

# Structural and Optical Properties of CoO Nanoparticles Doped PMMA Films

Shailendra S. Rajput<sup>1</sup>, A. Mishra<sup>2</sup>, A. Sharma<sup>3</sup>, J. Singh<sup>1</sup>, G. S. Chandrawat<sup>1</sup>, and J. Tripathi<sup>1</sup>

<sup>1</sup>Department of Physics, ISR, IPS Academy, Indore, India

<sup>2</sup>Department of Physics, Devi Ahilya University, Indore, India

<sup>3</sup>Department of Physics, Manipal University Jaipur, Jaipur, India

## \*Correspondence to:

J. Tripathi

Department of Physics, ISR, IPS Academy,  
Indore, India

E-mail: [jtripathi00@gmail.com](mailto:jtripathi00@gmail.com)

A. Sharma

Department of Physics, Manipal University  
Jaipur, Jaipur, India

E-mail: [anupamcsr@gmail.com](mailto:anupamcsr@gmail.com)

Received: August 23, 2022

Accepted: October 12, 2022

Published: October 13, 2022

**Citation:** Rajput SS, Mishra A, Sharma A, Singh J, Chandrawat GS, et al. 2022. Structural and Optical Properties of CoO Nanoparticles Doped PMMA Films. *NanoWorld J* 8(S1): S45-S48.

**Copyright:** © 2022. Rajput et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY) (<http://creativecommons.org/licenses/by/4.0/>) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

## Abstract

We report the synthesis and initial characterization of cobalt oxide nanoparticles (CoO NPs) doped Poly (methyl methacrylate) (PMMA) self-standing film. The samples were prepared using chemical synthesis route and X-ray diffraction (XRD), Fourier transform infrared (FTIR), and Ultraviolet-Visible (UV-Vis) spectroscopy measurements were performed to check the crystalline quality, presence of constituent bonds and optical bandgap of the film before and after doping. The overall results indicate slight increase in bandgap along with some modifications in the bonding behavior, although drastic changes are seen in XRD, which after doping, is dominated by the presence of Nano size crystallites in the polymer host matrix.

## Keywords

Chemical synthesis, Nanoparticles, X-ray diffraction, Fourier transform infrared spectroscopy Ultraviolet-Visible spectroscopy

## Introduction

PMMA is a very important polymer as it is being used in numerous useful applications including plastic industry construction field where it is applicable in making highway structures giving strength to bridges, in aero planes, automobiles, wind-energy converters, medical implants, navy, air-force, and several other industries as well as in basic research areas. These applications are seeded from the useful properties of pure PMMA and also of PMMA doped/composite form. PMMA is highly transparent (~92%) to visible wavelength region of electromagnetic spectrum and has a refractive index of 1.49, which makes it useful for optical applications. It also exhibits light weight, good environment stability, suitability for outdoor applications, mold ability, colourability, as well as easy melting, cutting, and fabrication possibilities [1-3].

Due to its high flexibility, it can accommodate any or combinations of different elements like transition metals, magnetic, non-magnetic elements/compounds/alloys, gold and other nanomaterials, other compatible polymers and many more. Materials prepared with these combinations may present an alternative for existing costly metals that are brittle and ceramics in multiple applications.

Looking into future applications possibilities in the present work, we report the synthesis of synthetic CoO NPs –PMMA composite and its characterization using XRD, UV-Vis, and FTIR techniques.

## Material and Methods

CoO NPs were prepared using the chemical synthesis method using cobalt acetate and ethylene glycol as the starting materials. For this, 1 gm quantity of cobalt acetate was dissolved in 50 ml ethylene glycol followed by heating at 180 °C for 3 hours after which the solution was cooled down. The precipitate was washed thoroughly using ethanol a few times and then dried. Coarse powder was then ground to obtain fine powder of NPs for further characterization and for making CoO NPs-PMMA composite [1, 3, 4].

The composite containing PMMA and CoO NPs were prepared by dissolving 5 gm of PMMA in 50 ml benzene. This solution was continuously stirred at 125 °C until a viscous solution was formed. At this stage, 10 mg CoO NPs were dispersed in 20 ml of this solution by ultrasonication for a few hours to prepare self-standing films of pure PMMA as well as of CoO-PMMA composite. To make the films, solution casting method was applied by drying the desired quantity of the prepared solutions onto a petri dish at room temperature. The films were then taken out and used for the measurements.

