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Computer-Controlled Biogas Production from Organic Waste

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Abstract

The advanced system of (AD) was designed to generate biogas using organic waste. The system consists of an entering, cutting and mixing unit for waste and water, a fermentation unit with a capacity of 2000 liters and a gas storage unit. The fermentation process is controlled by programming the temperature, the methane gas and the pH sensor connected to the system. The gas was generated from household waste by mixing with water and fermenting it for a period time up to 25 days. The highest amount of gas was during the 17th day from the time of retention. The total amount of gas produced by the system is approximately 60 liters. System waste from the fermentation process can be used as an organic fertilizer. The system is designed with suitable specifications for home use, ease of maintenance and to meet renewable energy. The system was controlled completely by computer.

Keywords: Alternative energy; Anaerobic digestion; Organic waste; Methane gas

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1. Introduction

The main source of energy is fossil fuels and the combustion process causes problems of atmospheric pollution. Waste energy is ideal and renewable because it can be converted to non-polluting into biogas that can be used as environmentally friendly biofuels [1]. The perspective of solid waste has dramatically changed with increasing population and economic development, therefore, the effects of climate change must be mitigated and the transition from fossil fuels to renewable energy must be accelerated. The process of waste treatment can generate clean energy, whether electric or thermal, and it also touches on the idea of waste disposal, which is considered as a waste management option [2]. Biogas is capable of alleviating growing concerns about the energy crisis and climate change as well as reduce dependence on fossil fuels. Biogas can be produced from organic waste, consisting mostly of methane (CH_4) and carbon dioxide (CO_2), used to generate thermal energy, and considered as a light fuel that releases less CO_2 into the atmosphere during combustion [3]. Biogas is produced by decomposing and breaking down organic materials into their

basic organic components, where methane bacteria are used to ferment and decompose these materials under special conditions under anaerobic conditions and at appropriate temperature rates [4]. There were many designs for biogas production systems, although, they were primitive and containing obstacles that led to their failure. Such obstacles – ignored in the system design – are the weak construction skills and the lack of use of appropriate materials in manufacturing. As well, most designs need to be drilled in the ground [5], which is not suitable in rocky terrain and with difficult maintenance and cleaning, where they need to be cleaned every period and have a short life. In addition, there are other defects in such designs that are not tightly closed, which leads to a leak in the gas. In this work, a system that addresses all these problems and defects is designed and manufactured to show the ease of manufacture, security, and transportability, as well as an advanced control of the anaerobic digestion process in terms of follow-up through the sensors connected to it that makes the whole system controlled by computer. The best biogas production can be obtained and the remnants of materials can be used after the

anaerobic digestion process as organic fertilizer.

Many different technologies are used to treat waste from the organic portion of household waste. These systems vary depending on the reactor design and operating parameters. Reactor design depends on the raw materials to be processed, while the digester design depends on the amount available of raw materials, which determines the actual capacity of the reactor to produce [6].

While designing the biogas production system, the factors that will affect the anaerobic digestion process within the system must be taken into accounts, such as temperature, pH, and loading rate of organic waste. In our study, these were taken into account and can be classified as follows:

The pH of biomass within the digester is one of the factors affecting the digestion of organic waste, where the methane-producing bacteria are affected by the change in pH and affecting the bacterial growth and the rate of methane gas production in the anaerobic digestive reservoir. In this study, it was observed that the best amount of biogas production in the anaerobic digester is achieved when the pH value is 7.5-6.5. The retention period and amount of organic waste inside the digester affect the pH amount [7]. Figure (1) shows the variation in pH value with the retention time.

Temperature is one of the factors that affects the process of anaerobic digestion within the digestive unit and has a role in determining the amount of biogas production, as it is a prerequisite for optimal survival and growth of microbial concentrations. Although, the digester can operate at different temperatures, methane bacteria have two temperature levels, representing a thermophilic level as it reacts at high temperatures up to 25-40°C and medium-temperature bacteria that work within 50-65°C [8].

The biomass loading rate determines the amount of organic waste that can be introduced into the anaerobic fermentation tank and represents an indicator for measuring

the biodegradable capacity of the anaerobic digestion unit. The amount of produced biogas decreases when there is an overloading of organic waste in the anaerobic digestion unit due to the accumulation of fatty acids in the digester that inhibits the process of anaerobic digestion [9]. Therefore, specific ratios of organic materials with water were adopted to reach the best production of gas and to get rid of the inhibitors in anaerobic fermentation process.

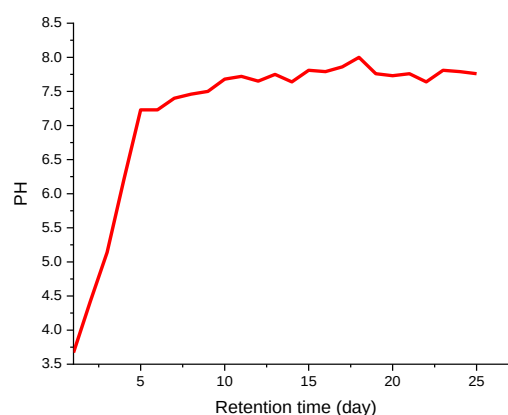


Fig. (1) Variation of pH value during the retention time

2. Materials and Methods

An effective and advanced model was designed to take into account all obstacles, defects and errors in previous designs in order to reach the best model design. As well, the reasons that affect the anaerobic digestion (AD) process were studied to reach the best design and highest productivity of biogas. Factors affecting the anaerobic fermentation process were followed up through sensors connected to the Arduino program to control the anaerobic digestion unit. Table (1) shows the design parameters of the biogas generating unit.

It is an airtight tank designed in the form of a cylindrical with an operating capacity of 2000 liters and the thickness of the zinc-galvanized iron plates chosen for the manufacture of the fermentation tank was 1.6 mm. This tank is very durable for difficult stressful work while all tanks of other anaerobic digestion designs are made of fiber-reinforced plastic, which are well tolerated for external conditions. Also, this type of iron provides protection against corrosion and salts

and is easy to manufacture the shape required for the design. The dimensions of the cylindrical tank to provide sufficient surface area for the fermentation process are 2m in length and 50cm in radius with total volume of 6.28 m³.

Table (1) Design parameters of the Biogas unit

Design parameters	Value
Fermentation tank capacity	2000 L
The thickness of the iron sheets used in the design	1,6 mm
Fermentation tank length	200cm
Fermentation tank radius	50cm
The diameter of the outlet hole of the digestion unit	10cm
Inlet pipe length	100cm
Shredder tank length	50 cm
Shredder tank diameter	37cm
gas tank length	60cm
Gas tank diameter	40cm

This unit is designed on the side of the fermentation tank as an output hole with a diameter of 10 cm containing a tight lid that can be closed and opened. This hole is used for emptying at the end of the fermentation process, to take out the remnants of waste after decomposition through it and to facilitate the cleaning process. It was placed in a suitable place at the bottom of the fermentation tank so that the remaining biomass comes out with ease. The hole was placed at an appropriate height from the ground due to the presence of iron bases installed on the fermentation tank.

This is inlet hole designed from the top in order to enter the biomass easily and a cylindrical pipe with a diameter of 10 cm and a length of 100 cm was welded cut from the bottom direction of the ellipse while the other side is serrated in order to put it on the PVC plastic valve. This hole contains a valve to provide an advantage to control the closing and opening of the pipe when needed.

It is a tank designed to mix biomass with water before entering the fermentation tank, where the mixing tank is cylindrical in shape with a diameter of 37cm and a height of 50 cm, from the bottom it is connected to the inlet hole valve and carried by a base designed to carry the mixing tank and installed at the top of the cutting motor, where a motor containing a cutting blade was installed on it in order to cut and mix the biomasses, and this facilitates the decomposition process during the

fermentation process, and there is also a tank of water A numbered next to the fermentation tank supplies the tank with water according to the amount that is determined during mixing, and there is a base that holds this tank.

It is a closed cylinder has been manufactured two holes for gas valves the first valve is located at the bottom of the gas tank and is linked with the fermentation tank with a PVC tube and the second valve is located at the top of the tank and the valve is connected to a rubber balloon that expands when there is biogas production and to avoid excessive pressure on the gas filling tank as well as the gas valve can be closed and the gas system separated when the filling is completed.

