RESEARCH ARTICLE

INTERNATIONAL RESEARCH JOURNAL OF
MULTIDISCIPLINARY TECHNOVATION

DOI: 10.34256/irjmt2135

Synthesis and Structural, Optical Properties of Cadmium Doped Cobalt Oxide Nanoparticles

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DOI: https://doi.org/10.34256/irjmt2135
Received: 10-03-2021, Revised: 07-05-2021, Accepted: 08-05-2021, Published: 11-05-2021

Abstract: The nanostructure cadmium doped cobalt oxide nanoparticles were prepared by microwave irradiation techniques. The prepared nanoparticles were further characterized using Powder X-ray diffraction, Fourier transform infrared spectroscopy and UV-Vis spectroscopy. The Powder X ray diffraction results shows good crystalline nature. The Fourier transform infrared spectroscopy conforms stretching and bending vibration of metal oxygen groups. UV-Vis spectroscopy results show absorption edges are 204 nm, 220nm prepared nanoparticles additionally optical parameter skin depth, extinction co-efficient, reflectance, refractive index is calculated.

Keywords: Nanoparticles, Microwave-assisted, Functional groups, Optical properties

1. Introduction

In recent years, Nanoparticles vital role in engineering, medicine, chemistry, physics etc. The attenuation has made to synthesis nanoparticles (NPs) based on their size; shape is [1-2]. In this view, cobalt oxide nanoparticles consider to be super capacitor, lithium-ion batteries, gas sensor application were reported [3-10].

The synthesis of cobalt oxide NPs by sol gel, thermal, son chemical and precipitation methods [11-18]. Recently, Metal ions doped cobalt oxide nanoparticles physical and chemical properties are varied. Also, cadmium doped Co3O4 nanosheets prepared electrode materials [19] Cd doped CoS nanocluster alloys [20]. Microwave heating methods synthesis of NPs due to the high purity, shorter reaction time, low cost by internal volumetric heating process [21-24]. In this present research work, the attempt was fall on to synthesis of cadmium doped cobalt oxide nanoparticles by precipitation methods. The optical parameter skin depth, extinction co-efficient, reflectance, refractive index is calculated for analysis of optical properties.

2. Experimental details

2.1 Materials and methods

Cd-Co_3O_4 NPs were synthesized by taking cobalt (II) nitrates hexahydrate (AR grade 99% pure) and cadmium sulphate (AR grade 99% pure) and 25% ammonia solution (Merck) chemicals are used. All other chemicals used were of reagent grade and double distilled water used as a solvent.

A 0.2M concentration solution of cobalt nitrate hexahydrate was prepared by dissolving in double distilled water. Then cadmium sulphate of 5 weight percentage was added to the cobalt hydroxyl solution.

pH value of the solution was maintained at 8 precipitation were obtained. The sample dried hot air oven at 100 °C for 2 hours and the prepared sample was annealed up to temperature of 600 °C for 2 hours collected sample A. The similar way prepared samples precipitation was irradiated by microwave radiation frequency 2.45 GHz and power up to1 KW for 5 minutes continuously. The prepared sample was annealed at a temperature of 600 °C for 2 hours collected sample B.

2.2 Characterization

The structural properties of the samples were analyzed by Powder X-Ray Diffraction using a Bruker AXS D8 Advance instrument and the monochromatic wavelength of the 1.5406 Å over the diffraction angle range of 2θ 10°-100°. The functional group of the sample identified using Attenuated total reflectance

spectroscopy was recorded by a carry 50 ATR- FTIR spectrometer, The Ultraviolet spectrum was analysis carry 60 Uv-Vis Spectro photometers

3. Results and discussion

3.1 Powder X-ray diffraction

The phase of the as-prepared samples cadmium doped Co_3O_4 was investigated by Powder X-ray diffraction. Figure.1. (A), (B) Shows the diffraction peak can be assigned to 31°,36°,59°,65° indexed as (220), (311), (511), (440) lattice planes of cobalt oxide (JCPDS NO 76-1802).

3.2 Attenuated total reflectance (ATR)

The various functional groups presented in the samples were identified by ATR spectroscopic studies. The recorded ATR spectra of the samples are shown in Figure 2. (A, B) The absorption peak at 643,651, 531,539 cm^{-1} is due to the presence of cobalt oxide stretching and bending vibration [25]. The peak 1167, 1180 cm^{-1} to the vibration modes of cadmium ions.