The XRD data was recorded on Bruker D8 diffractometer in the  $2\theta$  range of 10–70° with a step size of 0.2°. The measurements were performed using Cu K $\alpha$  (un-monochromatized) X-ray source operated at 40 kV, 40 mA (wavelength 0.154 nm).

UV-Vis spectroscopy measurements in transmission mode were performed in the wavelength range of 200–800 nm on FluoroMax-4P spectrophotometer equipped with a continuous light source of 150 W ozone free xenon arc lamp with 1200 grooves mm<sup>-1</sup> grating and slit width of 2 mm.

Vibrational properties of the samples were studied using FTIR spectroscopy measurements performed on Alpha FTIR spectrometer with a resolution of 1 cm<sup>-1</sup> in the mid IR range.

## Results and Discussion

Crystalline or amorphous nature of the samples was checked from the XRD patterns shown in Figures 1 and 2. Broad humps at  $2\theta$  ~15° and 30° are the characteristics of amorphous PMMA (see Figure 1). When mixed with CoO, modifications in the XRD pattern are observed. The major amorphous nature of PMMA is preserved although the hump became sharper and more intense, along with the appearance of a new sharp crystalline feature observed at  $2\theta$  position of 29.5°, which also belongs to PMMA.

All the other crystalline peaks are due to CoO NPs and the peak positions 29.5°, 36.1°, 39.5°, 43.2°, 47.5°, 48.62°, 57.5°, and 64.8° correspond to CoO crystal planes as also marked in the Figure 2.

The most intense XRD peak at 29.5° (for doped PMMA, see inset of Figure 2) was further utilized to extract average crystallite size using the standard Scherrer's formula

$$L = \frac{K}{\beta \cos \theta} \quad \text{----- (1)}$$

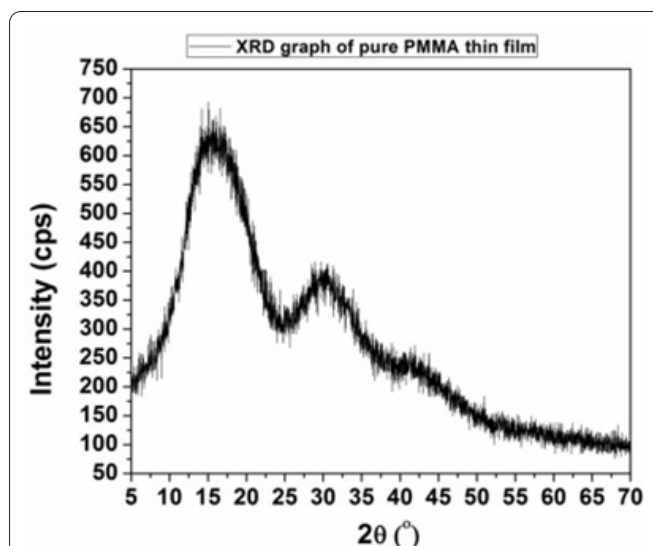


Figure 1: XRD pattern of pure PMMA.

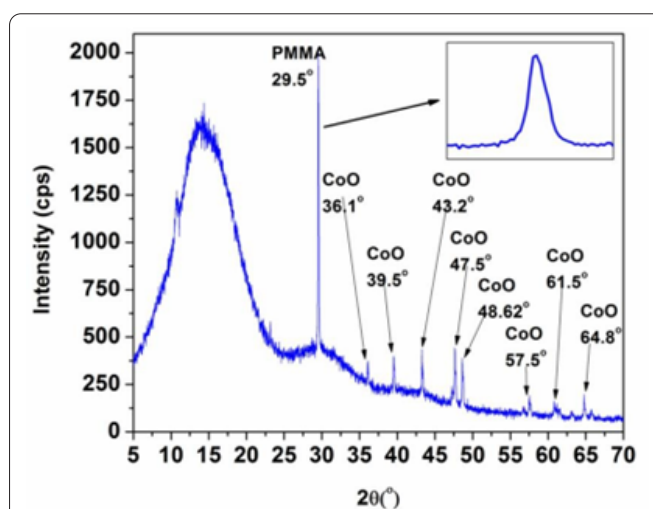


Figure 2: XRD pattern of 1 wt% CoO NPs-PMMA composite. Inset shows the most intense XRD peak, which was used for calculating average crystallite size.

Where,  $L$  is the mean size of the crystallite,  $K$  is a dimensionless shape factor (taken as 0.9 in general),  $\lambda$  is the wavelength of X-ray (0.154 nm),  $\beta$  is the line broadening at half the maximum intensity (FWHM),  $\theta$  is the Bragg angle. The average crystalline size was found to be ~48.5 nm indicating the formation of nano-sized polymer host with nano size crystallites of CoO embedded inside it.