3. Results and discussion

In order to test the treatment unit that was manufactured, 140 kg of organic waste was placed with 280 kg of water and the quantity was placed in the form of parts in the cutting tank in order to be mixed well and stirred to ensure the dispersion of the worn parts of the organic waste and achieve a homogeneous mixture and then we open the valve to enter the mixture inside the fermentation tank and close it well and the retention period was 25 days and the amount of cumulative biogas production was about 60 liters and the pH rate was controlled During the fermentation process and it was between (7.3-7.7) and that the temperature was between (42°C-46°C) for the fermentation process. Finally, it can be said that the results obtained can be represented in the Fig. (8), which shows the amount of biogas production (ml/day), which was obtained during the fermentation processes and in different retention periods and within 25 days. This amount of biogas produced from the manufactured digestion unit is very good and will be useful as renewable energy and an alternative to fossil fuels. This system is considered an experimental system that can be used to conduct many biogas researches. Where all the electronic parts were connected by the Arduino board for the temperature sensor. In

addition, all the activities in the system were controlled by the computer.

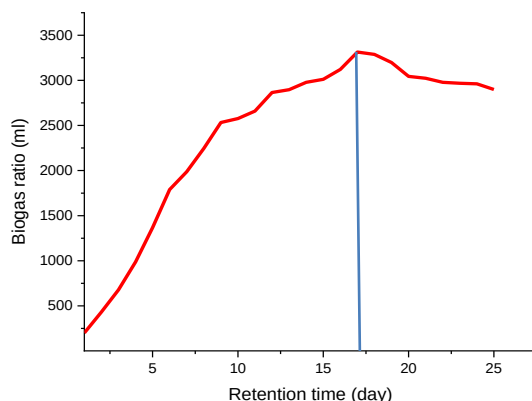


Fig. (8) The proportion of biogas produced (ml/day) for each day of the retention time

4. Conclusion

In this research we presented the design and manufacture of an anaerobic digester unit for biogas generation and the materials selected in the manufacture of the digester were effective as they meet practical needs (AD). The design meets all previous studies for the production of biogas and taking into account all the factors affecting the digestion process and treating it by design in terms of the effect of external temperatures and insulation of the manufactured materials, including the fermentation tank, as well as adding a cutting tank to untie the biomasses, cutting them and mixing them with water, in addition to controlling the digestion process and following it up electronically through sensors related to the digester, and taking into account the choice of material availability for everyone as well as its cheapness. The typical design of the manufactured unit gives additional advantages in terms of longer life, high durability, ease of cleaning and maintenance. This manufactured unit is highly

recommended due to its low operating costs and special features such as manufacturing costs and ease of use. In addition, manure will also be produced as a by-product.

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Mechanical Characterization of Small Sized Bladed Wind Turbine under Low Wind Speed

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Abstract

In this paper, a small horizontal wind turbine rotor blade is designed to operate under low wind speed, it is well known that the design of the rotor blade is a difficult task due to the calculations involved in the design process. The Q-Blade program was used to design and simulate the turbine rotor blade during working conditions, with some engineering improvements to the shape of the blade by distributing the airfoils along the blade and controlling the airfoil chord length and twist angle using the blade element theory (BEM). Where airfoil (NACA7611) was used for a three-blade rotor and a five-blade rotor based on the turbine type and rotor size to generate mechanical power from wind power. Comparison and analysis (turbine power, power coefficient, torque coefficient) were carried out at low wind speed (2-7m/s) and highly accurate results were obtained. Also, it was found that the best performance in which a three-bladed turbine rotor can work with a turbine power of 3.951 kW and a power coefficient of 0.43. Also, the power of the turbine was obtained 4.757 kW, and the power coefficient of 0.51 for the five-blade rotor. These values do not exceed the Betz limit (0.59%), which is good efficiency for a small wind turbine. It was found that the design of a small horizontal wind turbine with five blades is better than a turbine with three blades and is suitable for working in areas with low wind speed, and with high efficiency compared to the size of the turbine.

Keywords: Wind Energy; Blade of Wind Turbine; Power Coefficient; Torque Coefficient; Low wind speed

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1. Introduction

Industrial growth in countries is related to their energy resources, the use of oil, hydrocarbons, and coal, which was the main source of energy production in the past, has a significant impact on the environment. Therefore, at present, some developed countries are turning to use alternative energy to reduce Environmental pollutants, such as the use of hydro, solar, and wind energy. Wind energy is one of the clean and preferred energies for some countries, and the energy that is produced by wind turbines depends on the blade engineering and wind speed, since wind speed varies in time and place and according to geographical location, this led to the use of small wind turbines on the roofs of buildings, which are characterized by its low cost, due to the small size of the turbine, as the cost, increases with the increase in the number of blades and vice versa for wind turbines with a small number of blades also, one of the advantages of small-sized wind turbines is simple structure and low noise in addition to its versatility make it a preferred choice for

many and a reliable source [1,2]. A horizontal axis wind turbine is designed being a clean source of energy, there are no hazards to electricity production by a wind turbine. These turbines neither emit any toxic nor have any specific productivity time, making these a superior alternative to fossil fuels and solar power. The wind turbine is analytically designed and then the results were verified using simulation (Q-blade) software. A theoretical efficiency of 38.25% was obtained as the simulation results determined a power of 750-800 W at an average wind speed of 4-8.5m/s [3]. New and effective airfoils were developed for small-sized horizontal axis wind turbine rotor blades using blade element theory and momentum theory, and calculations were carried out using the Q-Blade program and ANSYS CFX program and they reached a power of 1kW at a wind speed of 8.4 m/s [4]. A horizontal wind turbine was designed using a NACA 4412 airfoil and a five-blade rotor with a diameter of 1.4 m with a change in wind speed 2-6m/s. Where the aerodynamics of the blade was analyzed

based on the blade element theory (BEM), which refers to parsing each section of the blade independently from the other. So that the results of the blade sections are combined as a function of the blade geometry, and using the Q-blade program, it was found that the energy of the wind turbine increases with the increase in wind speed based on the increase in the value of TSR in addition to the increase in the power factor as the wind speed increases [5]. Helical blades, horizontal wind turbines, were designed for urban electric power generation and it was concluded that such turbines produce (RPM) at wind speed 5m/s, and to get the best power output the wind speed should be 18-25 m/s and that this design withstands wind disturbances and enjoys a high efficiency of up to 80% of the energy available in the wind and at low altitudes [6]. A flexible blade design technology study was conducted for the Savonius-type vertical axis wind turbine (VAWT). So that the shape of the blade changes due to the inertial forces of the blade during rotation or due to aerodynamics, and by comparing it with the blades of classic wind turbines, it was found that the new design led to an increase in the power coefficient (C_p) by 8% and the tip speed ratio (TSR) high and that The system has achieved good efficiency compared to traditional blades. That is, the shape of the blade must be improved to suit the wind speed in the geographical location and not rely on a traditional shape or design [7].

3. Rotor Design

The first step in designing a wind turbine is to choose the most suitable airfoil for the turbine rotor blade, where a high-lift coefficient and low-drag flap is chosen at low wind speeds to achieve the best power coefficient (C_p), and obtain an effective and intuitive design for the turbine rotor, Q-Blade software was used, to design the blade, and make some engineering improvements to the shape of the blade by distributing the airfoils along the blade and controlling the airfoil chord length and twist angle using the blade element theory (BEM), where the airfoil (NACA 7611) was selected based on the type

of turbine and the size of the rotor to generate mechanical energy from wind energy (Fig. 2).

