafter, the solution was filtered and washed several times with deionized water and ethanol. The achieved precipitate was dried at 80°C and then grinded to fine powder with the help of agate mortar. Then the final product was calcined at 400°C for 2 hours.

3. RESULTS AND DISCUSSION

3.1 XRD analysis

The XRD patterns of the CdO_2 nanoparticles showed diffraction peaks absorbed at 2θ values in the range of 20-70 degree (Fig. 1). The prominent peaks were used to calculate the average grain size via the Scherrer formula expressed as follows:

$$D = \frac{0.9\lambda}{\beta \cos\theta} \text{ nm}$$

Where, D is the average crystallite size, λ is the wavelength (λ = 1.5406 Å) (CuKα), β is the full width at half maximum (FWHM) of the line, and θ is the diffraction angle. The grain

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size estimated using the relative intensity peak (111) for CdO_2 nanoparticles was found to be 34 nm and increase in sharpness of XRD peaks indicates that particles are in crystalline nature. The (111), (200), (210), (220) and (311) reflections are clearly seen and closely match the reference patterns for CdO_2 (JCPDS card No - 39-1221). The sharp XRD peaks indicate that the particles were of Cubic structure, and that the nanostructure grew with a random orientation [7].

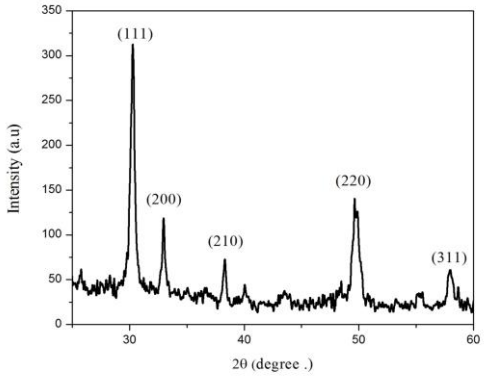

Fig.1 XRD pattern of CdO_2 nanoparticles

3.2 FTIR study

The FT-IR spectra of as synthesized CdO_2 nanoparticles are shown in (Fig. 2). The peaks that appeared obviously belonging to the organic functional groups of the synthesized precursor. The absorption bands at 3442 cm^{-1} can be attributed to the N-H asymmetrical and stretching vibration bands; respectively. The observed broad band in this area can be originated from the overlapping O-H stretching bands of H_2O molecules with the NH_2 vibration bands, respectively, the specified strong peaks at about 2469cm^{-1} and 1,792 cm^{-1} belong to the stretching vibration bands C=O. The observed absorption bands at 1,423 cm^{-1} can be attributed to the ν(CN). In addition to the C-O vibration band, strong peaks at 859cm^{-1} is due to Cd–OH, which is the input of Cd–O phase. The weak peak in 715 cm^{-1} confirms the characteristic metallic bonding of CdO_2 [8].

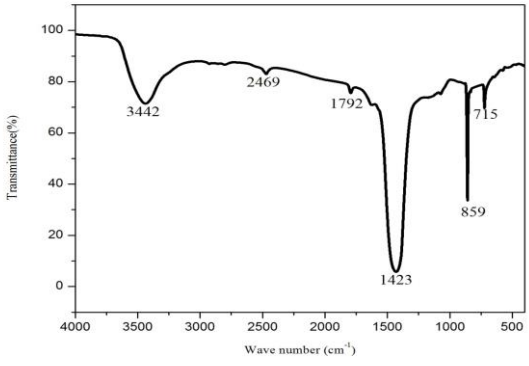

Fig.2 FTIR spectrum of CdO_2 nanoparticles

3.3 HRSEM and EDAX analysis

The HRSEM image of almost spherical-shaped CdO_2 nano-powder is shown in (Fig. 3(a)). Moreover, single CdO_2 particles have a strong tendency to form nano particle agglomerates. The solid-state reconstruction of nanoparticles into aggregates is a usual phenomenon showing a tendency of Nano particulate systems to restrain unsaturated surface forces via surface recombination [9]. From SEM observations, it showed that the mean size of the particles was about 40nm, which was in agreement with the results obtained from the XRD analysis (34nm). The high purity chemical composition of as synthesized CdO_2 nanoparticles was performed using energy dispersive X-ray (EDX) analysis. From (Fig. 3(b)), it is clearly shown that the product consists of Cd and O elements. No appropriate impurities were detected in EDX spectrum analysis.

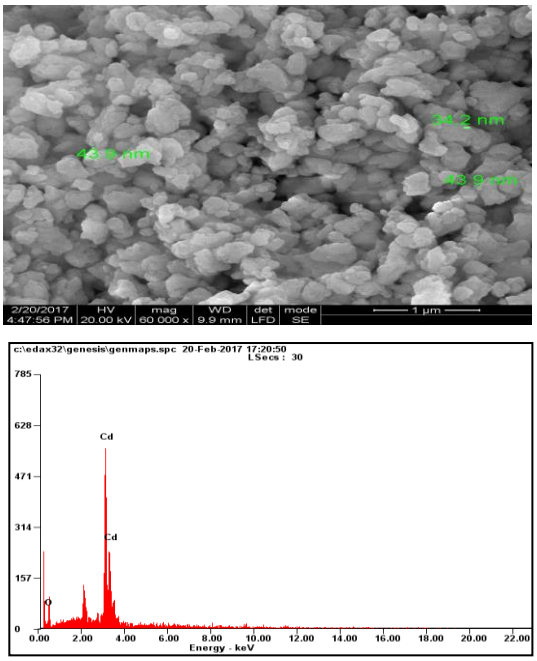

Fig. 3 (a) & (b) HRSEM image and EDX Spectrum of CdO_2 nanoparticles

3.4 Dielectric studies

Dielectric properties contains of dielectric constant of the test material and dielectric loss. Dielectric constant ε' is considered from the measurement of capacitance value, it can be attained using the following equation,

$$\varepsilon' = \frac{t \times Cp}{A \times \varepsilon_o}$$

Where, t is thickness, C_p is the capacitance, ε_o is the permittivity of free space and its value is 8.85×10^{-12} F/m and A is area of the sample.

