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كلية العلوم

قسم الكيمياء

Preparation and Characterization of CuO and CuO-NiO Nanocomposite

A graduation research project

Submitted to the department of Chemistry in partial fulfillment of the requirements for the completion of the degree of Bachelor of Science in Chemistry.

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List of abbreviations and symbols

CVD	chemical vapor deposition
DSC	Differential Scanning Calorimetry
EDX	Energy Dispersive X-ray microscopy
FTIR	Fourier transform infrared spectroscopy
NPs	Nanoparticles
SEM	Scanning Electron Microscopy
TEM	Transmission Electron Microscopy
XRD	X-ray diffraction

g	Gram
h	Hour
kJ	Kilo Joule
mg	Milligram
ml	Milliliter
mol	Mole
MW	Molecular weight
nm	Nanometer
^{o}C	Temperature degree in Celsius
wt%	Weight percent
cm^{-1}	Centimeter

Acknowledgment

We thank God for his countless blessings, and we would like to extend our sincere thanks to Dr. Soad Al-Zahrani. For their proposal, planning and collaboration for this research project. And to King Saud University for supporting us in this research. We are very grateful to our families for their continuous support.

Abstract

Since nanoscience has these remarkable chemical and physical properties, researchers have recently concentrated their efforts in this area. In this study, a simple method was used to prepare copper oxide CuO and its NiO nanocomposite in this process, the capping material was glucose sugar and the nanoparticles were produced via calcinated for calcinated for 4 h at 500°C. FTIR, SEM, and EDX techniques were used to characterize the produced nanoparticles. The vibration peaks in the range 600 ~ 400 cm^{-1} in the FTIR characterization of the obtained CuO and CuO-NiO provided as evidence of the conformation of Cu-O and Ni-O. According to the SEM data, the produced NPs observed a spherical shaped particle with varying diameters in the range of 39.3 – 92 nm and in the range 37.4 -53.9 nm for CuO and CuO-NiO nanocomposites respectively. The results of the EDX analysis showed that Copper (Cu) and oxygen (O) elements were present in the CuO, with weight percentages of Cu 86.2% and O 13.8%, respectively and showed the presence of Copper (Cu), nickel (Ni), and oxygen (O) elements in the CuO-NiO nanocomposites with weight percent equal to Cu 79.2%, O16.9%, and Ni 4% respectively.

الملخص بالعربي

نظرًا لأن علم النانو له هذه الخصـائص الكيميائية والفيزيائية الرائعة، فقد ركز الباحثون جهودهم في هذا المجال. في هذه الدراسـة، تم اسـتخدام طريقة بسـيطة لتحضـير أكسـيد النحاس CuO ومركبه النانوية NiO . في هذه العملية، كانت مادة التغطية عبارة عن سكر الجلوكوز وتم إنتاج الجسيمات النانوية عن طريق المتكلس 4 ساعات عند 500 ^{o}C درجة مئوية. تم استخدام تقنيات FTIR و SEM و EDX لتوصيف الجسيمات النانوية المنتجة. يصل الاهتزاز إلى ذروته في النطاق من 600 الى 400 سم$^{-1}$ في توصيف FTIR لـــ CuO و CuO-NiOالذي تم الحصول عليه والمقدم كدليل على التشـكل بين Cu-O و Ni-O .وفقًا لبياناتSEM تم ملاحظة NPs المنتجة جسـيمات كروية الشـــكل بأقطار متفاوتة في نطاق 39.3-93 نانومتر وفي المدى 37.4-53.9 للمركبات النانوية CuO و-CuO NiOعلى التوالي. وأظهرت نتائج تحليل EDX أن النحاس كانت عناصـر (Cu) والأكسـجين (O) موجودة في CuO، بنسـب وزنية تبلغ 86.2% Cu وO 13.8%على التوالي وأظهرت وجود عناصـر النحاس (Cu) والنيكل (Ni)والأكسجين (O) في المركبات النانوية CuO-NiO بوزن يساوي،Cu 79.2% ،O 16.9% Ni 4% على التوالي.

Chapter 1

(Introduction)

1 Introduction

Nanotechnology is a technique-new, rapidly developing technology with a wide range of uses. It involves the production and application of materials with one of the dimensions in the range of 1–100 nm [1]. Due to its unique physicochemical properties, such as high surface area, high reactivity, and configurable pore size, nanotechnology opens up a wide range of new applications in the biotechnology and agriculture industries [2], compared to materials made up of larger particles will be far more reactive than a similar mass of material made up of large particles. Due to their high surface area, mechanical strength, optical activity and chemical reactivity, nanoparticles have distinctive physical and chemical properties [3]. Of its wide applications in biomedical, wastewater treatment, catalyst and electronic device [4]. A wide range of NPs can be synthesized by a variety method. Green synthesis a method used for preparation a wide range of nanomaterial which used in potential uses in the medicinal and environmental sciences. The advantages of this method is to reduce the harmful chemicals and it is offering an eco-friendly, and energy-efficient for instance, it is typically safe to employ organic resources like plants[6]. There are many methods of synthesis of nanoparticles including: a) Bottom-up or constructive method is the build-up of material from atom to clusters to nanoparticles. Sol-gel, spinning, chemical vapor deposition (CVD), pyrolysis and biosynthesis are the most commonly used bottom-up methods for nanoparticle production. b) Top-down or destructive method is the reduction of a bulk material to nonmetric scale particles. Mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition are some of the most widely used nanoparticle synthesis methods.

