Nickel oxide Nano-composite–Synthesis, Structural and Antimicrobial Study

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Abstract: Nickel oxide (NiO) Nanocomposite was synthesized by sol-gel citrate method. As synthesized NiO was structurally characterized by X-Ray Diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). From XRD analysis, the NiO Nanocomposite had face-centered cubic (*fcc*) phase with crystallite size was found to be nearly 15 nm. Synthesis of NiO was confirmed by FT-IR. The antimicrobial activity was carried out against Escherichia coli (gram negative bacteria) and Staphylococcus aureus (gram positive bacteria). The NiO nanoparticles showed inhibitory activity in both strains of bacteria with best selectivity against gram-positive bacteria.

Keywords - Nickel oxide, Escherichia coli, Staphylococcus aureus, XRD and FT-IR.

Introduction: Nanoparticles (NPs) are cluster of atoms having at least one dimension in the size range of 1–100 nm. Due to their unique optical, magnetic, catalytic, and electrical properties, they have potential applications in various fields [1]. The physicochemical properties of NPs are different as compared to those of their bulk counterparts owing to the fact that surface area to volume ratio increases and quantum effects become dominant as the size decreases. The increase in surface area to volume ratio alters the mechanical, catalytic, and thermal properties of material [2].

For centuries metals such as silver, copper, zinc, gold and nickel have been used as bactericidal and bacteriostatic agents. Among those used is silver, copper, zinc, gold and nickel each with different properties and spectrum of activity. The antimicrobial activity of silver ions was known since ancient times and silver ions are widely used in catheters, burn wound and dental work [3].

High purity and ultra-fine nickel metal powder is a key component of many different materials that is used to manufacture a wide range of end-use products such as catalysts, magnetic devices, powder metallurgical components and gas sensing. Nickel nanoparticles are used in magnetic recording devices, catalysis, paint industry and used effectively as antimicrobial agent.

SYNTHESIS

PREPARATION OF NiO NANOPARTICLE

The Nanocrystalline NiO specimens were prepared by using sol-gel citrate method. A stoichiometric mixture of nickel nitrate was magnetically stirred with citric acid and ethylene glycol at 80^{o}C for 4 h to get homogeneous and transparent solution. The solution was further heated at about 130^{o}Cfor 12 h in a pressure vessel to form the gel precursor. The prepared product was subjected to 3 h heat treatment at 350^{o}C in a muffle furnace and then milled to a fine powder. The dried powder then calcined at 500^{o}C in order to improve the crystallinity of ceramic.