3.3 UV Vis spectroscopy

Figure 3. (A) (B) shows the UV-vis-NIR absorption spectrum. It is observed that absorption band maximum at 204 nm, 220 nm due to surface plasma resonances at the surface of the nanoparticle [26]. The absorption edge of the nanoparticles related to the size of the nanoparticles. quantum size effect become dominating when the size of the Nano crystallites is less then bulk excition bohr radius and it affects the electronic energy bands of the semiconductors [27].

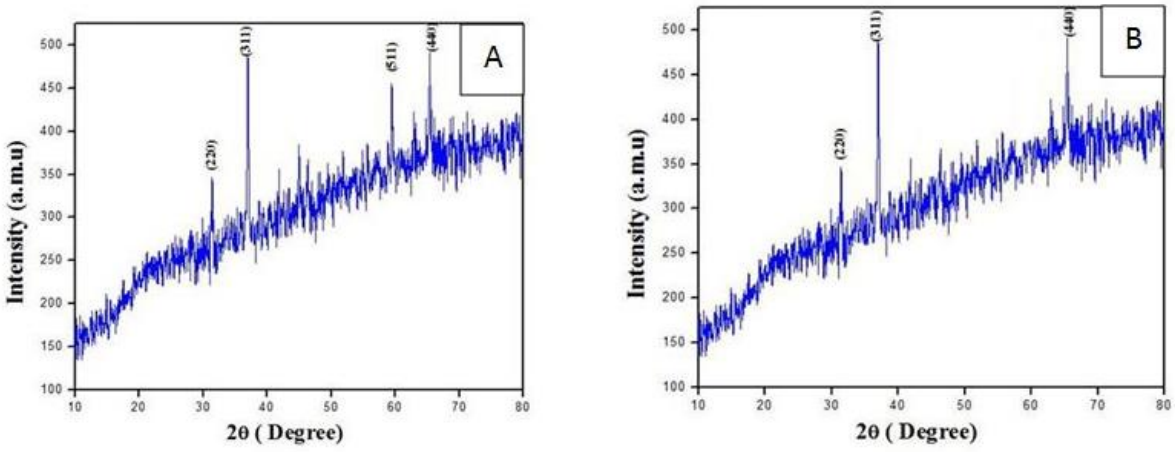

Figure 1 Powder X-ray diffraction pattern (A) without irradiation (B) with irradiation cadmium doped Co3O4 nanoparticles

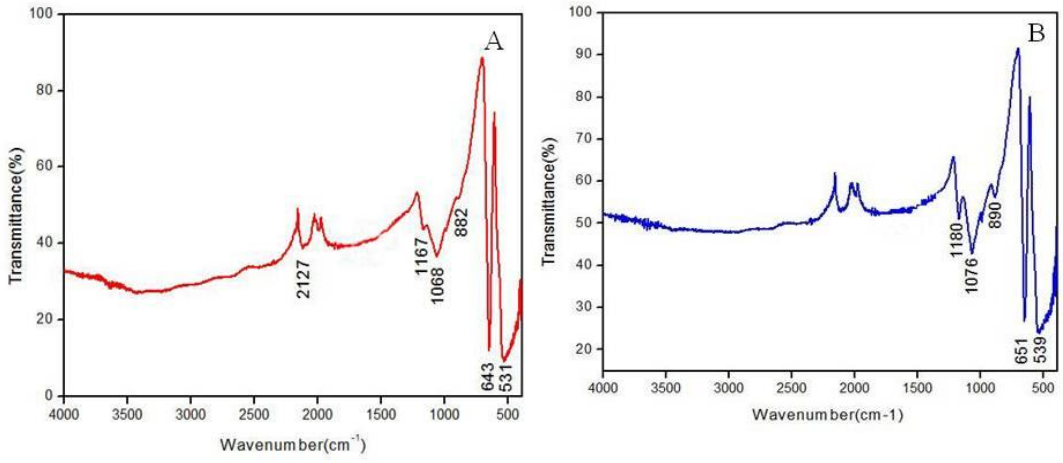

Figure 2. Shows the ATR Spectrum (A) without irradiation (B) with irradiation cadmium doped Co_3O_4 nanoparticles