1.2 Synthesis of Nanoparticles

1.2.1 Top-down approach

Top-down is the size of macroscopic systems is reduced to the nanoscale to produce nanoparticles. Different physical or chemical processes can be used to reduce the particle size [5].

1.2.1.1 Mechanical milling

The milling process reduces the grain size of all solid elements to the nanoscale along with the generation of new phases and surface properties, the operation is carried out by putting a suitable powder in a suitable medium in a high energy ball mill, which energizes the powder by rolling down the chamber's surface in a series of parallel layers. The powder is given energy as it is being ground. Numerous elements, such as the type of powder being ground, the type of mill, the speed at which it is being ground, the size distribution of the balls, whether the grinding is dry or wet, the temperature at which it is being done, and the continuing coalescence processes that take place during the milling process are all taken into account [6].

1.2.1.2 Nanolithography

Nanolithography is the study of creating particles with a nonmetric size from bulk materials. For the synthesis of nanomaterials. In this process, the compound's bonds are broken by heat produced by endothermic chemical decomposition. The precise temperature at which an element begins to chemically breakdown is known as the decomposition temperature. Thus, the metal is broken down at its decomposition temperature to produce the nanoparticles [7].

1.2.1.3 Laser ablation

Synthesis of nanoparticles generated by laser. When a laser beam is focused on the surface of a solid target material in the surrounding media (gas or liquids) it quickly raises the temperature of the irradiation spot, vaporizing the target material. When evaporated atoms and clusters collide with surrounding molecules, the electron state is excited, light is emitted, and electrons and ions are produced. This process produces a laser- induced plasma plume. The ambient media must be carefully chosen since the laser-generated particles easily interact with the molecules in the environment to produce complexes like oxides and other undesirable species [8].

1.2.1.4 Sputtering

The sputtering process deposits nanoparticles on a surface by the ejecting particles as they collide with ions. Sputtering is the process of depositing ca thin layer of nanoparticles followed by annealing. The shape and size of the nanoparticles are determined by the substrate type, thickness of the layer, duration of annealing, and operating temperature [9].

1.2.2 Bottom-up approach

Bottom-up methods of making nanomaterials involve breaking down the components of the material to the atomic level and then going through an extra process that creates nanostructures. The methodology is primarily founded on the molecular recognition (self-assembly) principle.
Self-assembly refers to the process of continually producing more of the same kind [10].

1.2.2.1-Sol-gel

a gel is created when solid and liquid phases are combined, at first, a sol is formed when colloidal particles are disseminated in a liquid. This sol can be sprayed, spun, or coated onto any surface to create a thin coating. In order to create a complex network gel, the stabilizing components are remove from the sol and the particles are allowed to polymerize. In the end, heat treatments cause the residual organic and inorganic components. This method is preferred because it is economically feasible and because the low-temperature process allows us to control the final product's composition [11].

1.2.2.2 spinning fabrication

A spinning disc reactor is used in this method to produce nanoparticles. The rotating disc's inner chamber contains controls for controlling physical parameters like temperature. In order to eliminate oxygen and prevent chemical reactions, the reactor is filled with inert gases like nitrogen. Pumping the liquid precursor and water into the chamber while rotating the disc at a variable speed. As a result of the spinning, the atoms or molecules are combine which cases them to precipitate, congregate, and dry [12]. Different operating factors, such as the disc rotation speed, liquid flow rate, feed position, disc surface, and liquid/precursor ratio, affect the characteristics of the produced nanoparticles [13].

1.2.2.3 Chemical Vapor Deposition (CVD)

CVD is a process that involves depositing a solid material from a gaseous phase. The substance is deposited onto a substrate material in CVD. The coating material is transported to the reaction chamber to be painted in the form of steam, which is heated to a specific temperature. In the chamber, the substrate and gas interact, causing deposits to form on the substrate's surface. The deposition depends greatly on the temperature of the substrate. Therefore, there ought to be a means to regulate the apparatus's internal pressure and temperature. additionally, the equipment ought to include a mechanism to get rid of extra gaseous waste [14].