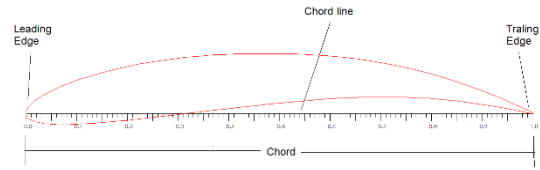


Fig. (2) The shape of the airfoil, which was chosen for the rotor blade design

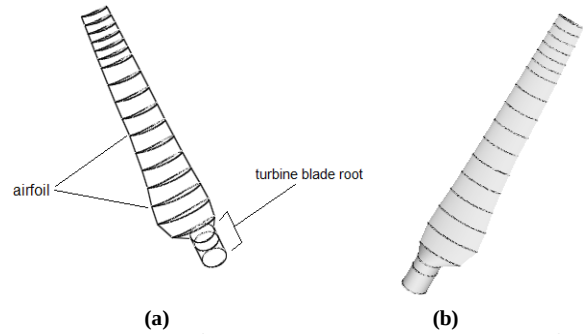


Fig. (3) The design of the blade (a) shows the distribution of the ailerons along the length of the blade. (b) The final blade shape

Table (1) Horizontal axis wind turbine rotor specifications

No.	Position (cm)	Chord (cm)	Twist-angle (deg)	Foil
1	0	10	0	Circular foil
2	10	10	0	Circular foil
3	15	10	0	Circular foil
4	20	18.7	14.2	NACA7611
5	30	22.7	13.8	NACA7611
6	40	21.4	13.4	NACA7611
7	50	19.1	13	NACA7611
8	60	17.6	12.6	NACA7611
9	70	16.5	12.2	NACA7611
10	80	15.4	11.8	NACA7611
11	90	15.1	11.4	NACA7611
12	100	14.3	11	NACA7611
13	110	14.3	10.6	NACA7611
14	120	13.3	10.2	NACA7611
15	125	12.9	10	NACA7611
16	130	12.5	9.8	NACA7611
17	135	12.1	9.6	NACA7611
18	140	11.7	9.4	NACA7611
19	145	11.3	9.2	NACA7611
20	150	10.8	9	NACA7611

The second stage of the design is to divide the blade, which has a length of 150 cm, into 20 sections, and use the first three sections as the root of the blade, and 17 of the other sections as the airfoils (NACA 7611) are distributed on it Table (1), so that the airfoil is larger in the parts close to the root and smaller in the outer sections of the blade, where the length of the airfoil (NACA 7611) near the root is 18.746 cm and at the tip of the blade is 10.898 cm long, and the twist angle is

distributed from 14.2° at the root of the blade to 9° at the tip of the blade.

4. Results and Discussion

After completing the design process and making some appropriate modifications to the shape of the blade, a simulation was conducted to find out the mechanical properties (turbine power, power coefficient, torque coefficient), to perform the rotor blades, whether the design can be used in practical applications or not, where an analysis of the turbine rotor was conducted wind, with three blades, and five blades, to find out which one is better for producing power and which one works to generate mechanical power at a wind speed rate of 2-7m/s, and using Eq. (2) approved in the analysis program Q-blade, at a low wind speed, it was found that the power of a five-bladed turbine increases with the increase in wind speed with greater power than a three-blade turbine. Where the power of the turbine with three blades 3.951 kW and five blades 4.757 kW. Figure (5) shows the difference in the increase in the mechanical power of the turbine gained from the wind. Thus, it can be said that the power of a small wind turbine can be increased by increasing the number of blades, without The need to change the diameter of the rotor to capture wind energy, as the performance of the wind turbine is more sensitive to changes in wind speed whenever the number of blades is more, in a way that suits the size of the turbine, which is coincident with [17]. The choice of the number of blades is important because it directly affects the speed and efficiency of the wind turbine, as the energy gained by the turbine from the wind is proportional to the area swept by the turbine rotor blades. Thus, the number of blades affects on power generation, and the greater the number of blades, the greater the torque of the turbine rotor. In addition to easier rotation at low wind speed, provided that the number of blades is appropriate to the size of the turbine, and by comparing the three-blade turbine and the five-blade turbine, we note that the five-blade turbine, improves performance significantly

in areas where the wind speed does not exceed 7 m/s, compared to the traditional three-blade turbine. In addition to the turbine's self-operating, on the other hand, the turbine rotor blade has an unbalanced torsional force acting on the shaft and this undesired deflection may reduce the energy produced and may lead to vibrations. The three-blade turbine has minimal vibration.

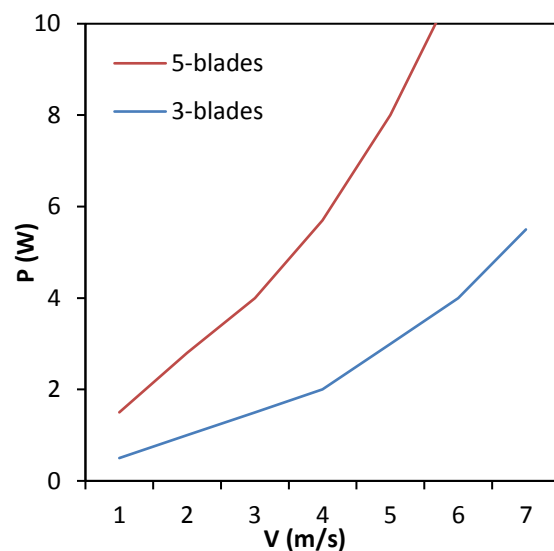


Fig. (5) The power of the turbine with wind speed

5. Conclusions

In this paper, a horizontal axis wind turbine was designed with a rotor consisting of three blades and five blades, and a comparison was made to find out which of the two turbines is better at average wind speed 2-7m/s, to generate mechanical energy from wind energy based on the (BEM) theory using the Q-blade design software, The results of the study showed that using a curved airfoil for the central geometric line the middle line, is better for the blade of a small wind turbine to achieve a lifting force that rotates the turbine rotor.

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XRD Analysis and Structural Properties of Nickel-Doped Zinc Ferrite

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Abstract

Nickel ferrite ($\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$) nanoparticles were synthesized using co-precipitation method. The x-ray diffraction (XRD) pattern was used to determine the structure of $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ nanoparticles. The details of the surface morphology of $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ nanoparticles were obtained by scanning electron microscopic analysis (SEM). The particle size of the $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ nanoparticles could be determined by XRD also the another parameter was determined from the lattice constant (a) and theoretical density ($\rho_{\text{x-ray}}$).

Keywords: Nickel ferrite; Zinc ferrite; Nanoparticles; Lattice constant, Structural properties

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1. Introduction

Due to its diverse and unique structural, spectroscopic, and magnetic features, spinel ferrite has been produced by a significant number of researchers and scientists in recent years [1]. Microwaves [2], drug delivery [3], gas sensors [4-5], and electronic devices [6] are only a few of the uses for spinel ferrites, all of which are related to the type of transition metals in their network [7]. For their technological uses, low porosity, high density, and species microstructure are necessary [8]. The ferrite nanopowders under investigation crystallize into spinel. The octahedral or tetrahedral positions are occupied by the divalent A and trivalent B cations, respectively, depending on their lattice surroundings. Depending on how they are distributed, the spinel ferrites are divided into two categories of M^{2+} and Fe^{3+} cations on (A) or [B] sites: normal spinel AB_2O_4 with the formula $(\text{A}^{2+})\text{A}[\text{Fe}^{3+}\text{Fe}^{3+}]\text{BO}_4^{2-}$, and the inverse type B (AB) O_4 with the formula $(\text{A}^{2+}\text{Fe}^{3+})\text{A}[\text{A}^{2+}\text{Fe}^{3+}]\text{BO}_4^{2-}$ [9]. Figure (1) shows that spinel ferrites crystallize [10], and because the radius of the metal ion is smaller than the radius of the oxygen ions, it is trapped between the two oxygen ions.

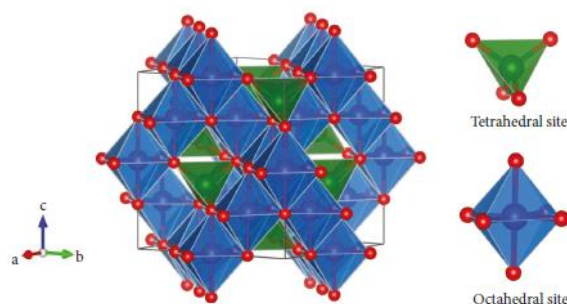


Fig. (1) The cubic spinel structure. Oxygen locations are shown in red, while the tetrahedral (A-site) and octahedral cation (B-site) are indicated in green and blue, respectively

The structural and magnetic characteristics of spinel ferrites are affected by the cation occupancy along the (A) and [B] sites. Because of its usual characteristics, decreased eddy current losses, low conductivity, and good electrochemical stability, nickel ferrite is one of the versatile and technologically significant soft ferrite materials that is ferromagnetic [11]. Due to their high magnetic permeability, low electrical conductivity, and excellent performance at high frequencies, Ni-Zn spinel ferrites are remarkably intriguing [14]. A variety of techniques, such as the hydrothermal approach [15], co-precipitation [16], sol-gel [17], microwave combustion [18], and others [19-20], were utilized to create the Ni-Zn Nano ferrite. The sol-gel technique is one of

these methods that is both practical and efficient. Chemical homogeneity, high purity, and energy savings have all been accomplished with success using the sol-gel technique [21]. For Ni-Zn ferrites, microscopic features include factors like composition, grain size, dopant quantity, impurities, production process, and heating conditions. [22].

