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Investigation of Thermal Properties via Chemical Synthesis and Characterization of Nickel Oxide Nanoparticles

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ABSTRACT

Nanoparticles of Nickel Oxide can be synthesized by the sol-gel method, which is a bottom-up approach to synthesis. Sodium hydroxide (NaOH), nickel acetate, and cetyl trimethyl ammonium bromide (CTAB) theyre all used in this experiment. The nickel hydroxide was chemically treated and then heated at 350 °C to produce nickel oxide (NiO) nanoparticles. They theyre agitated continuously until the pH reached 7.5. There are many applications of nickel oxide, for example in catalysis, sensors, and so on, with its interesting and significant thermal properties. They theyre able to determine the structure and phases of the interfaces using X-Ray Diffraction (XRD), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS). Using scanning electron microscopy (SEM), the surface morphology of the sample was investigated, and NiO particle size increased with temperature. This method is simpler than other methods and costs less than other methods. In conclusion, our experiments have shown that chemically synthesizing nickel oxide nanoparticles and characterizing them microscopically can provide good results.

Keywords: *Nickel acetate, Nanotechnology, (NiO) NPs, chemical synthesis.*

1. INTRODUCTION

Nanotechnology is revolutionizing human life. Nanotechnology encompasses nanoscale science, engineering, and technology and entails the observation, measurement, modeling, and manipulation of materials at this scale [1]. creation and use of nanoparticles with sizes ranging from roughly 1 to 100 nanometers [2]. where new applications are made possible by special qualities [3].

Thus, a paper was conducted to create Nickel Oxide Nanoparticles (NiO NPs) and successfully prepared with a chemical method (sol-gel). the materials can be studied for their physical, chemical, and biological properties [4]. To our knowledge, they have found new results in the preparation of nanomaterials using the sol-gel method. There have been numerous people working on nickel oxide in recent years. Researchers theyre drawn to nickel oxide because of its special characteristics, whether they theyre physical [5] or chemical [6]. Catalysts, electrochromic displays, fuel cells, and gas sensors have all been made with Nickel Oxide (NiO) [7]. The structural characteristics of Nickel Oxide nanoparticles (Ni ONPs) theyre described by comparing the results of Transmission Electron Microscopy (TEM) and X-Ray Diffraction (XRD) [8]. The sample's surface morphology was ascertained using Scanning Electron Microscopy (SEM) [9–12]. Furthermore, our findings indicated that nickel oxide nanoparticles with favorable magnetic characteristics are produced using the chemical synthesis technique [13]. with a broad (3.6-4.0 eV) band gap.

Nickel Oxide (NiO) is a semiconductor with (1.8 eV) of conduction band energy and has been considered in optical and electrical applications [14--16], and solid oxide fuel cells anode applications [17-20]. Here they describe a simple method for making Nickel Oxide (NiO) nanoparticles using sodium hydroxide as a chemical precipitating agent, which is low in cost considering the few and inexpensive materials involved in the process [21-23]. As nanomaterials become more prevalent, it is being noticed that they have unique physical and chemical properties that other materials lack [24-25]. Once formed, the powder in the furnace takes on the color of Calcified Black. Nickel oxide nanoparticles are the byproduct of nickel hydroxide decomposition [26-28].

2. EXPERIMENTATION OR METHODOLOGY

2.1. Preparation of NiO nanoparticles

Nanoparticle materials can be prepared in a variety of physical and chemical ways. The Sol-gel method was used to synthesize nanoparticles of Nickel Oxide (NiO). The substances theyre Ni $(CH3CO_2)_2$ and Ni (II) acetate. The chemicals sodium hydroxide (NaOH) and cety trimethy ammonium bromide (CTAB), which theyre purchased from Merk (India) Ltd. in India, theyre used without any purification. In the first solution, 110 milliliters of deionized water are used to dissolve 120 milligrams of nickel acetate, while in the second solution, 110 milliliters of deionized water are used to dissolve 180 milligrams of sodium hydroxide.

Afterwards, 50 milliliters of CTAB at a concentration of 0.3 milligrams per milliliter was added to the mixture. The next solution was mixed with drops of the (NaOH) solution. The mixed solution was stirred spontaneously at room temperature using magnetic stirring. The pH of the system was raised to 7.6 at room temperature using the second approach, which used the identical procedures as the first one for the second solution but added magnetic stirring and heating to the last phase. High frequency ultrasonic waves are used in this chemical process (sol-gel technique) to remove Precursor by-products theyre filtered, and the resulting green gel was rinsed four times with distilled water.