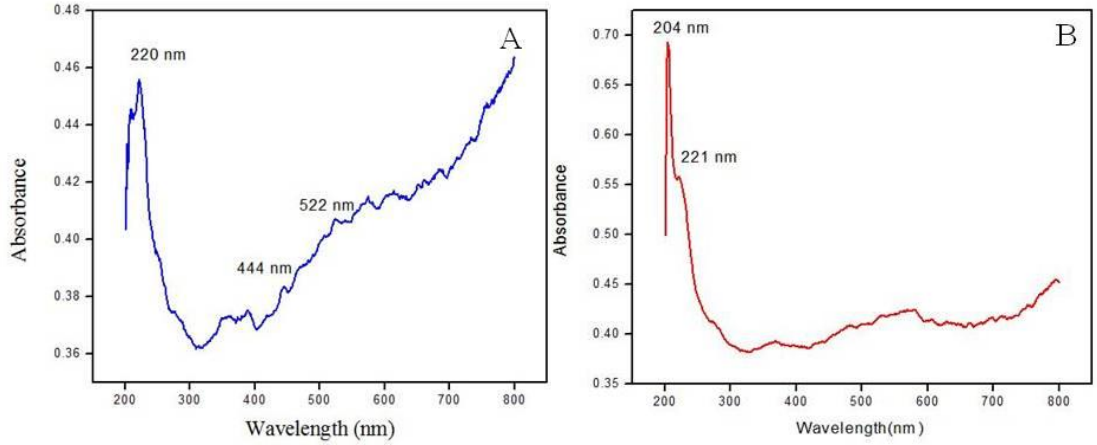

Figure 3. Shows the UV-Vis-NIR absorption spectrum (A) without irradiated (B) with irradiated cadmium doped Co_3O_4 nanoparticles

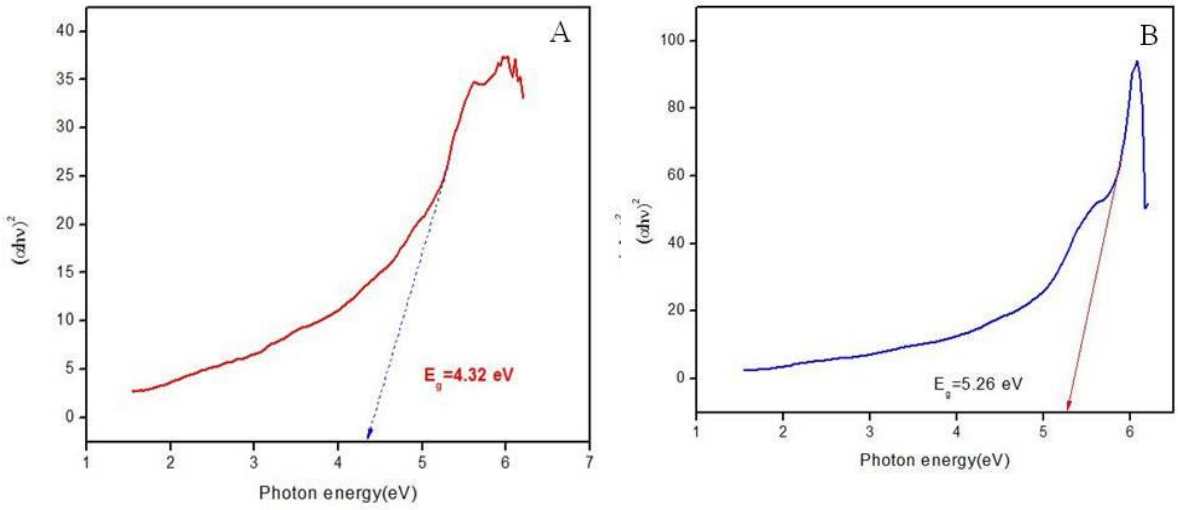

Figure 4. Shows the Indirect transition band gap shows plot photon energy (hυ) eV verses (αhυ)2(eV) (A)without irradiated (B) with irradiated cadmium doped Co_3O_4 nanoparticles