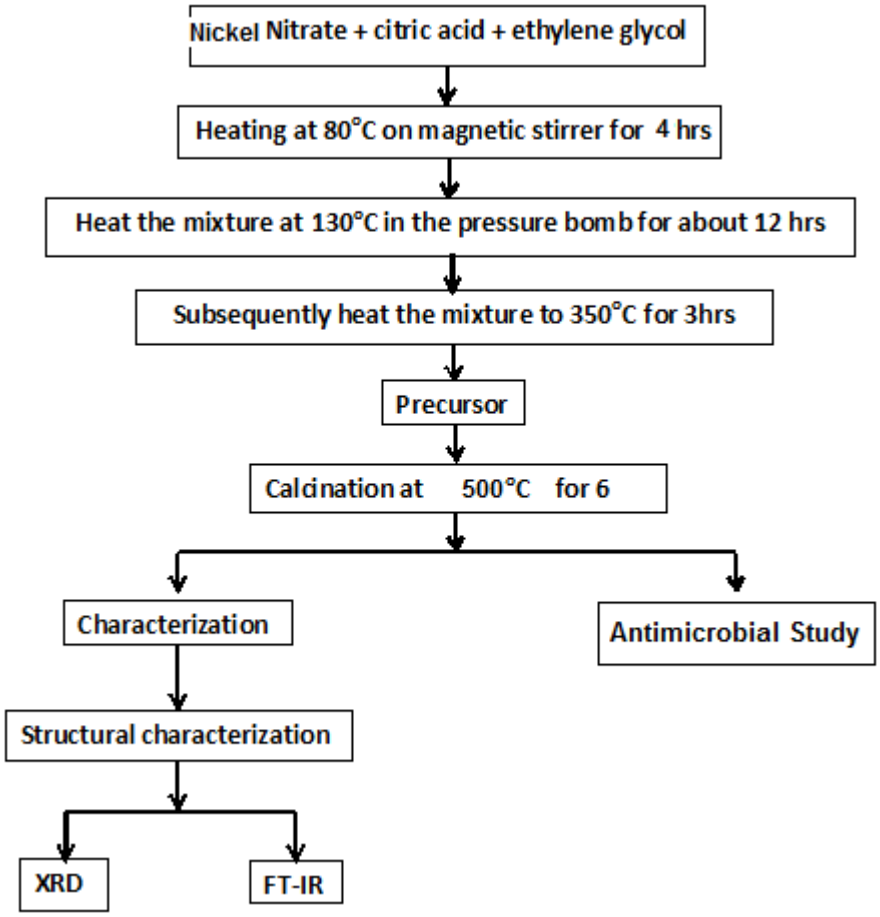

Figure 1: flow chart for the fabrication of NiO Nanocomposite

RESULTS AND DISCUSSION

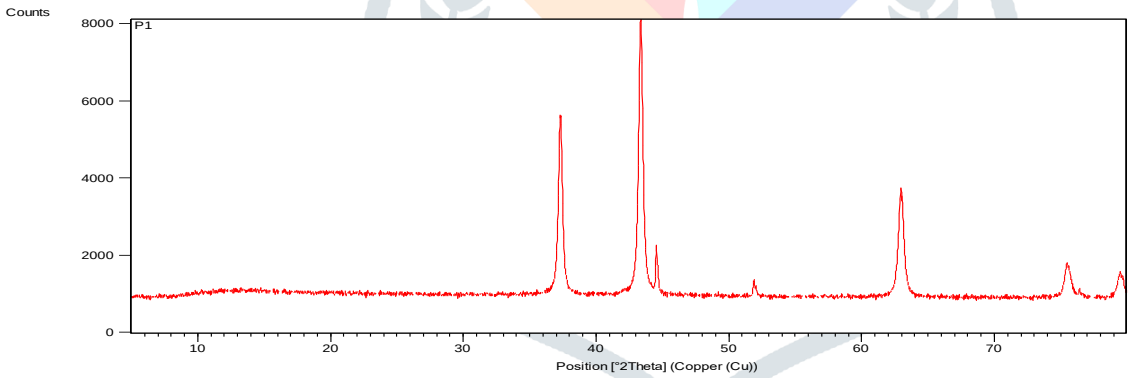

Figure 2: XRD plot for the ZnO Nanocomposite prepared by sol gel technique

Figure 2 gives the X-ray diffraction pattern for sol-gel derived nanostructured NiO calcined at 500^{O}C. Each crystalline solid has a unique XRD pattern to identify its crystal structure. When X-ray light with a wavelength λ is incident on a crystal, a diffraction peak occurs if the Bragg condition is satisfied:

$$n\lambda = 2d \sin\theta,$$

Where d is the lattice spacing of the crystal and θ is the angle of incidence. The Cu-Kα emission (λ= 1.5418 °A) from a copper target is the most common X-ray source for the diffraction measurement. Furthermore, a powder XRD pattern is also used to determine the average size of the nanoparticles. The average crystallite size can be calculated by using the Scherer formula:

$$D=k\lambda/\beta\cos\theta$$

From the graph,the average crystallite size of these samples is found to be ~35 nm. The peaks positions appearing at 2θ=37.50°, 44.30°, 62.87°, 76.50°, and 79.22° can be readily indexed as (111), (200), (220), (311), and (222) crystal planes of the bulk NiO, respectively. All the reflections can be indexed to face-centered cubic (*fcc*) NiO phase [4].