1.2.2.4 Pyrolysis

Pyrolysis is the most popular technique for industrially generating nanoparticles on a large scale. It entails using flame to burn a precursor. The precursor, which can be either liquid or vapor, is introduced under high pressure through a small hole and ignited in the furnace. The nanoparticles are then air categorized from the combustion or byproduct gases. Some of the furnaces generates high temperatures for simple evaporation using laser and plasma rather than flame. Pyrolysis has the advantages of being a straightforward, effective, inexpensive, and continuous process with a high yield [15].

1.2.2.5 Biosynthesis

use of biological processes in the creation of nanoparticles The involvement of proteins, including enzymes and cofactors with redox potential, as well as the electron playing a significant role in the metal reduction, is the conventional explanation for it [16]. Instead of using conventional chemicals for bio reduction and capping, biosynthesis produces nanoparticles using bacteria, plant extracts, fungi, and other microorganisms together with the precursors. Because of their distinctive and improved features, biosynthesized nanoparticles are used in biomedical applications [17].

1.3Characteristics of Nanoparticles

1.3.1Scanning electron microscopy (SEM)

The SEM is a microscope that uses electrons instead of light to form an image allows for the imaging of the sample surface by observing the secondary electrons that the sample emits after coming into contact with the impinging electron beam. The SEM operator has control over a wide range of electron beam, detector, and stage parameters, making them exceedingly flexible equipment. As a result, there are practically infinitely many imaging setups that can be used to study any given material [18].

1.3.2 Fourier transform infrared (FTIR) spectroscopy

Among several methods of characterizing FTIR is one of the best techniques for locating functional groups in membranes and possible molecular interactions between chemicals. An illuminated black-body source within the instrument emits a beam of infrared radiation. The spectral encoding is then completed once the beam enters the interferometer. Now that the beam has entered the sample compartment, the sample is absorbing certain frequencies of energy that are specific to the sample from the interferogram. The detector then simultaneously detects the particular interferogram signal's energy versus time for all frequencies [19].

1.3.3 Energy Dispersive X-ray microscopy (EDX)

The EDX microanalysis is a method that carries out a sample's chemical and elemental analysis for scanning electron microscopy. The electron beam from an electron microscope will stimulate or ionize some of the sample's atoms when it hits a thin sample. They will release typical x-rays once they are back in their ground state. The x-ray emission at different wavelengths can then be measured using a detector with sensitive to photon energy [20]**.**

1.4Application of CuO NPs and CuO-NiO nanocomposite

Transition metal oxides are the most commonly used nanoparticles. Cupric oxide (CuO) is of particular interest due to its unique properties and has been used in a variety of applications, including gas sensors, bio sensors, photodetectors, catalysis, biotechnologies, and energetic materials [21]. including solar cells, lithium-ion batteries, heterogeneous catalysis, and solar cells [22].cytotoxicity, antibacterial activity and photocatalytic activity [23]. Due to its chemical stability and capacity to break existing molecular bonds of Ni-doped CuO is advantageous and makes these nanoparticles ideal for the removal of heavy metals and organic contaminants from wastewater. They can also be used to disinfect drinking water and eliminate viruses and bacteria that are present in water [24].

1.5Literature Review

Benhammada et .al were prepared a precipitation approach to achieve the green synthesis of efficient copper oxide nanoparticles, employing (aqueous Malva Sylvester's) leaf extract as a covering agent and copper sulfate and copper chloride layers as copper starting materials and They discovered that overall CuO-NP crystallite sizes between 19 and 26 times the magnification are smaller than those of CuO-S. So Copper Nano gels made with chloride layers have higher crystallinity. And the structural composition and structure of their prepared CuO-NPs were identical and according to the differential scanning calorimetry (DSC) study, the Nitrocellulose NC-CuO is well prepared and aligned. For example, contrast activation, which is the copper material utilized, can also be efficient in activation without significantly changing the grade of the protein of interest. After examining the modifications of NC and NC-CuO-NPs using four complimentary transfer methods in comparison with various conformations, differential scanning calorimetry (DSC) analysis is included. The findings demonstrate that CuO-NPs can be employed in a safe manner as a catalyst for NC as well as an activator and core agent with two and a half affinities, regardless of the type of the precursor. And it finally arrived CuO-NPs have been found as a result of the activation by 7.75 kJ mol-1 [21].

Su et al. we're synthesizing controllable of heterostructured CuO-NIO nanotubes and their synergistic effect for glycol gas sensing. The unique p-p heterojunction used in this paper Nanotubes of CuO-NiO have been carefully synthesized for high-performance glycol gas sensors using a one-pot method and a specific calcination process. The feeding ratio of Cu^{2+}/Ni^{2+} in the synthesis process has been extensively investigated in order to improve the element ratio of Cu to Ni for high-performance gas sensors. With response/recovery times of 15 and 45 s, the gas sensor based on ideal hybrid nanotubes (CuO-NiO (13:7)) exhibits the maximum sensitivity toward 100 ppm glycol at 110 °C. Additionally, the hybrid sensor exhibits outstanding repeatability and durability. Glycol's improved sensing properties are mostly due to under the optimal Cu to Ni element ratio, to the synergistic effects of the CuO-NiO heterostructure and the huge production of oxygen vacancies. This study shows that the newly created heterostructured CuO-NiO nanotubes have high-performance gas sensor has a lot of promise [25].