3.3.1 Determination of Energy Band Gap (Eg)

Tauc and Davis-Mott relation following formula

$$(\alpha h\upsilon)^{n} = A(h\upsilon - \mathrm{Eg}) \qquad (1)$$

Fig. 4. (A, B) Shows in Tauc plot method we plot energy on X-axis while $(\alpha h\upsilon)^2$(eV) on the y-axis. The cadmium sulphate doped cobalt oxide optical band gap values to be E_g = 4.32 eV and E_g = 5.26 eV. The bandgap of material introduction of impurities, which create shallow states in the bandgap. shallow states have small ionization energies, and when the doping densits high, the dopent generate a band. Among the narrower bandgap for the absorption of the visible light [28].

3.3.2 Determination of extinction co-efficient (K)

The extinction coefficient (K) explains the amount of absorption when electromagnetic wave propagates through a medium and it can be used following relation

$$\mathrm{K} = \frac{\propto\lambda}{4\pi} \qquad (2)$$

Fig.5 (A, B) shows the extinction coefficient, versus wavelength for investigated sample. The extinction coefficient values increase with increasing photon energy.

3.3.3 Determination of skin depth (α)

The skin depth (χ) was calculated using the following formula

$$\chi = 1/\alpha \qquad (3)$$

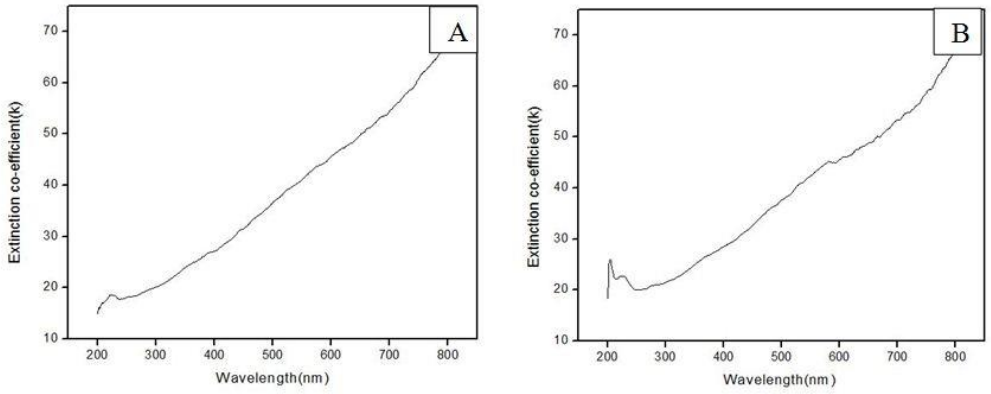

Figure 5 (A, B) Shows the Plot of wavelength versus extinction coefficient

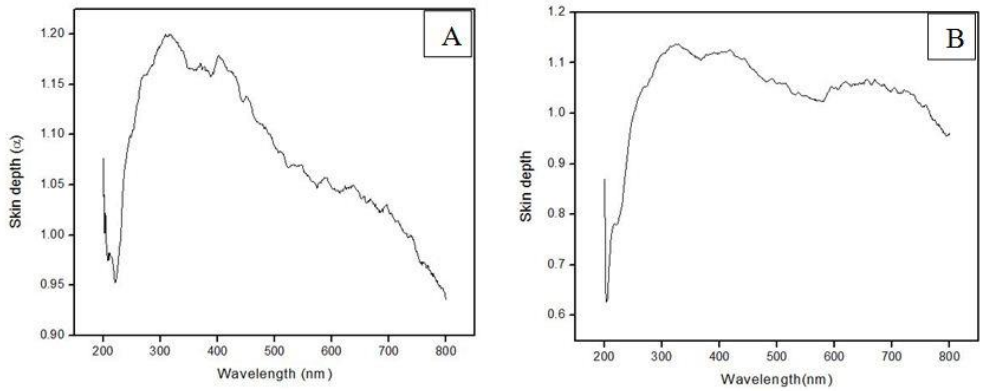

Figure.6 (A, B) Shows the Plot of wavelength versus skin depth

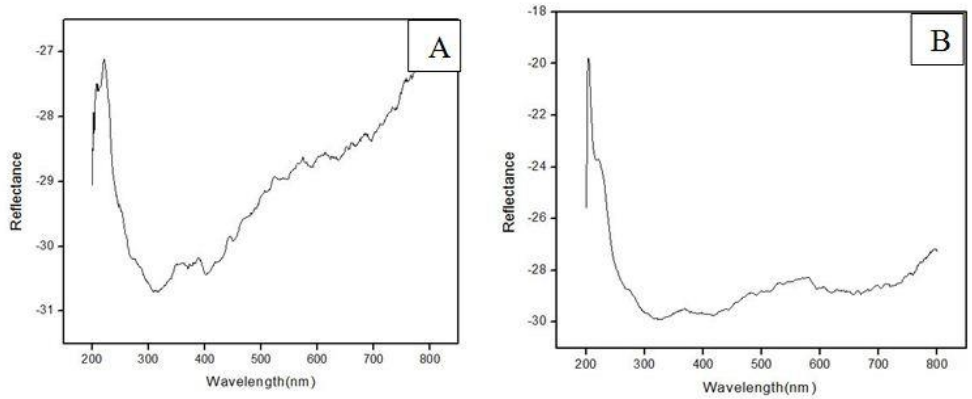

Figure. 7 (A, B) Shows the Plot of wavelength versus reflectance

Fig.6 (A, B) shows the skin depth, versus wavelength for investigated sample. Skin depth values decrease with increasing photon energy.

3.3.4 Determination of reflectance (R)

The Reflectance (R) was calculated by using the relation