2. Experimental details

To prepare the compounds used in experimental by chemical precipitation method, iron nitrate, zinc nitrate and nickel nitrate were dissolved in (100ml) of distilled water using a magnetic stirrer (Stirrer magnetic) at a temperature of (60°C) and for half an hour in order for the substance to be completely and homogeneously dissolved in water, then all the solutions are mixed in a glass flask at a temperature of (60°C) for half an hour with continuous stirring by means of the magnetic mixer.

As for the second stage, (40g) of sodium hydroxide (NaOH) was dissolved in (200 ml) of distilled water in a glass flask with continuous stirring using a magnetic mixer at a temperature of (60°C) for 15 minutes. Sodium hydroxide solution is used as a precipitating agent and to determine the pH value.

As for the third stage, it included mixing all the solutions in a glass flask at a temperature of (60°C) for half an hour with continuous stirring by means of the magnetic mixer. Then we distill the sodium hydroxide solution mixture by a burette slowly over the solution of the mixture of solutions while continuing the mixing process at a temperature (60°C) until the sodium hydroxide solution is distilled to determine the pH value.

After completing the distillation process, the solution will be clear with a pH that we determine. This solution is filtered with filter paper and then washed several times with distilled water to get rid of insoluble nitrates. Then the resulting substance is taken and dried in a drying oven at a temperature (100°C) to obtain a dry, moisture-free

compound. Then the powder we obtained is calcined at a temperature of (700°C) for two hours

3. Results and Discussion

The ferrite samples were prepared based on the molar concentration and molecular weights by comparing the X-ray diffraction patterns of ferrite after sintering at a temperature of 700°C and in comparison with the standard labels it was found that they are identical to the standard label number (JCPDS 8-324). And as shown in Fig. (2), and from the X-ray diffraction pattern of the sample, the appearance of peaks (220), (311), (222), (400), (422), (333), (440) and (533) within the angular range (20°-80°) for all the compounds prepared by chemical precipitation method, where the peaks are considered dominant, which refers to the geometric crystal structure of ferrite powder and from the shape of the diffraction spectrum, the appearance of the spin phase of zinc [88]. No impurities were found for any other material, which proves that the material has a very high purity. A variation in intensity was found where the highest intensity was due to the (311) peak corresponding to the angle 35.7°, when looking at the spectrogram We notice an increase in the intensity of the peaks with increasing pH, which leads to the formation of nanoparticles of varying size according to the pH value. As the pH increases, the granular size increases [89]. The ferrite compound with the formula $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ and pH values was prepared, (pH = 1.5, 7, 10, and 13) we find that the granular size has reached the value 18-48nm of the pH value, respectively, and the reason for the increase in size is The granularity of ferrite materials is due to the fact that magnetic materials tend to agglomerate, which leads to the increasing of particles with each other, which leads to an increase in the surface area of the material, thus increasing the granular size. We can also justify this increase due to the recrystallization that reduced the amplitude of the lattice constant [90].

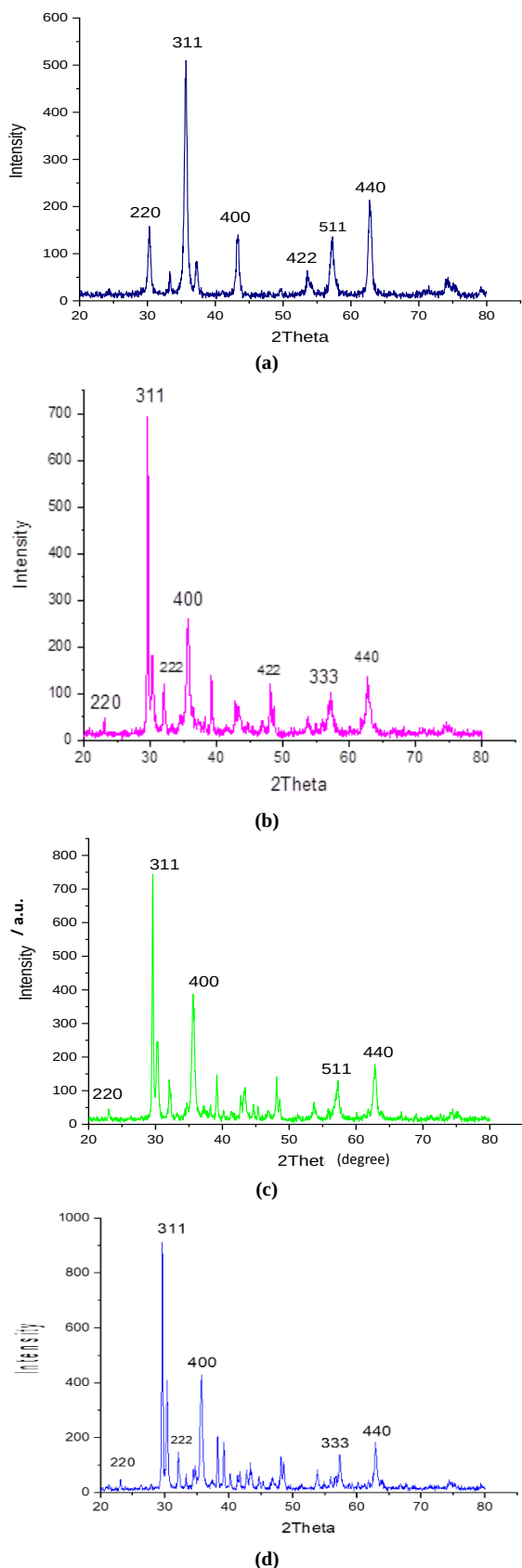


Fig. (2) XRD patterns of $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ with pH value of (a) 1.5, (b) 7, (c) 10, and (d) 13

The lattice constant based on Miller's coefficient for the highest obtained intensity and for the peak (311), which was prominent in terms of intensity, location and granular size. It increased with the increase of the pH and also with the increase in the content of the zinc ion whose value was different between the two formulas, as it causes the increase to the migration of the triple iron ion from the tetrahedral sites to the range of the octahedral sites [23].

The theoretical density, where it was found that the theoretical density decreased with increasing pH and also with an increase in the zinc ion content, where the ratios varied between $5.32\text{-}5.42\text{g/cm}^3$, where in the ferrite spinel structure, which contains the tetrahedral and octahedral structure, it is preferred to occupy the eight-surfaced corners with Zn^{2+} ions because of the predominance of volume over mass and also because the diameters of the ions are not the same size [24].

Table (1) Values of lattice constant with pH for (311) peak

pH value	Lattice constant a (Å)
7	8.382
10	8.391
13	8.373

Table (2) Values of theoretical density at different pH values

pH value	Theoretical density ($\rho_{x\text{-rd}}$) (g/cm^3)
7	5.25
10	5.384
13	5.342

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Al₂O₃/Si Structures Synthesized by DC Reactive Sputtering for Optoelectronic Devices and Their Applications

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Abstract

This work examines the optoelectronic properties of Al₂O₃/Si multilayers deposited by dc reactive sputtering with Al₂O₃ thicknesses of 200, 250, and 325 nm. The 200-nm sample exhibited the highest current and strong photoresponse, similar to the 250-nm sample. Both peaked in spectral responsivity at ~0.38 A/W in the near-infrared (800–850 nm), with a sharp rise beyond 750 nm, indicating effective long-wavelength absorption in Si. In contrast, the 325-nm sample showed higher dark current but much lower responsivity (~0.0038 A/W), suggesting carrier collection is hindered. EQE and detectivity followed the same trend, peaking at ~55–56% and ~0.55×10¹² Jones, respectively.