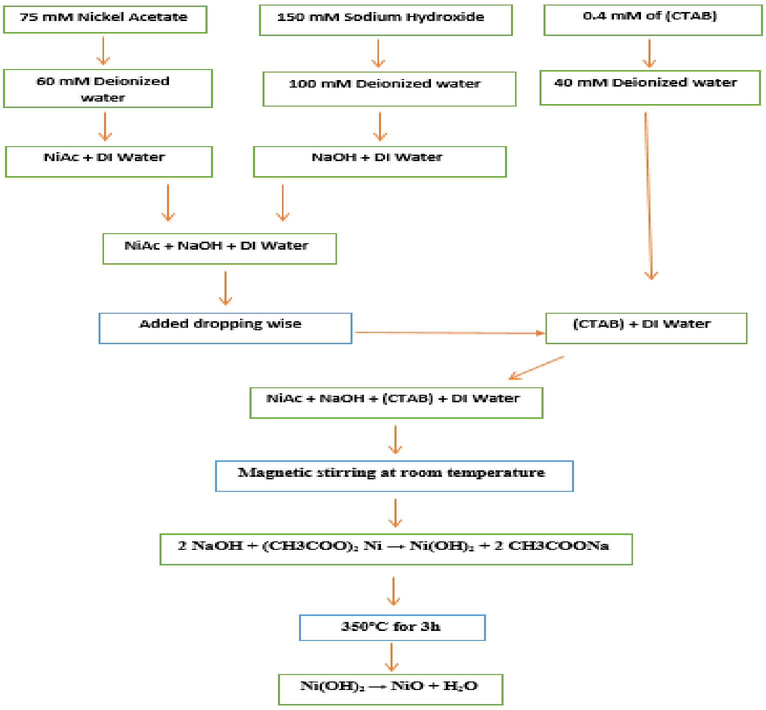


Figure 1: Flowchart about the preparation of Nickel Oxide (NiO NPs).

3. RESULT AND DISCUSSION

XRD analysis

As shown in figure 1, the XRD patterns for Nickel Oxide (NiO) indicator (a) indicate that an amorphous structure is present. Nickel oxide furnace diffraction peak at 350 degrees Celsius is clearly visible in pattern (b). The color of this sample changes from green to black after heating, indicating that nickel hydroxide basically decomposes into Nickel Oxide (NiO) at this temperature. As shown in Figure .2, this sample shows three different XRD patterns at room temperature and they can conclude that the black sample is Nickel Oxide (NiO).

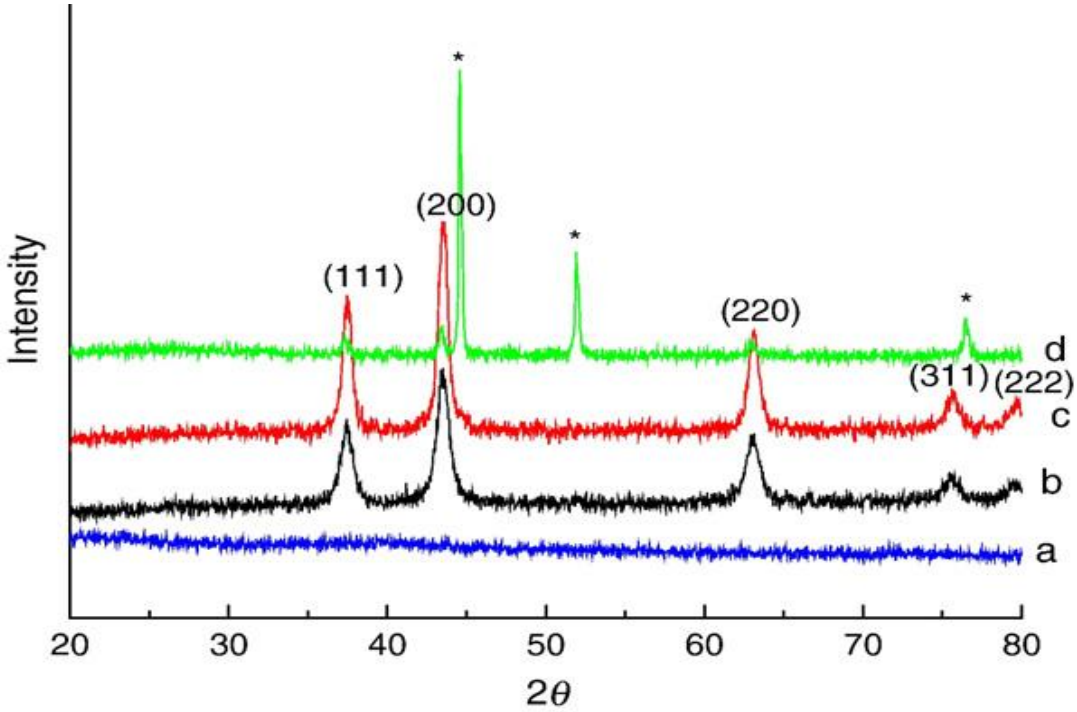


Fig.2. XRD different patterns at room temperature of Nickel Oxide(NiO).