$$R = [1\text{-}T \exp A]^{1/2} \quad (4)$$

Fig 7. (A, B) shows reflectance verses wavelength, and it's indicated that decreases reflectance with photon energy increases.

3.3.5 Determination of refractive index (n)

The Refractive index (n) was calculated from the following formula

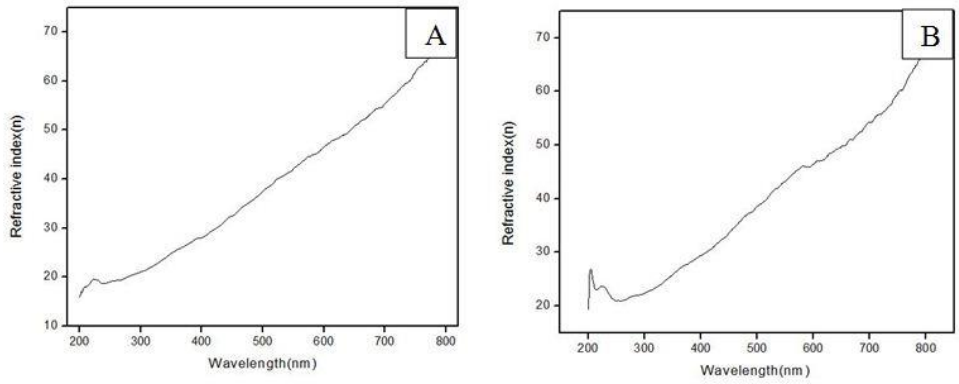

Figure. 8 (A, B) Shows the Plot of wavelength versus refractive index

$$n = \left\{\left[\frac{1+R}{1-R}\right]^2 - [1-K^2]\right\}^{1/2} - \left[\frac{1+R}{1-R}\right] \qquad (5)$$

Fig 8 (A, B) shows the refractive index in the visible region for investigated sample. It is clear that the refractive index increases slowly with increasing the wavelength.

4. Conclusion

The cadmium doped cobalt oxide nanoparticles were synthesized by microwave irradiation method. The Powder X ray diffraction confirms good crystalline nature. The FTIR-ATR confirms the presence of functional groups in the sample. UV-Vis spectroscopy results shows optical absorption bandgap of the cadmium doped cobalt oxide nanoparticles were estimated to be 4.32 and 5.26 eV, which are blue shifted in the absorption edge might be due to decrease in lattice strain. The optical parameter skin depth, extinction co-efficient, reflectance, refractive index is calculated and the prepared nanoparticles suitable for optical device applications.

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Acknowledgments

The Authors are thankful to Alagappa university karaikudi, Karunya University Coimbatore, SAIF IIT Madras for characterization studies.

Funding

No funding was received for conducting this study.

Conflict of interest

The authors have no conflicts of interest to declare that they are relevant to the content of this article.