Keywords: Thin films; Multilayer structure; Sputtering, Optoelectronics

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1. Introduction

Aluminum oxide (Al₂O₃), commonly known as alumina, is a material with diverse applications due to its excellent optical, electrical, and mechanical properties [16-18]. In nanostructured forms, Al₂O₃ exhibits enhanced characteristics suitable for various fields, including optoelectronics [19,20]. Preparation methods for Al₂O₃ nanostructures include techniques like pulsed-laser deposition (PLD), atomic layer deposition (ALD), chemical vapor deposition (CVD), and reactive sputtering [21-24]. For optoelectronic applications, Al₂O₃ thin films are valued for their high transparency across a wide spectral range, high dielectric constant, and good insulating properties. These characteristics make them ideal for use as gate dielectrics in thin-film transistors, passivation layers in solar cells, and protective coatings for optical components [25,26]. Their stability and tunable refractive index also contribute to their importance in fabricating anti-reflection coatings and waveguides in integrated optical devices [27,28].

DC reactive magnetron sputtering is a versatile and reliable technique for preparing thin films, including nanostructured Al₂O₃. This method involves introducing a reactive gas, such as oxygen, which reacts with the sputtered target material to form a compound film [29-32]. A key advantage of DC reactive sputtering lies in its ability to precisely control the film's properties by optimizing parameters like oxygen partial pressure, DC power, working gas pressure, and substrate temperature [33,34]. This fine control is particularly beneficial for fabricating multilayer structures, where distinct layers with tailored compositions and properties are required [35]. By sequentially depositing different materials or varying reactive gas compositions, sophisticated multilayer stacks can be achieved, enabling the creation of advanced devices with enhanced functionalities [36]. The technique allows for the deposition of a wide variety of compounds, offering broad applicability [37,38].

2. Experimental Part

A dc reactive sputtering system was used to deposit Al_2O_3 thin films on silicon substrates with different thicknesses. The film thickness was determined by the deposition time of the Al_2O_3 layer. A highly-pure (99.99%) target of aluminum was sputtered in presence of oxygen with mixing ratio of 50:50 with argon in the gas mixture. The target and silicon substrates were thoroughly cleaned and dried before the deposition process. The target was maintained carefully on the cathode and the deposition chamber was initially evacuated to 0.001 Torr. The plasma column was generated by electrical discharge of argon as a high dc voltage (up to 5 kV) was applied between the electrodes. The deposition process was carried out at room temperature, the discharge voltage during operation was 650-700 V, and the discharge current was kept at 25 mA. The deposition times were 60, 90 and 120 min. and the inter-electrode distance was 4 cm. The optimum discharge current was determined according to the stability of the discharge plasma and the pressure of gas mixture was about 0.15 mbar. The flow rate of the gas mixture into the deposition chamber could be precisely controlled, and the temperature inside the chamber was measured by a precision thermometer. The gas mixer was supplied with argon and oxygen gases from gas cylinders and the mixing ratio was controlled by fine needle valves. More details on this sputtering system can be found elsewhere [39-42]. The film thickness measurements were carried out using the optical interferometry method. This method is based on the interference of a coherent light beam reflected from a thin film surface and substrate bottom, with error rate of about 3%. A 630nm diode laser was used as a light source and the film thickness was determined using the following formula:

$$d = \frac{\Delta x}{x} \cdot \frac{\lambda}{2} \quad (1)$$

where x is the fringe width, Δx is the distance between two adjacent fringes, and λ is the laser wavelength

The electrical and optoelectronics characteristics were determined throughout the current-voltage characteristics, photocurrent as a function of applied reverse voltage, spectral responsivity, external quantum efficiency, and specific detectivity.

3. Results and Discussion

Figure (1) illustrates the current-voltage (I-V) characteristics of the $\text{Al}_2\text{O}_3/\text{Si}$ structures prepared with different thicknesses of the Al_2O_3 layer (200, 250, 325 nm). A clear trend emerges as the deposition time, and presumably the film thickness, increases. Figure (1a) shows the highest current levels, reaching approximately 190 μA in forward bias at 5V and about -120 μA in reverse bias at -5V. As the Al_2O_3 layer thickness was increased to 250 nm, (Fig. 1b), the current significantly decreases, with forward current reaching only about 40 μA and reverse current around -7 μA at 5V and -5V respectively. The most dramatic reduction in current is observed in Fig. (1c), where the current levels are substantially lower, peaking at just over 10 μA in forward bias and remaining very close to zero in reverse bias. This progressive decrease in current with increasing Al_2O_3 layer thickness suggests that thicker Al_2O_3 layers act as more effective insulating barriers, reducing leakage current and enhancing the rectifying behavior of the $\text{Al}_2\text{O}_3/\text{Si}$ junction. The transition from a more resistive behavior at 200 nm to a more insulating behavior at 325 nm highlights the crucial role of Al_2O_3 film thickness in controlling the electrical properties of these heterostructures.

Figure (2) illustrates the photocurrent response of the prepared $\text{Al}_2\text{O}_3/\text{Si}$ structures under both dark and illuminated conditions. It displays the photocurrent (μA) as a function of reverse voltage (V). In Fig. (2a), under dark conditions, the photocurrent remains very close to zero, reaching approximately -10 μA at -5V. Upon illumination, the photocurrent significantly increases, reaching approximately -60 μA at -5V. Figure (2b) shows a similar trend but with significantly

lower current magnitudes. Under dark conditions, the photocurrent is nearly zero, reaching about $-0.4 \mu\text{A}$ at -5V . With illumination, the photocurrent increases, reaching around $-1.1 \mu\text{A}$ at -5V .

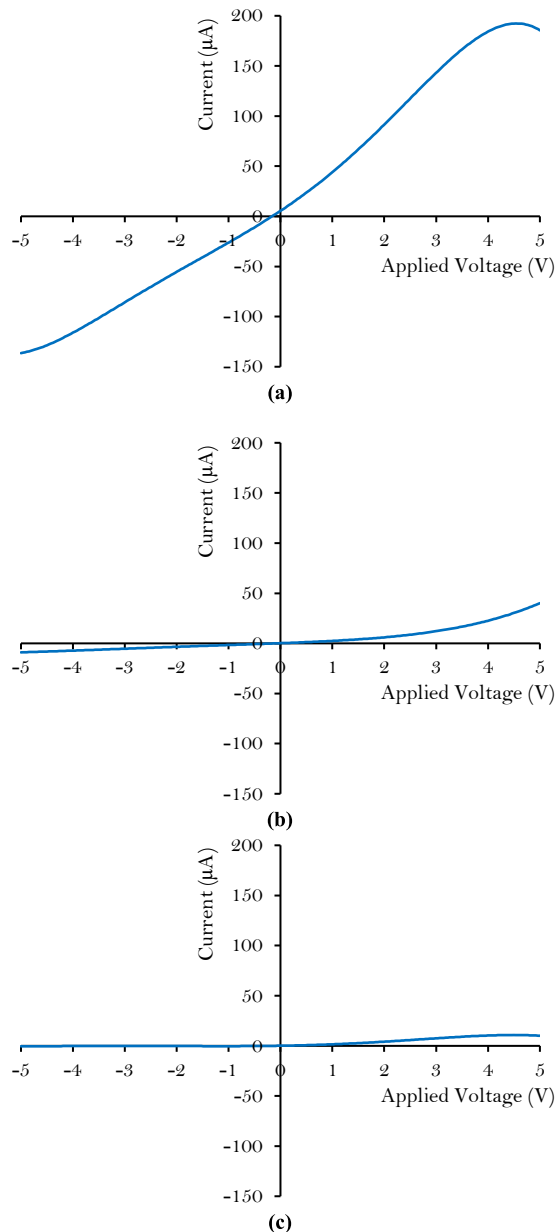


Fig. (1) I-V characteristics of the $\text{Al}_2\text{O}_3/\text{Si}$ structures prepared with different thicknesses of Al_2O_3 layer (a) 200nm, (b) 250nm, and (c) 325nm

Figure (2c) presents a different behavior compared to the first two. Here, the dark current is more substantial, reaching approximately $-135 \mu\text{A}$ at -5.5V . Under illumination, the photocurrent is higher than the dark current, but the difference between

the two curves appears less pronounced in terms of relative increase compared to the first two figures, reaching about $-105 \mu\text{A}$ at -5.5V .