Jasmeen Kaur and Suman Rani were prepared banana peels to create CuO, NiO, and CuO-NiO nanocomposites. CuO, NiO, and NiO/CuO had yields of 1 g each, 0.99 g, and 1.2 g, respectively. Utilizing techniques such as X-ray diffraction, Fourier transform infrared spectroscopy, UV absorption, and fluorescence spectroscopy, the structural and optical characteristics of the produced material were examined. CuO, NiO, and CuO-NiO all have crystalline monoclinic, cubic, and mixed phases, according to XRD analysis. The Scherer formula was used to calculate the average crystalline size, which was found to be 18.89 nm, 11.27 nm, and 16.55 nm for CuO, NiO, and CuO-NiO, respectively. According to the FTIR spectrum, the Ni-O bond stretching vibrations are assigned to a broad band in the range of 440-470 cm^{-1}, while the Cu-O bond in the CuO structure is characterized by a broad band in the range of 480-486 cm^{-1}. The optical band gap determined by the UV absorption investigation was 1.74 eV for CuO, 3.60 eV for NiO, and 5.22 eV for NiO/CuO. Similar emission spectra for CuO, NiO, and CuO-NiO were discovered by fluorescence spectroscopy, and these materials are excellent for grow lights [22].

P. V. Bakre et al. were prepared CuO-NiO-TiO_2 nanocomposites with a Cu: Ni (1:1) support using a decomposition technique. By using XRD, SEM, EDX, TEM, FT-IR, UV-DRS, and BET-analysis, the catalysts' structure and chemical composition were examined. They were then compared to commercial P25 catalyst for the photo-degradation of methylene blue under direct sunlight. These investigations showed that the percentage of Cu-Ni dopants is the only factor affecting catalyst efficiency. Better photocatalytic activity was demonstrated by the catalyst with reduced metal dopants. The ideal amount of doping for photo-degradation was 0.05 weight percent. The nanocomposite with increased metal loading (5.0 wt%) was successfully used as a heterogeneous catalyst for the air oxidation of tertiary amine functionality to a tertiary amide and for the selective reduction of nitro benzene to aniline using sodium borohydride. By contrasting the catalytic activity with individual metal doping, the synergistic effect of the metals was confirmed [26].

Zahra Alhalili was synthesizing of copper oxide nanoparticles CuO NPs from Eucalyptus Globoulus leaf extract. The results of scanning electron microscopy (SEM) and dynamic light scattering (DLS) showed that the green synthesized copper oxide nanoparticles are spherical, have a mean particle size of 88 nm, and a negative zeta potential of 16.9 mV. The XRD graph showed the crystalline and monoclinic phases of CuO nanoparticles. The Debye-Scherer formula revealed an average crystal size of 85.80 nm. Methyl orange was used to study the Nano-adsorbents' adsorption properties, and the efficiency of the adsorption at room temperature was 95 mg/g. At pH 4.5, methyl orange dye is most successfully absorbable by copper oxide nanoparticles (CuO NPs), when the dye is added in concentrations of 0.04 g/50 ml. To optimize several process parameters, such as pH solution (X1: 2 - 11), adsorbing dose (X2: 0.01 - 0.08 g/L), and [MO] dye concentration (X3: 10 - 80 mg/L), Box-Behnken design (BBD) in response surface methodology (RSM) was utilized. Overall, the employed model was pretty adequate, and the selected RSM was successful in optimizing the decolonization conditions of MO, as evidenced by the adjusted coefficient of determination (R2) value of 0.99 [23].

G. p. Singh et al. were prepared pure and Ni-doped CuO nanoparticles by used Allium staivum (garlic) extract in the green production. In order to create pure and Ni-doped CuO nanoparticles, Allium staivum (garlic) extract was employed as an intermediate precursor for cupric nitrate ($Cu(NO_3)_2$) and nickel nitrate ($Ni(NO_3)_2$). The monoclinic phase of CuO and successful doping of Ni into the CuO matrix were suggested by the XRD patterns, which also confirmed the absence of any impurity peaks. Tauc's graphs demonstrated that the addition of Ni dopant increased the optical band gap energy. Under the UV light spectrum, the photocatalytic activity of the produced samples was examined in relation to Methylene blue (MB) dye and ciprofloxacin (CIP). The results of the photocatalytic activity showed that Ni-doped samples were more effective at photodegrading both MB and CIP organic contaminants. According to the experimental findings, MB and CIP can degrade to 70% and 67%, respectively. Thus, the synthesized materials have the potential to treat antibiotic-contaminated waters in order to get rid of or cut down on antibiotic residues in the environment. CuO and CuN nanoparticles were employed to study bacterial resistance against E. coli at doses of 5, 10, 20, and 30 mg/ml. Nickel-doped CuO nanoparticles are referred to as CuN.