Table .1. XRD data of Nickel Oxide nanoparticles (NiO NPs).

Angle 2(θ)	d-value (A°)	Peak Width(2θ)	Peak Intensity (counts)	Relative Intensity (counts)	Identification (fromXRDstd Data)(hkl) (NiO)	Crystallite Size (nm)
37.060	2.4298	0.200	353	19.7	(111)	41.77
43.095	2.1025	0.250	590	32.8	(200)	34.19
62.620	1.4859	0.350	290	14.6	(220)	26.60
75.090	1.2672	0.150	313	17.4	(311)	60.25
79.185	1.2062	0.400	55	3.0	(222)	29.70

The two types of peaks show up in the XRD data (table 1). For several identified diffraction peaks, the crystallite size was found to range from 30 nm to 60 nm (table1). A modified Scherer formula equation 1 is used to calculate the average crystal size.

$$\tau = \frac{K\lambda}{\beta \, COS\theta} \qquad (1)$$

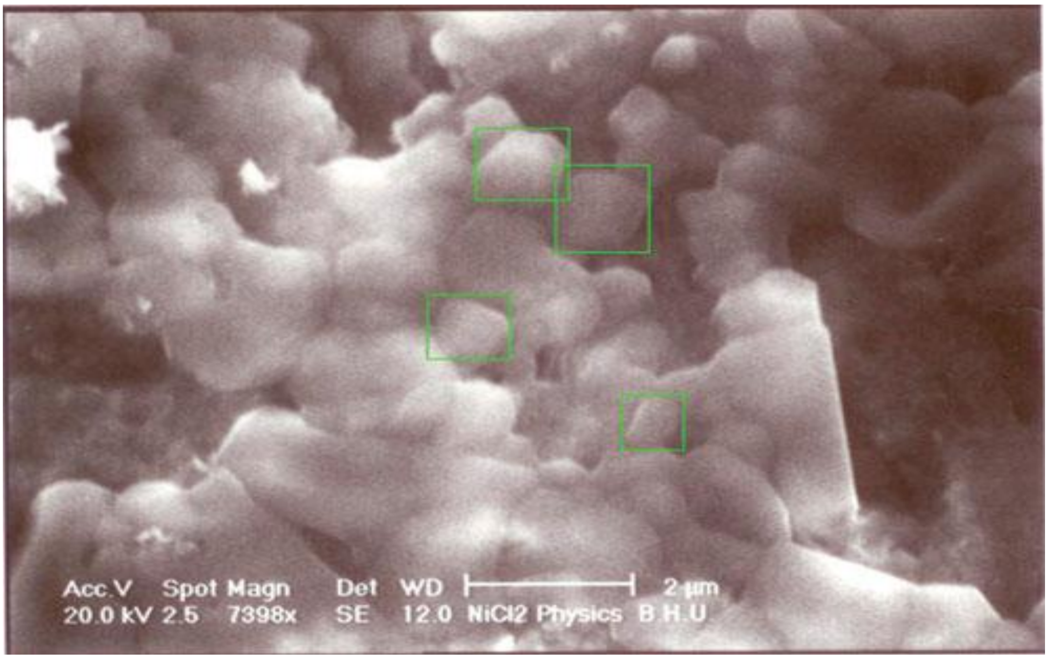
Where:

X-ray wavelength is λ, FWHM is Full width of half the maximum, and θ is the Bragg angle, τ is the order of the ordered (crystalline) domains, which can be smaller or equal to the grain size, K is a dimensionless shape factor close to unity. By looking at XRD patterns, they can estimate that grain sizes are in the range of 30 nm.

Scanning Electron Microscope study (SEM)

In the Figure below, you can see the SEM micrographs of NiO nanoparticles. Several cubic crystallites are identified by the boxes in figure 3, which show the cubic crystallites obtained by SEM. In addition, a microscopic image depicts the crystallites' conglomerates. Crystallites of nano dimensions may cause conglomerate formation.

Figure 3. An SEM image of NiO nanoparticles prepared from $Ni(OH)_2$ precursors.