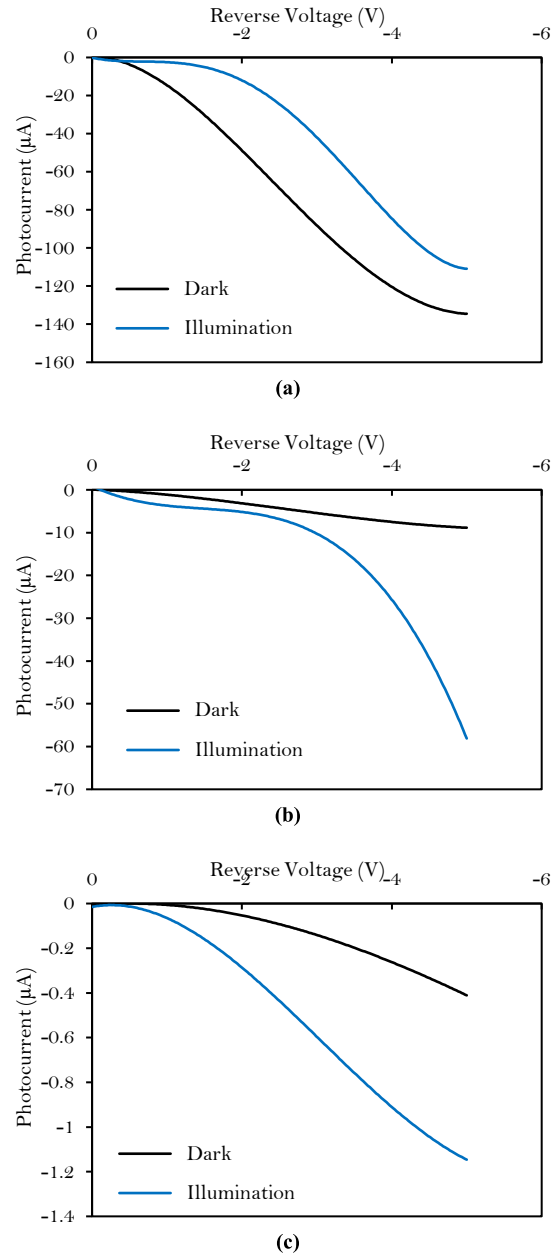


Fig. (2) Variation of photocurrent with applied reverse voltage in dark and under illumination for the $\text{Al}_2\text{O}_3/\text{Si}$ structures prepared with different thicknesses of Al_2O_3 layer (a) 200nm, (b) 250nm, and (c) 325nm

Comparing the three figures, there's a clear variation in the scale of the photocurrent, which suggests differences in the device's photosensitivity or characteristics across samples. The samples of 200 and 250nm Al_2O_3 layer thickness exhibit a much more

pronounced photoresponse, where illumination leads to a significant increase in current from a near-zero dark current. In contrast, the sample with 325nm Al₂O₃ layer thickness shows a higher dark current to begin with, and while illumination still increases the current, the overall shape and magnitude of the curves indicate distinct electrical properties, possibly due to variations in material properties or device architecture.

4. Conclusion

Al₂O₃ thickness critically governs the performance of Al₂O₃/Si structures. A 325 nm layer enhances insulation by reducing leakage current but severely impairs photodetection—lowering photocurrent, responsivity, quantum efficiency, and detectivity. In contrast, thicknesses of 200–250 nm offer an optimal balance, delivering strong photoresponse, high near-infrared sensitivity (peaking at 800–850 nm), and superior detectivity. This underscores a clear trade-off between insulating capability and light-detection efficiency in silicon-based photodetectors.

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Theoretical Analysis of Radiation Dose for Gamma Rays in Tissue Equivalent Materials

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Abstract

In this paper, γ -rays energies at 60, 662, 186, 242, 295, 352, 609, 1120, 1765 keV emitted from radioactive sources (^{124}Am , ^{137}Cs , ^{226}Ra) were used to determinate the radiation dose and attenuation coefficients for samples of different composition prepared from organic compounds (paraffin wax) and sodium chloride. The measurements were made using a gamma ray spectrometer. It is linked to sodium Iodide detector (NaI(Tl)). The obtained results were compared with the ICRU 44 report values. It was found that there is good agreement between these results and that the values of difference is less than 7%. Compared to ICRU 44, this confirms that the materials used in this study are a good alternative for dosimetry and potentially a good alternative material for tissues to make tissue phantoms for the biological tissues studied.

Keywords: Radiation dose; Attenuation coefficients; Gamma radiation; Sodium iodide detector; Exposure rate
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1. Introduction

In the medical, sciences and biological field, study of γ -ray interaction is very important to calculate radiation dose rate received by the organic compounds and distinguish other parameters of interaction for example mass attenuation coefficients in organic tissues for example soft and bone-tissues. The γ -ray energy in keV are very interest in therapy and medical diagnosis as well as in radiation biology. Different materials have been utilized to mimic human-tissues to determine rate radiation dose to patients exposed for high energy radiations. These organic compounds are called tissue-equivalent materials [1–5]. The attenuation of radiation, which usually occurs in tissues, one of most significant studies of gamma radiation in nuclear treatment. Therefore, attenuation coefficients represent the possibility of interaction between radiation and matter. Attenuation of radiation in a substance per unit length is known as the linear attenuation coefficient. Mass attenuation coefficients ($\frac{\mu}{\rho}$) are of great importance through the absorption of radiation by materials which can study some basic atomic parameters such as radiation

dosimetry [6 - 11]. Radiation therapy methods depend on the absorption or scattering of the incident radiation by the body's organs, tissues and bones, and therefore radiology techniques give anatomical images depending on the physical characteristics of the body tissues. Where it was found by studying the differences in tissue patterns to describe genes when exposed to a constant radiation dose to be completely uniform and equal [12-15]. Tissue exposure to high radiation doses is unacceptable for patients with radiotherapy problems, as this can be reduced by good approximation of tissue type and thickness when radiation passes through and careful selection of radiopharmaceutical sources [16, 17]. The exact values of material attenuation coefficients are very important basic parameters in various scientific fields such as nuclear physics and radiological physics [18-20].

2. Theoretical and Methods

The radionuclide efficacy is a measure of the intensity of the radiation emitted during radioactive decay, and is defined in the following equation [21, 22]:

$$A_i = -dN_i / dt = \lambda_i N_i \dots (1)$$

A_i , It is the effectiveness of the isotope of a radioactive source, equal to the number of radioactive decay nuclei dN_i at a given time (dt) and proportional to the number of radioactive nuclei N_i at the moment (t), λ_i is the decay constant. The half-life ($t_{1/2}$) associated with the decay constant is given by the following relationship [23]:

$$t_{1/2} = \ln 2 / \lambda_i \dots (2)$$

and the solution to the equation (1) is given as follows [24]:

$$N_i = N_0 e^{-\lambda_i t} \dots (3)$$

N_0 the number of nuclei at a time ($t=0$) and N_i is the number of nuclei at a time (t). The above equation can be written in terms of radioactivity in the following form [24]:

$$A_i = A_0 e^{-\lambda_i t} \dots (4)$$

A_0 is initial nucleus activity in time ($t=0$) and A_i is final nucleus activity at time (t). The minus sign indicates the fact that radioactivity decreases with time.

When ionizing radiation penetrates a substance, such as the human body, it deposits energy with it. Absorbed energy each unit mass of radiation exposure is called a dose. And the concept of dose may mean (dose absorbed, equivalent dose, equivalent effective dose). The radiative forcing occurs only when transmitted energy from radiation to some material being irradiated, and possibly the radiative effect is different when a certain amount of energy is added to a small mass of matter instead of distributing energy over a large mass. The change in energy absorbed (ΔE) per unit mass (m) called the absorbed radiation dose is measured in (Gray) units, as in the following equation [25]:

$$D = \Delta E / m \dots (5)$$

As for the dose-rate, it represents the radiation dose per unit time (*Gray/h r*).