CuO and CuN's zones of inhibition against E. coli were 11 mm and 28 mm at 30 mg/ml, respectively, for the produced nanoparticles (derived from green synthesis). The significant zone of inhibition values shown in this work demonstrate that the produced nanoparticles have improved antibacterial activity [24].

Huang et al. were prepared a hierarchical NiO-CuO nanocomposite without the need of a surfactant. Focus ion beam scanning electron microscopy (FIB/SEM), X-ray diffraction spectroscopy (XRD), and high-resolution transmission electron microscopy (HRTEM) were used to analyze the shape and structure of the hybrid nanostructure. Furthermore, cyclic voltammograms, galvanostatic charge/discharge tests, and electrochemical impedance spectroscopy in 6 M KOH electrolyte were used to clarify the electrochemical characteristics of the hierarchical NiO/CuO nanocomposite electrodes. The electrochemical results showed that this special NiO/CuO nanostructure had an exceptional cycling stability (91.4% retention after 3000 cycles) and a specific capacitance of 280 F g^{-1}. The outstanding electrochemical performance and simple synthesis of the hierarchical NiO/CuO nanocomposite pointed to the material's enormous potential for use in super capacitors [27].

Abbas et al. were prepared a 12 amendment in-situ co-precipitation technique, CuO-doped NiO (CuNiO) with a porous hexagonal shape was created, and its carbon nanotube (CNT) nanocomposite was created. Through the use of cyclic voltammetry (CV), galvanostatic charge discharge experiments, and electrochemical impedance spectroscopy (EIS), the electrochemical characteristics of CuNiO/CNT nanocomposite are examined. At a current density of 100 mA/g, the CuNiO/CNT nanocomposite outperforms bare CuNiO (78.9% of the second cycle), CuO-CNT (76.8% of the second cycle), and NiO/CNT (77.7% of the second cycle) in terms of initial columbic efficiency (82.7% of the second cycle) and capacity retention (78.6% on 50th cycle). This partial substitution of Cu^{+2} for Ni^{+2}, which increased the concentration of holes and improved p-type conductivity as well as an intimate interaction with CNTs that provided a large surface area, excellent conduction, mechanical strength, and chemical stability, is responsible for this high capacity and good cycling ability [28].

1.6 Aim of the study

The aim of the study is

- To prepare CuO nanoparticles and its NiO nanocomposites.
- The nanocomposite will be characterized using Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray microscopy(EDX)

Chapter 2

(Experimental)

2Experimental

2.1Chemicals

$Cu(NO_3).3H_2O$, $Ni(NO_3).6H_2O$, glucose ($C_6H_{12}O_6$) and distilled water were used in the preparation.

2.2 instrumental

Hotplate-stirrer, Muffle furnace, scanning electron microscopic (SEM), and the Fourier transform infrared spectroscopy (FT-IR).

2.3 preparation of nanoparticles

To obtain pure CuO,12.15g of $Cu(NO_3).3H_2O$ was used and dissolved in 200 ml of distilled water and stirred under the magnetic stirring at 80 ^oC for 30 min. After that, 10 g of glucose was added as a capping agent and stirred at 100 ^oC for 6 h to dryness. The formed solid was transferred into a porcelain crucible for calcination at 500 ^oC for 5 h to eliminate the impurities and obtain the CuO-NPs as shown on Fig (1). The CuO-NiO nanocomposite was prepared in the same manner. In detail,0.77g $Ni(NO_3).6H_2O$ were mixed with 11.54g of $Cu(NO_3).3H_2O$ to produce the CuO 5 %-NiO.