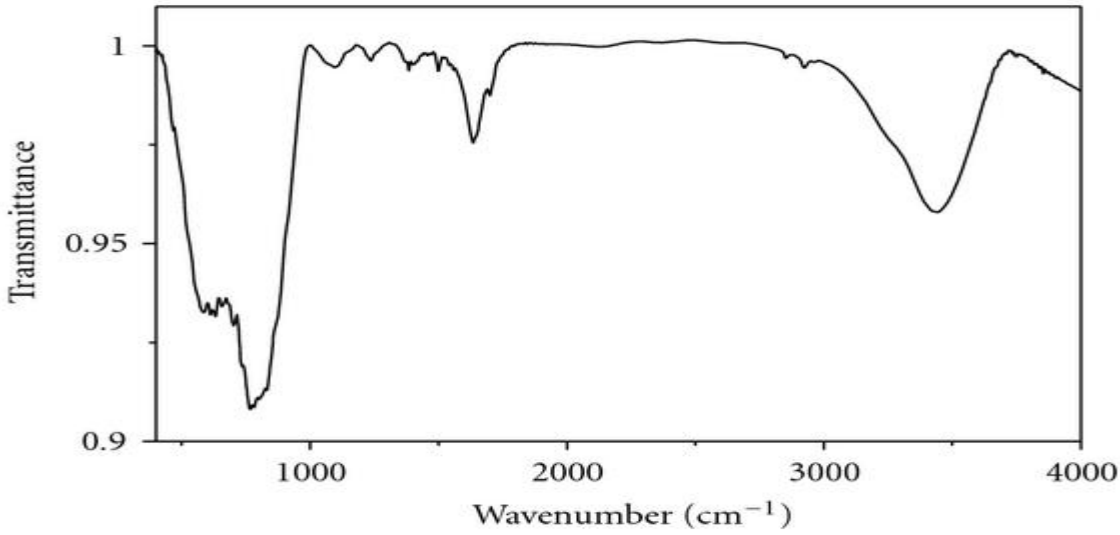

Figure 3: FT-IR plot for the ZnO Nano composite prepared by sol gel technique

Figure 3 shows the FT-IR spectrum of NiOnanoparticles recorded in the range of 500 to4000 cm-1. The KBr technique has been used to record the spectra. The FTIR spectra of NiO nanoparticles, which showed several significant absorption peaks. The broad absorption band in the region of 600–700 cm^{-1} is assigned to Ni–O stretching vibration mode; the broadness of the absorption band indicates that the NiO powders are Nano crystals. it could be seen from Figure 3 that the broad absorption band centered at 3440 cm^{-1} is attributable to the band O–H stretching vibrations and the weak band near 1635 cm^{-1} is assigned to H–O–H bending vibrations mode were also presented due to the adsorption of water in air when FTIR sample disks were prepared in an open air. The serrated absorption bands in the region of 1000–1500 cm^{-1} are assigned to the O– symmetric and asymmetric stretching vibrations and the C–O stretching vibration, but the intensity of the band has weakened, which indicated that the ultrafine powers tend to strong physically absorption to H_2O and CO_2[5].