As in a given material medium, each photon in the beam is either completely removed from the beam by scattering or absorption, and this leads to an exponential weakening of the beam proportional to the thickness of the absorbing medium to the package or not interacting with the physical medium at all. The attenuation of a beam of gamma rays may be the attenuation of its

energy or the attenuation of its intensity along the path through the medium [26].

The dose rate for a symmetric point radioactive source is given by the following relationship [27]:

$$D' = D e^{-\mu x} \dots (6)$$

$$D = \Gamma A_i / d^2 \dots (7)$$

Γ the fixed dose rate and (d) the distance between radiating source and the detector, where the factor $\frac{\Gamma A_i}{d^2}$ is called exposure rate.

Since the rate of radiation dose in units ($\mu Sv/hr$) can be calculated using the following relationship [28]:

$$D = 0.142 \times A_i / d^2 \times \sum_i f \times E_\gamma \quad (8)$$

(f) is ratio of number of gamma-ray emitted with a specific energy of line per (100) decay of the decay of the radioactive isotope and E_γ the energy of incident gamma ray.

When calculating the total radiation dose rate ($D't$) for a radioactive source that contains more than Energy we use the following relationship [28]:

$$D'_t = \sum_i D' \quad (9)$$

Attenuation of Radiation of transmitted by a medium can be describe through Beer-Lambert law [29]:

$$I/I_0 = e^{-(\mu x)} \quad (10)$$

$$\mu = (\ln(I_0/I)/x) \quad (11)$$

$$(I/I_0) = e^{-(\mu/\rho \times \rho x)} \quad (12)$$

$$\mu/\rho = (\ln I_0/I / (\rho x)) \quad (13)$$

I and I_0 is initial intensity of the radiation and the intensity of the attenuated radiation respectively, where x is thickness of absorption material, μ is linear attenuation coefficient in (cm^{-1}), Therefore, from Eq. (11) when dividing it by the density of the samples, we get the mass attenuation coefficient

$$\mu/\rho = ((\ln I_0/I) / \rho x) \quad (14)$$

ρ is density of material.

3. Results and Discussion

The coefficients of attenuation and radiation dose of the equivalent materials for the prepared tissues were found. The results are shown in Tables (1) and (2), and the

difference values between the mass attenuation coefficients and the ICRU-44 [30] was calculated. It was noted that the differences are less than 7%, and this confirms the possibility of using these prepared materials as equivalent materials for tissues as an alternative to smooth and hard tissues that are used in nuclear medicine and radiotherapy.

Table (1) Attenuation coefficients, and radiation dose ($\mu\text{Sv/hr}$) of A and B samples

E keV	6	18	24	29	35	60	66	112	176
$\mu \times 10^{-2}$	2	13	12	11	10	8.2	8	7	5.4
$\mu_m \times 10^{-2}$	1	12	11	10	9	8	7	6	5
$D' \times 10^{-4}$	7	21	22	22	23	23	61	24	25

Table (2) Attenuation coefficients, and radiation dose ($\mu\text{Sv/hr}$) of C and D samples

E keV	6	18	24	29	35	60	66	112	176
$\mu \times 10^{-2}$	4	30	26	24	22	19	18	14	12
$\mu_m \times 10^{-2}$	3	21	18	17	15	14	13	10	8
$D' \times 10^{-4}$	6	21	21	21	22	22	54	231	235

Also, the radiation dose was found for all the prepared samples, and it was noted that the radiation dose decreases with the increase in the concentration of the additive, while the radiation dose increases with the increase in the energy of gamma rays, as well as with the increase in the radioactivity of the radioactive source, as shown in figures (8) and (9). It was found that there is a good agreement between the experimental values and the values of ICRU-44. The study demonstrated the possibility of using these prepared materials as alternative tissue equivalent materials for smooth and hard tissues that are used in nuclear medicine and radiotherapy.

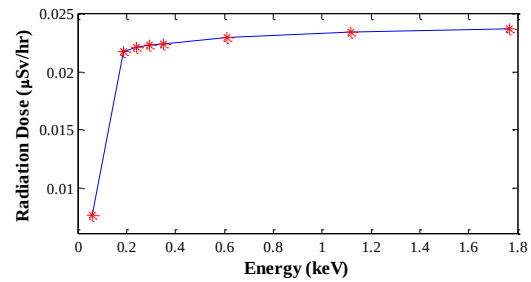


Fig. (8) Radiation dose of A and B samples

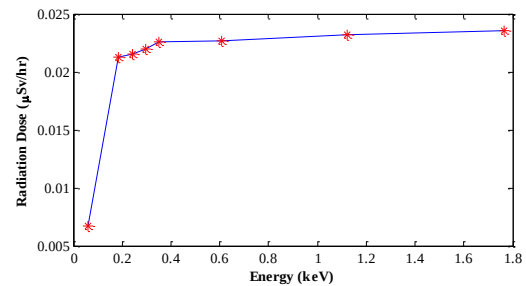


Fig. (9) Radiation dose of C and D samples

4. Conclusion

The values of the mass attenuation coefficients depend on the physical and chemical composition of the atomic elements that make up the sample. It was found that these values of the attenuation coefficients decrease for all samples when the energy of the gamma rays increases. The difference between the obtained values and the practical values is less than 7%. Therefore, these parameters improve our understanding of how the attenuation coefficients change with different atomic number, electronic density, and percentage of additive to organic matter. This study also demonstrates the possibility of using the prepared material to provide tissue equivalents for phantom fabrication.

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Effect of Acidity Environment on Synthesis of $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ by Co-Precipitation Method

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Abstract

$\text{Zn}_{0.5}\text{Ni}_{0.5}\text{Fe}_2\text{O}_4$ nanocomposites have been prepared by a simple co-precipitation method. The prepared samples were characterized by powder x-ray diffraction (XRD) and scanning electron microscopy (SEM) after analysis it found that with increasing the PH value for the nickel-zinc ferret the grain size decrease with increase the concentration of zinc content also it found the morphology of the simple also effected by adding different concentration for pH.

Keywords: Nonmagnetic material; Chemical co-precipitation; Zinc ferrite; Nickel ferrite

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1. Introduction

Nowadays, spinel type magnetic metal oxide nanoparticles (NPs) have attracted significant attention in many areas such as ceramics, semiconductors, sensors and catalytic materials, due to their unique dielectric, magnetic, and optical properties, Nano-crystalline ferrites are materials of great interest from both a scientific and technological standpoint [1-2]. Due to the interaction of quantum, finite-size, surface, and interfacial effects, these magnetic materials serve as the foundation for a very active area of research. New phenomena are occurring at the nanoscale, and these phenomena are the result of this interaction. Spinel ferrite nanoparticles have numerous technical applications in a variety of fields, including hyperthermia, magnetic separation, magnetic resonance imaging, high-density information storage, Ferro fluids, catalysts, drug targeting, and magnetic separation [3]. The critical inquiries in these frameworks are the manner by which these Nano-structures adjust their attractive and electronic properties and how one can exploit those new properties to work on the applications. Subsequently, understanding and controlling the impacts of the nanostructures on the properties of the particles have become progressively significant issues for innovative applications [4].

In the present work, synthesis of ZnFe_2O_4 nanoparticles was carried out by chemical co-precipitation method. Synthesized NiZn -ferrite nanoparticles were characterized by standard characterization techniques to study the structural and morphology of surface.

2. Experimental Work

To prepare the compounds used in work by chemical precipitation method, iron nitrate, zinc nitrate and nickel nitrate were dissolved in (100ml) of distilled water using a magnetic stirrer (Stirrer magnetic) at a temperature of (60°C) and for half an hour in order for the substance to be completely and homogeneously dissolved in distilled water, then all the solutions are mixed in a glass flask at a temperature of (60°C) for half an hour with continuous stirring by means of the magnetic mixer. As for the second stage, (40g) of sodium hydroxide (NaOH) was dissolved in (200 ml) of distilled water in a glass flask with continuous stirring using a magnetic mixer at a temperature of (60°C) for 15 min. Sodium hydroxide solution is used as a precipitating agent and to determine the pH value. As for the third stage, it included mixing all the solutions in a glass flask at a temperature of (60°C) for half an hour with continuous stirring by means of the magnetic mixer. Then we distill the sodium hydroxide solution mixture by a burette slowly over the

solution of the mixture of solutions while continuing the mixing process at a temperature (60°C) until the sodium hydroxide solution is distilled to determine the pH value. After completing the distillation process, the solution will be clear with a pH that we determine. This solution is filtered with filter paper and then washed several times with distilled water to get rid of insoluble nitrates. Then the resulting substance is taken and dried in a drying oven at a temperature (100°C) to obtain a dry moisture-free compound. Then the powder we obtained is calcined at a temperature of (700°C) for 2 hours.