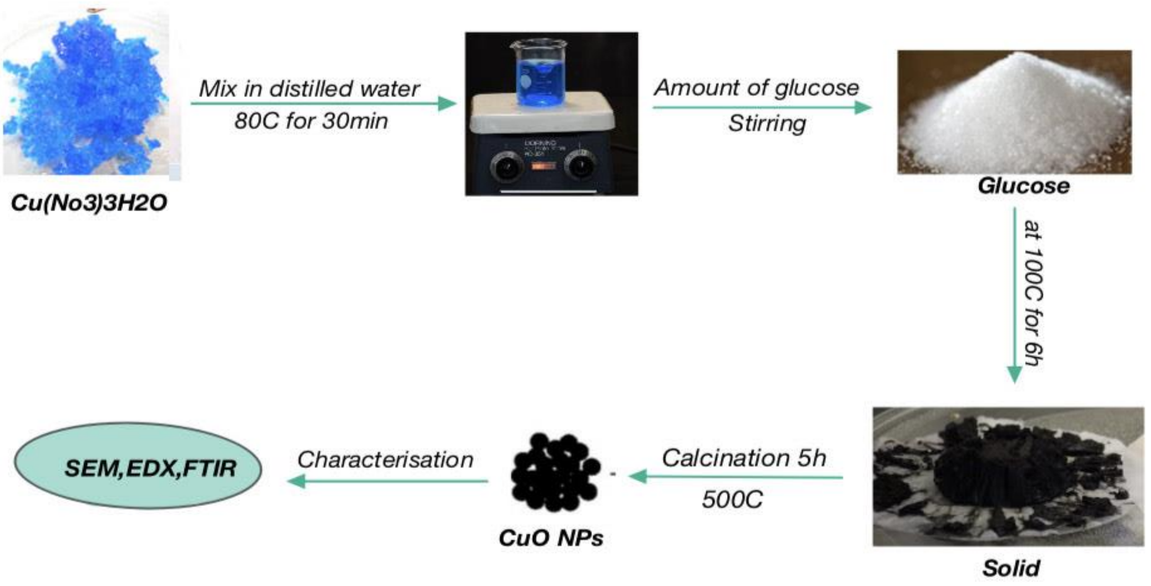


Fig (1): Steps preparation of CuO NPs.

Chapter 3

(Result and Discussion)

3 Results and Discussion

3.1Fourier Transform Infrared Spectroscopy FTIR

One of the most important and useful tools for determining a product's composition and structure is Fourier transform infrared spectroscopy (FTIR). Fig (2) shows the FTIR spectra of CuO nanoparticles. The sample shows a peak at 447.27 cm^{-1}, which is confirmed to the formation of Cu–O bonds. Fig (3) shows the FT-IR spectrum of the CuO-NiO in the wave-number range between 400 and 4000 cm^{-1}. Besides the characteristic peak of Cu–O, there is an observed peak around 600 ~ 400 cm^{-1} that originates from the metal-oxygen (NiO) vibration. The bands in the 400–600 cm^{-1} region are associated with vibrations of metal–oxygen–metal (M–O–M) [23].

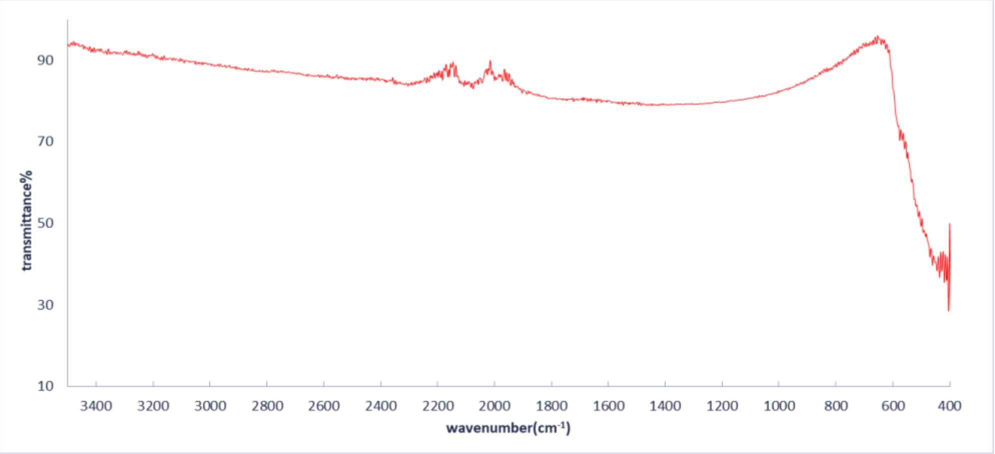


Fig (2): FTIR spectra of CuO nanoparticles

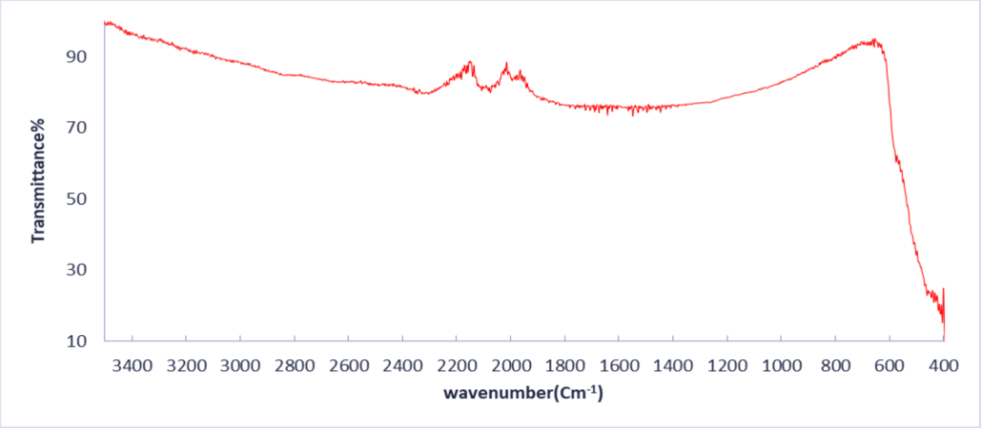


Fig (3): FTIR spectra of CuO-NiO nanocomposite

3.2 Scanning Electron Microscopy (SEM)

Scanning electron microscopy was used to analyze the surface morphology of the nanomaterial produced. Fig (4) shows the surface structure of CuO nanoparticles , with a particle size from 39.3 to 92 nm. Fig (5) illustrates an SEM image of CuO-NiO nanocomposites' surface morphology a spherical shape of particles ranged in size from. 37.4 to 53.9 nm.