Figure 3 shows the FTIR spectra of pure PMMA and CoO NPs-PMMA composite films. The IR bands appearing in the range from 600 cm<sup>-1</sup> to 1500 cm<sup>-1</sup> are called characteristic bands (fingerprint region) of PMMA. One can see from Figure 3 that peak intensity decreased with the doping of CoO NPs. Also, the peak (~1715 cm<sup>-1</sup>) corresponding to C=O bond is shifted towards higher wavenumber and a new peak is observed at ~2362 cm<sup>-1</sup> after doping, may be due to bonding between PMMA and CoO NPs. The peak intensity corresponding to O-H bond (at ~3742 cm<sup>-1</sup>) increased with doping of CoO Nanoparticles. All these changes suggest a modification in

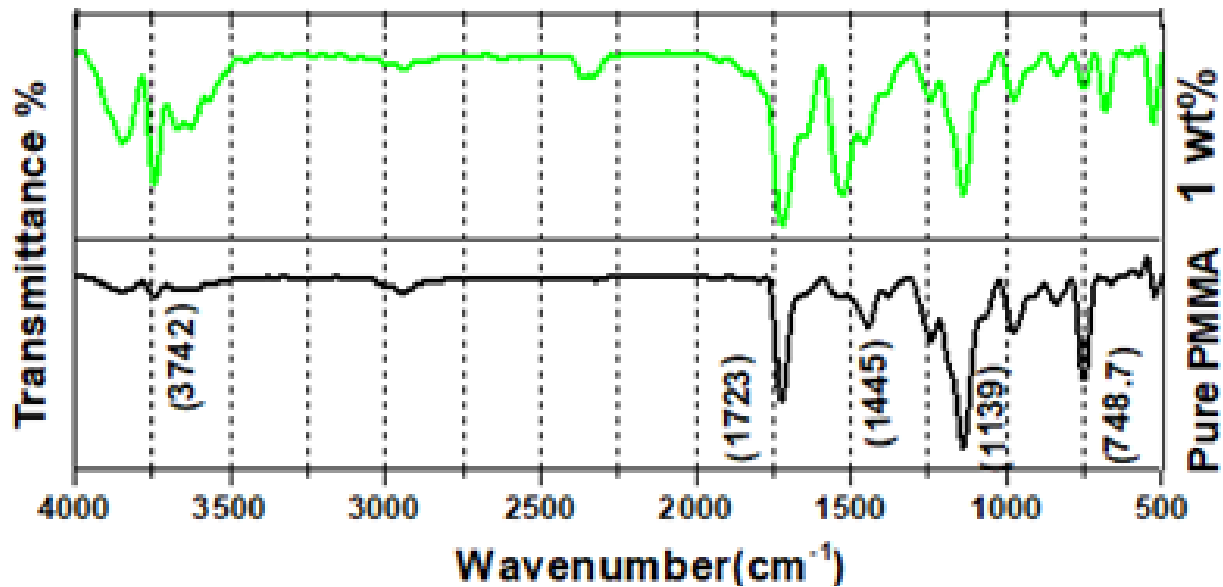


Figure 3: FTIR pattern of 1 wt% CoO NPs-PMMA composite. The bonds were assigned in accordance with the reported literature [6].

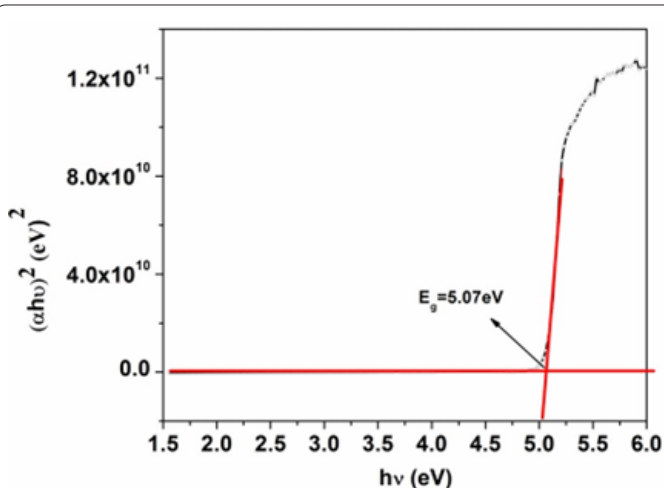


Fig. 4.1 UV-Vis spectra of pure PMMA.