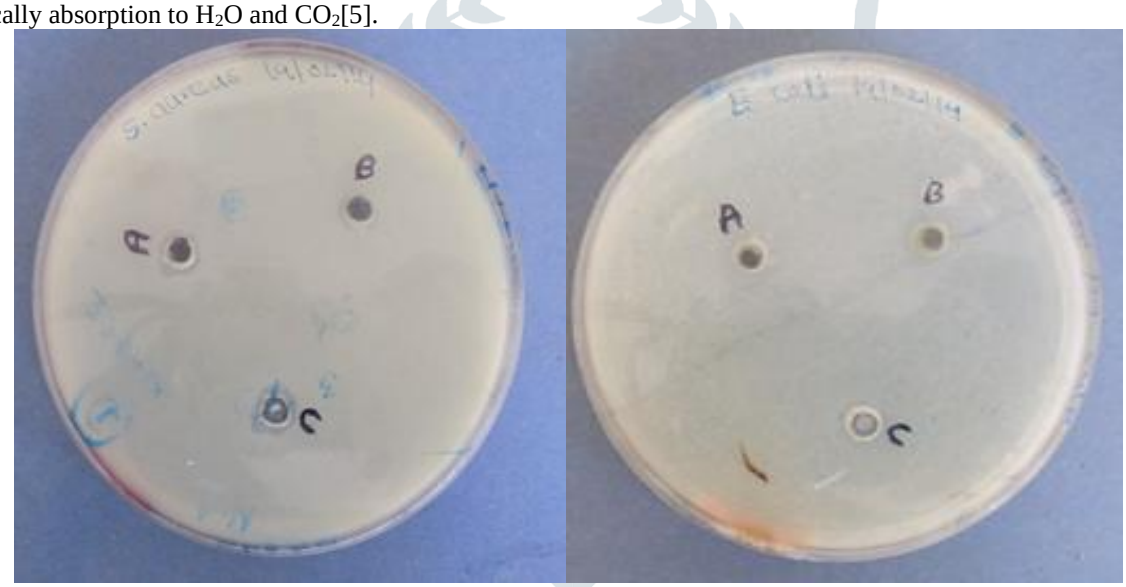

Figure 4: Antimicrobial study of Nickel oxide Nanocomposite

The antimicrobial potential of Nickel oxide Nanocomposite was evaluated according to their zone of inhibition against various pathogens. The results revealed that NiO is potent antimicrobials against all the microorganisms studied.

The purpose of antibacterial studies was to find out drug release from formulations and its efficacy to inhibit the growth of microorganisms. The antibacterial potency of the drug needs to be tested as the desired minimum inhibitory concentration (MIC) has to be achieved. Thus selected microsphere formulations along with pure drug Tetracycline was tested for the antibacterial activity. NiO dissolved in DMSO 70% + Acetone 30% about 1000 ppm and antibacterial disc of 6mm &15 µl samples for each disc were used for this antibacterial study. Incubation period for all organisms and Petri plates at 37^0C for 24 h.

Antibacterial activity of Nickel oxide Nanocomposite was tested For *Escherichia coli* (Gram Negative) and S. acnes (Gram Positive) in HIMEDIA. Figure4 shows, Antibacterial activity of Nickel oxide Nanocomposite calcined at 350ºC Maximum inhibition zone diameter for E. coli and S. acne with diameter 10 mm and 13 mm respectively.

Table 1, summarize the results of antimicrobial study, from data it was observed that Nickel oxide Nanocompositecalcined at 350ºC shows more inhibition as compared to Nickel oxide Nanocomposite calcined at 500ºC. The prepared NiO nanoparticles are more effective against gram positive bacterial strains than the gram negative strains. Gram positive bacteria typically have one cytoplasmic membrane and thick wall composed of multi layers of peptidoglycan. On the other hand, gram-negative bacteria have more complex cell wall structure, with a layer of peptidogly can between outer membrane and cytoplasmic membrane. Thus the cell membrane of gram positive bacteria can be damaged more easily [6].

Table 1: Maximum inhibition zone diameter of Nickel oxide Nano composite.

Sr. No.	Samples	Bacterial pathogens	Zone of inhibition in diameter (mm)	Control
1	NiO – 350ºC	E.coli	10mm	4mm
		S. aureus	13mm	6mm
2	NiO – 500ºC	E.coli	7mm	4mm
		S. aureus	10mm	6mm

CONCLUSION

NiO Nanocomposite was synthesized by sol-gel method. The crystals of the as synthesized NiO are characterized by XRD. The crystallite size of the NiO is estimated by using XRD, which is found to be nearly 35nm with face-centered cubic (*fcc*) NiO phase. Formation of the ZnO is confirmed by the FT-IR spectroscopy. Antibacterial activity of Nickel oxide Nano compositecalcined at 350ºCwas tested. It shows maximum inhibition zone diameter for E. coli and S. acne with diameter 10 mm and 13 mm respectively, they are more active towards gram positive stain as compared to gram negative. Nickel oxide Nano composite calcined at 350ºC shows more inhibition as compared to Nickel oxide Nanocomposite calcined at 500ºC.

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