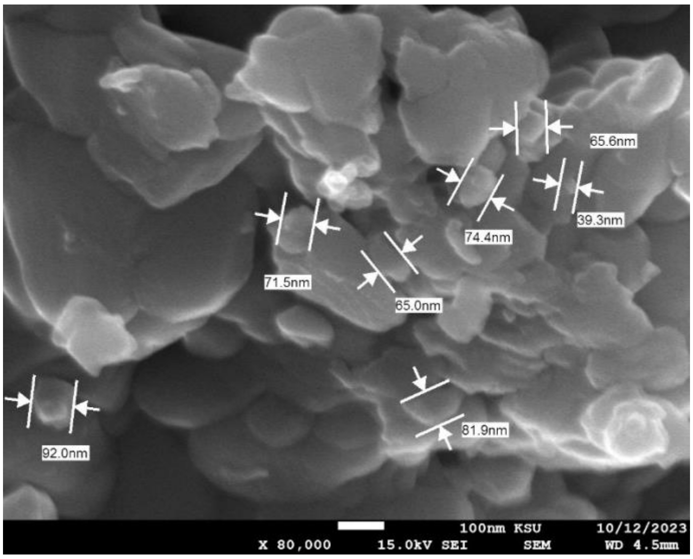


Fig (4): SEM image of CuO NPs

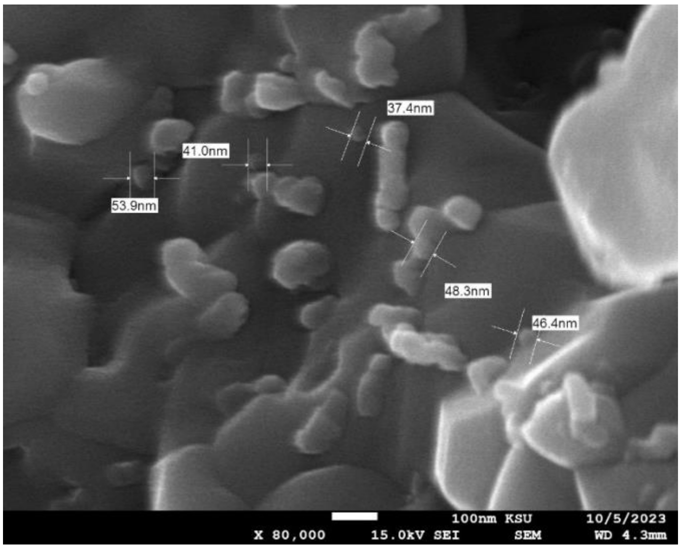
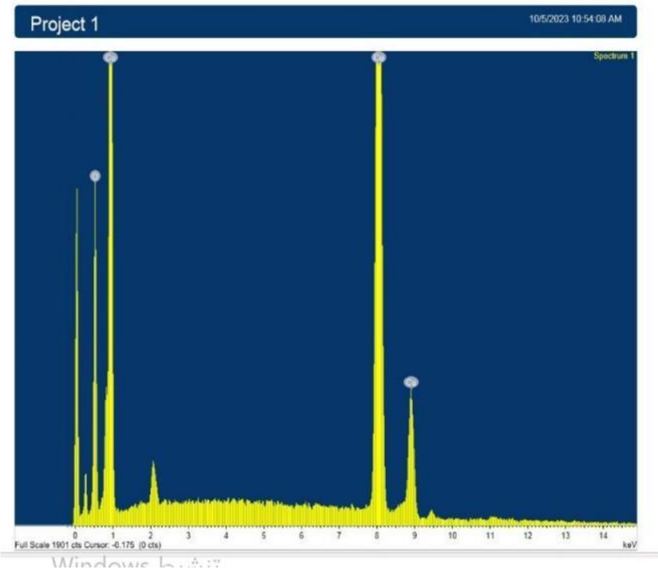


Fig (5): SEM image of CuO-NiO nanocomposites

3.3Energy Dispersive X-ray microscopy (EDX)

One of the most effective methods for characterizing the sample's % elemental composition is EDX, illustrated in Fig (6) CuO nanoparticles were exposed to EDX evaluation. The result shows that had copper (Cu) and oxygen (O) elements with percentages of weight of Cu 86.2%, and O 13.8%, respectively. As shown in Fig (6) the findings indicated that the CuO-NiO nanocomposites had copper (Cu), Nickle (Ni), and oxygen (O) elements with percentages of weight of Cu 79.2%, O 16.9%, and Ni 4%, respectively. It was found that the produced nanoparticles had formed based on observations and the EDX study results. Additionally, our explanations were supported by the EDX mapping, the results of the elemental mapping shown in Fig (6) and Fig (7), which reveals a very good homogenous product.