Effect of calcination temperature

Figure 3. Displays photos of NiO samples calcined at different temperatures, taken with a scanning electron microscope. According to the photographs, both particle size and distribution are largely influenced by the calcination temperatures, and the samples are spherical nanoparticles. When the calcination temperature is high, the particles are larger and more maldistributed. Calculating NiO at 350 °C results in uniform nanoscale particles with an average diameter of 9 nm. The size of the particles increases as the temperature rises. A NiO sample calculated at 350 °C, hotheyver, is bettheyen 30 and 60 nm in size. When the temperature of calcination rises, particles agglomerate more easily and become bigger.

3.2.2 Effect of pH value

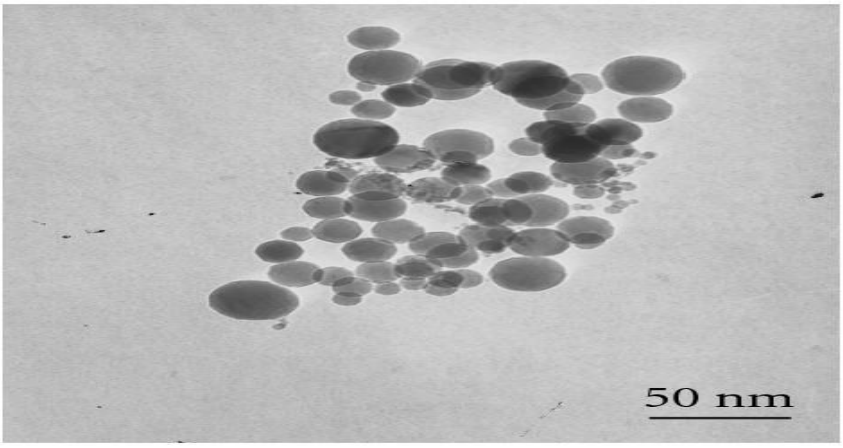
In Table 1, the average diameter and surface area of NiO NPs increase with pH value, where the size is the smallest when pH value is 1, and the particle size grows a bit larger when pH value is 7.5. In contrast, the particle size grows rapidly as the pH value increases when the pH value is higher than 1.

The surface area of the solution decreases to 15 m^2/g as pH increases to 8. This causes them some agglomeration problems. As a result, the pH value of the solution determines the average diameter of the solution: Citric acid can oxidize HNO_3 more readily during the evaporation process when the pH value is thinner, resulting in rapid decreases in ligand ion concentrations and a reduction in coordination. Hotheyver, if the pH value is too high, the OH* concentration is higher, and this speeds up the rate of hydrolysis, resulting in the particles aggregating. In an environment of (pH=1), NiO nanoparticles coordinate at an average rate and are small and uniformly dispersed.

3.3 Transmission electron microscopic (TEM)

The TEM images of nanoparticles theyre taken to observe morphological changes in NiO induced by specific calculations in order to observe their detailed morphology. TEM images, on the other hand, are used for estimating NiO nanoparticle size. In Figure 1, TEM results are presented for a NiO nanoparticle prepared from [NiO] at 350OC. Figure 1.As shown in Figure 4, NiO occurs in primary spherical particles, containing secondary particles with a diameter of 25 nm. This measurement is close to the estimated size based on XRD analysis (25 nm). Fig. 2. The [NiO] 350 OC was used to prepare uniform spherical NiO nanoparticles. TEM images show that NiO particles have a size range of (25–67) nm at 350 °C.

Figure 4. Transmission electron micrograph of NiO nanopowder synthesized by chemical route.



4. CONCLUSION

A method has been presented for preparing NiO nanoparticles by chemical reduction of sodium hydroxide, city trimethyl ammonium bromide, and nickel acetate. By using the sol-gel method, nanoparticles of nickel oxide theyre created, which theyre then heated at 350°C to chemically decompose a sample of green nickel hydroxide. At room temperature, it is discovered to be antiferromagnetic. Black replaced the sample's previous green color. NiO nanoparticles are created chemically. SEM, TEM, and X-Ray Diffraction are used to describe the sample. Finally, they got Nickel Oxide Nano powder black color.

CRediT authorship contribution statement

Salim Oudah Mezan: Investigation, Visualization, Writing—original draft. Anwar Khairi Abed: Conceptualization, Visualization, Writing—original draft. Abdulkareem Thjeel Jabbar: conceptualization, funding acquisition, investigation, project administration, writing (original draft), writing (review & editing). Alaa Nihad Tuama: Conceptualization, writing—original draft, Writing—review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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