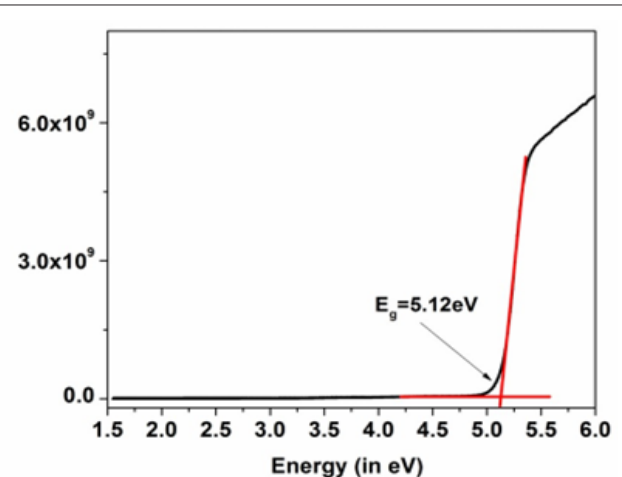


Fig. 4.2 UV-Vis spectra of 1wt% CoO NPs-PMMA composites showing the values of band gaps.

the PMMA host, when new bonds are incorporated and some PMMA bonds get modified when CoO NPs are introduced in this PMMA host matrix [5-7].

Corresponding optical properties were studied using UV-Vis spectroscopy, in which UV-Vis light was transmitted from the film and absorption was recorded (see Figures 4.1 and 4.2). The %T vs. energy ( $h\nu$ ) data was then converted to absorbance using Beer-Lambert law followed by conversion into  $(\alpha h\nu)^2$  versus  $h\nu$  curve to extract bandgap (direct) using the standard Tauc's law.

When in pure form, PMMA film shows a bandgap of 5.07 eV, which slightly enhances to ~5.12 eV after making the composite film. This may be due to nanoparticle incorporation. Detailed investigation of this nano size induced change in the bandgap is underway.

## Conclusion

In the present study, we have synthesized CoO NPs doped PMMA self-standing film using chemical synthesis route and some initial results are reported here. XRD technique shows formation of nano size polymer host with nano size crystallites of CoO embedded inside it which was confirmed from the average crystalline size (~47 nm) calculated from Scherrer formula. FTIR technique shows modification in the PMMA host when new bonds are incorporated and some PMMA bonds get modified when CoO NPs are introduced in this PMMA host matrix. UV-Vis spectroscopy measurements suggest modification in band gap in composite film. It is well-known that bandgap depends on crystal structure and hence overall changes in optical properties of PMMA films can be attributed to change in structural properties due to doping of CoO NPs, which is evident from the appearance of new crystalline peak of PMMA along with several crystalline peaks of CoO.

## References

1. Abbas RM, Mustafa FA. 2016. The structural characterizations of polymethyl(methacrylate) doped nanoparticle metal (Cu,Co,Fe) thin film by using Nd-Yag laser ablation. *International Research Journal of Pure and Applied Physics* 4(2): 31-44.
2. Hussain T, Ahmad MN, Nawaz A, Mujahid A, Bashir F et al. 2017. Surfactant incorporated co nanoparticles polymer composites with uniform dispersion and double percolation. *J Chem* 2017: 7191590. <https://doi.org/10.1155/2017/7191590>
3. Pawar E. 2016. A review article on acrylic PMMA. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* 13(2): pp 1-4.
4. Ali U, Bt. Abd Karim KJ, Buang NA. 2015. A review of the properties and applications of poly (methyl methacrylate) (PMMA). *Polym Rev* 55(4): 678-705. <https://doi.org/10.1080/15583724.2015.1031377>
5. Punter VF, Krishnan KM, Alivisatos AP. 2001. Colloidal nanocrystal shape and size control: the case of cobalt. *Science* 291(5511): 2115-2117. <https://doi.org/10.1126/science.105849>
6. Salman SA, Usami T, Kuroda K, Okido M. 2014. Synthesis and characterization of cobalt nanoparticles using hydrazine and citric acid. 2014: 525193. <https://doi.org/10.1155/2014/525193>
7. Lu AH, Salabas EL, Schuth F. 2007. Magnetic nanoparticles: synthesis, protection, functionalization, and application. *Angew Chem Int Ed Engl* 46(8): 1222-1244. <https://doi.org/10.1002/anie.200602866>