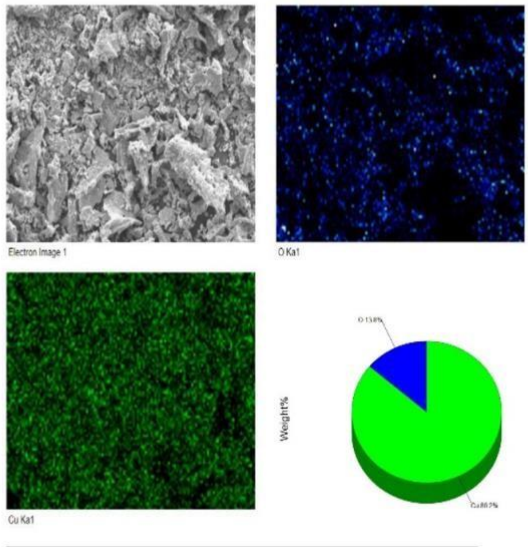


Fig (6): EDX results and EDX mapping of prepared CuO NPs

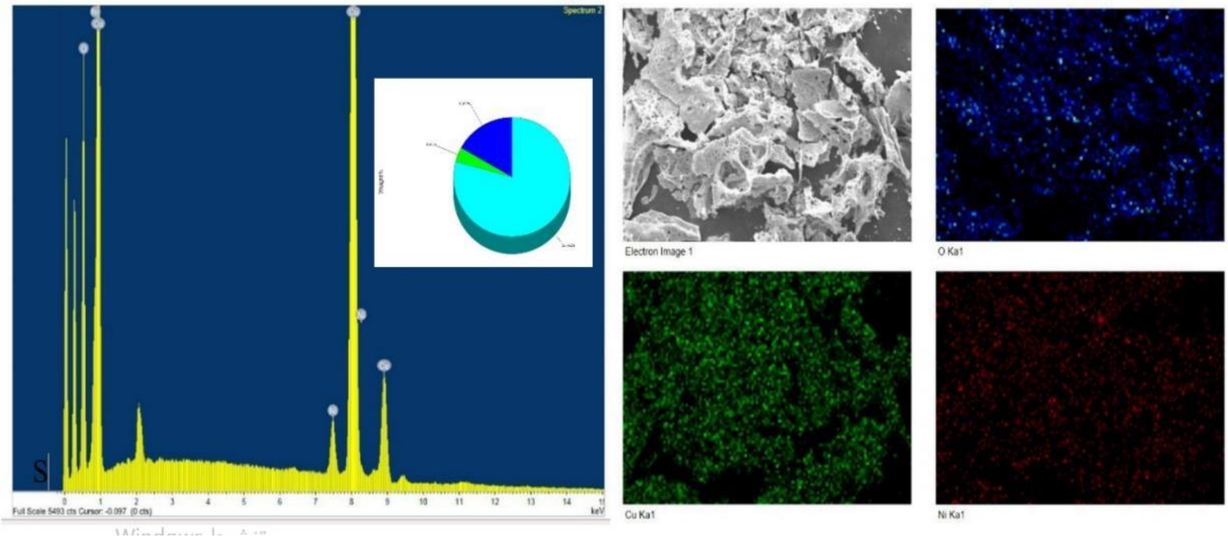


Fig (7): EDX results and EDX mapping of prepared CuO-NiO nanocomposites

Chapter 4

(Conclusion and Recommendation)

4.1Conclusion

CuO and CuO-NiO were synthesized using simple preparation method followed by various characterization analyses. SEM analysis showed spherical-shaped particles with varying diameters in range of 37.4 -53.9 nm and in the range 39.3 – 92 for CuO and CuO-NiO nanocomposites respectively. The results of the EDX analysis showed that Copper (Cu) and oxygen (O) elements were present in the CuO, with weight percentages of Cu 86.2% and O 13.8%, respectively and showed the presence of Copper (Cu), nickel (Ni), and oxygen (O) elements in the CuO-NiO nanocomposites with weight percent equal to Cu 79.2%, O16.9%, and Ni 4% respectively.

4.2Recommendations

-Studying the stability of CuO and CuO-NiO NPs using thermogravimetric analysis (TGA).

-Studying CuO and CuO-NiO NPs at different temperature and molarities.

-Investigation of microbial activities of CuO and CuO-NiO NPs.

-Studying the optical properties of CuO and CuO-NiO NPs.

-Studying the Absorption and scattering microscopy of CuO and CuO-NiO NPs.

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