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Dielectric constant versus frequency for CdO_2 nanoparticle is shown in (Fig 4(a)) and it is clearly found that dielectric constant decreases with increasing applied frequency due to polarization mechanism. In the frequency region between 1 kHz and 1 MHz, the total contribution of polarization arises from electronic, ionic, space charge displacements and dipole orientation.

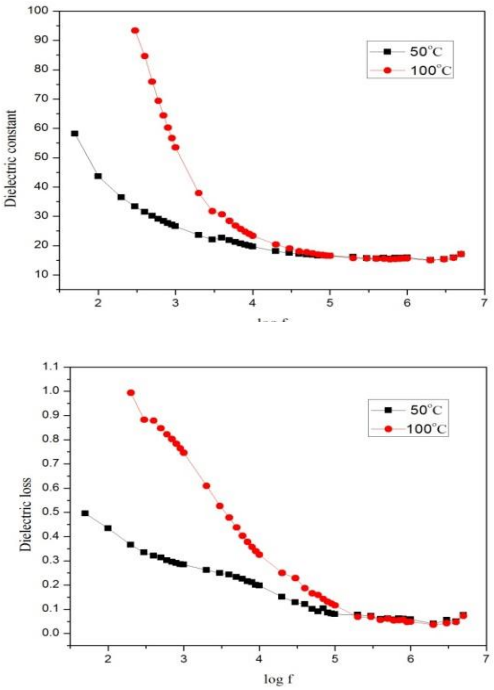

Fig. 4(a) Dielectric constant and **4(b)** Dielectric loss versus frequency of CdO_2 nanoparticles

Fig.4(b) shows dielectric loss (ε") versus frequency and the dielectric loss is decreasing with increasing applied frequency. This shows the ability of the material to be used for high frequency applications; also found that dielectric loss is small with increasing temperature. It may be due to molecules having large relaxation time with delayed polarization process.

$$D = \frac{\varepsilon''}{\varepsilon'}$$
$$\varepsilon'' = D \times \varepsilon'$$

AC conductivity (σ_{ac}) of the CdO_2 nanoparticle is calculated using the following relation, the frequency dependent ac conductivity could be described by the universal Jonscher's power law and its variation with applied frequency is shown in (Fig. 4(c))

$$\sigma_{ac} = \omega \varepsilon_o \varepsilon' \tan \delta$$

where σ_{ac} is conductivity of free space and ω is the angular frequency. The ac conductivity increased with increasing frequency at both temperatures. At low frequency, the particles have dc conductivity and at high frequency then they have ac conductivity. Generally, the electrical conductivity is directly related with the obtainable amount of free charge carriers and their mobility. The ac conductivity is affected by the mobile charge carriers. According to an ion-hopping mechanism, the ionic conduction of the CdO_2 sample results from the migration of exchangeable channels and cavities of the grains. As the mobile charge carriers hops to a new position, from its original position, it faces some displacements between the two minimum potential energy states. This may be because of the polarization of dipoles i.e. the dipoles rotate between the equivalent equilibrium positions.

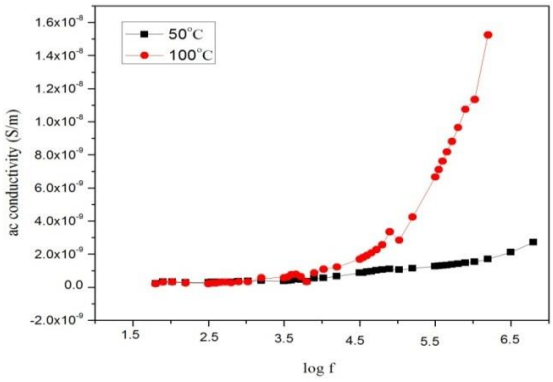

Fig.4(c) AC conductivity versus frequency of CdO_2 nanoparticles

4. CONCLUSION

In summary, we have successfully prepared CdO_2 nanoparticles via simple co-precipitation method. The structural, morphological and dielectric properties of synthesized nanoparticles were characterized by X-ray diffraction (XRD), Fourier transformation infrared spectroscopy (FT-IR), High resolution scanning electron microscopy (HRSEM), Energy dispersive X-ray analysis (EDX) and dielectric studies. X-ray diffraction patterns reveal that obtained sample has cubic crystal structure. The functional groups and chemical interactions of CdO_2 were determined at various peaks using FTIR data and clearly confirmed that the formation of CdO_2 nanoparticles. Dielectric constant and dielectric loss were decreased with increasing applied frequency due to polarization mechanism with applied frequency. AC conductivity increased with applied frequency for CdO_2 nanoparticles.

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