3. Results and Discussion

The ferrite samples were prepared based on the molar concentration and molecular weights by comparing the x-ray diffraction patterns of ferrite after sintering at a temperature of 700°C and in comparison with the standard labels it was found that they are identical to the standard label number (JCPDS 8-324) and as shown in Fig. (1) x-ray diffraction spectrum of $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ with a pH number (pH=1.8, 7, 10) and the appearance of peaks(220), (311), (222), (400), (422), (333), (440), (533) within the angular range (20°-80°) for all the compounds prepared by chemical precipitation method, where the peaks are considered dominant, which refers to the geometric crystal structure of ferrite powder and from Observe the shape of the diffraction spectrum, the appearance of the spin phase of zinc [5-6]. No impurities were found for any other material, which proves that the material has a very high purity.

The morphology and the size distribution of the $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ nanoparticles were determined using SEM. Typical SEM images of NiFe_2O_4 synthesized as for the sample with the structural formula Figure (2) shows the $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ prepared by the method prepared at different pH values, as the results showed that the grain size changes (32-55 nm) and is relatively regular, and this is consistent with the results of X-ray diffraction, as the results showed that the particles of the sample $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ consist of nanoclusters.

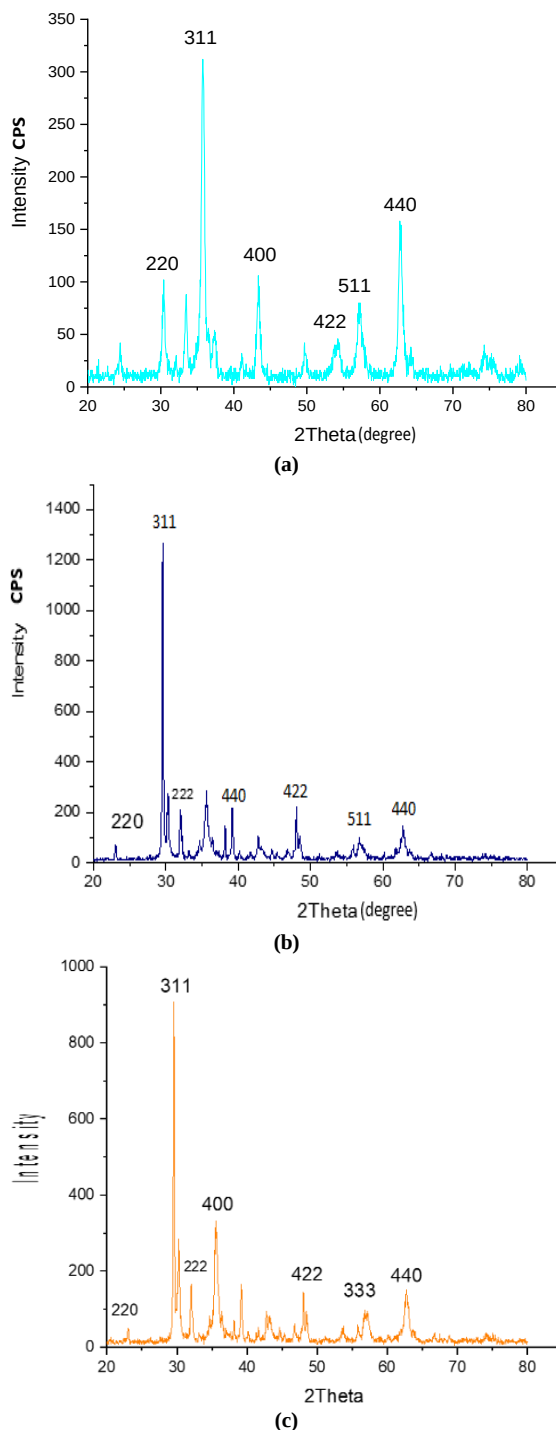


Fig. (1) XRD patterns of $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ at different values of pH (1.8, 7 and 10)

The presence of small particles and the presence of these assemblies is evidence of the presence of crystals free of pores on the resulting surface and also found that they have a strong tendency to stick together and form clumps, due to magnetic interactions between particles of ferrite materials during the

preparation process and this is consistent with what the researcher said [6-8].

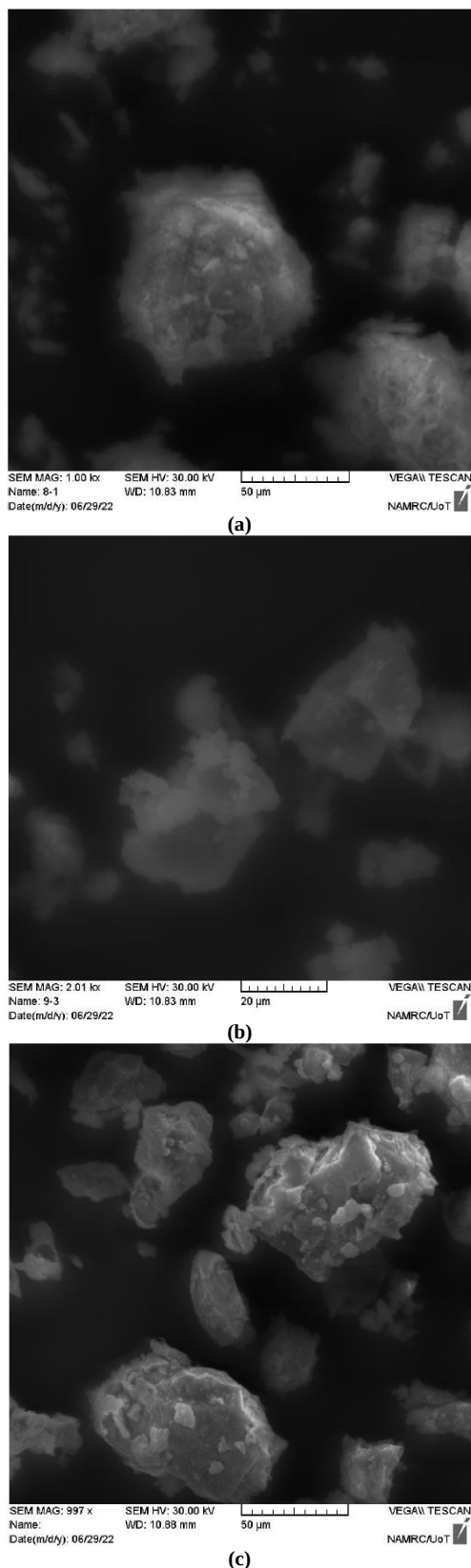


Fig. (2) SEM images of $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ at different values of pH (1.8, 7 and 10)

It was also noted that the nanoparticles are in larger sizes the higher the pH of the solution there are also some voids in the prepared sample and this may be due to the interaction between magnetic nanoparticles and thus these particles grow to some extent to form larger particles at a high pH of the solution. (1.8 to 10). The reason for the increase in the granular size of ferrite materials is due to the fact that magnetic materials tend to agglomerate, which leads to the gathering of particles with each other, which leads to an increase in the surface area of the material. Thus, the granule size increases. We can also justify this increase due to the recrystallization that reduced the amplitude of the lattice constant [9-10].

4. Conclusion

$\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ nanoparticles using Co-precipitation chemical routes were successfully synthesized with an ideal structure. XRD pattern showed the cubic spinel structure of Fd3m space group. Further, observed that the particle size of sample prepared by the co-precipitation method is very small. Thus, it is concluded that the co-precipitation is a better route for the synthesis of fine Zinc ferrite nanoparticles.

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