Verse

قال تعالى:

سورة النجم الآية (٣٩ – ٤٠)

Dedication

I dedicate this work,

To whom my life worth nothing without them; my father and mother.

To the great human being who stood up to her wonderful endowment, without his efforts this research wouldn't become possible; Eng:YASSER AHMED

To my brothers ABOBAKER and MOHAMMED.

To my lovely sisters HUDA and BARAA.

Acknowledgment

At this point, my inner joy is indescribable, in my graduate school career, experienced a lot of things. Time really flies, and in a blink of an eye the journey is coming to a stop. Here, Ｉ first thank my mentor, I know Ｉ am not your best student, or the most trouble to you students, but with your patient guidance, helped me to solve all kinds of difficulties., Ｉ would like to thanks who has been supporting me, encouraging me and saying to me: you have to stand higher. See very far. Thank you for taking care of me, supporting me and worrying about me. Ｉ have so many good memories in the past years.

Finally, I would like to thank my family; who gave me the most precious gift-in good faith, in my life, like a bright star.

Abstract

Today's scientists and engineers are finding a wide variety of ways to deliberately make materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts. However with an increasing awareness of green and clean energy, greener synthesis of nanoparticles represents an advance over other methods because it is simple, cost-effective, and relatively reproducible, and often results in more stable materials. In this work, the green synthesis of zinc oxide nanoparticles is done thermally using the aqueous extract of Tomato as non-toxic and eco-friendly reducing material. The synthesized nanoparticles were characterized Scanning Electron Microscopy (SEM). The calculated average size of the prepared ZnO nanoparticles is found to be in the range between 78.5 to 172.2nm.

المستخلص

يعمد العلماء والمهندسون اليوم لاختراع مجموعة متنوعة من الطرق لصنع المواد عمدًا بالمقياس النانوي للاستفادة من خصائصها المعززة مثل القوة العالية والوزن الخفيف والتحكم المتزايد في طيف الضوء والتفاعل الكيميائي الأكبر من نظرائهم على نطاق واسع. ومع زيادة الوعي بالطاقة الخضراء والنظيفة ، يمثل التحضير الأخضر أو الطبيعي الأكثر مراعاة للبيئة للجسيمات النانوية تقدمًا على الطرق الأخرى لأنه بسيط وفعال من حيث التكلفة وقابل للتكرار نسبيًا ، وغالبًا ما ينتج عنه مواد أكثر استقرارًا. في هذه الورقة ، أبلغنا عن التحضير الأخضر لجسيمات أكسيد الزنك النانوية في وجود الحرارة باستخدام المستخلص المائي للطماطم كمادة مختزلة غير سامة وصديقة للبيئة. تم تشخيص الجسيمات النانوية المُصنَّعة بالماسح المجهري الإلكتروني (SEM). وجد ، أن متوسط الحجم المحسوب لجسيمات اكسيد الزنك النانوية المحضرة يتراوح ما بين (٧٨,٥ - ١٧٢,٢) نانومتر.

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List of Abbreviations

NPs	Nanoparticles
Ph	Power of Hydrogen
ZnO	Zinc Oxide
SEM	Scanning Electron Microscope
NSM	Nanostructured Materials
MO	Metal Oxide
eV	Electronvolt
D	Diameter
HERTM	High-resolution transmission electron microscopy
EDS	Electronic Data Systems
XRD	X-Ray Diffraction

Chapter One

Introduction

1.1 Nanotechnology

Studies on nano-sized particles have been the range for the past 10–15 years. nanotechnology has been facilitating the transformations of traditional food and agriculture sectors, particularly the invention of smart and active packaging, nanosensors, nanopesticides and nanofertilizers (He et al., 2019).

Extremely low power consumption with rapid growth of nanotechnologies .During the last decades, the application of this material in the field of catalysis has also become a substantial research area. While conventional technologies such as chilling and freezing are used to avoid deteriorative processes like autolytic and microbial spoilage of seafood, innovative technologies have also been developed as a response to economic and environmental demands (Özogul et al., 2019).

Since these natural resources on earth are limited and could not be regenerated over a short period of time, therefore human beings in general and scientists/researchers in particular must be able to face these severe energy and environmental problems originating from the traditional energy consumption (Hussain, 2014).

1.2 Green Chemistry

In recent years, the development of efficient green chemistry methods for synthesis of metal nanoparticles has become a major focus of researchers. They have investigated in order to find an eco-friendly technique for production of well-characterized nanoparticles. One of the most considered methods is production of metal nanoparticles using organisms. Among these organism’s plants seem to be the best candidates and they are suitable for large-scale biosynthesis of nanoparticles. Nanoparticles produced by plants are more stable and the rate of synthesis is faster than in the case of microorganisms. Moreover, the nanoparticles are more various in shape and size in comparison with those produced by other organisms. The advantages of using plant and plant derived materials for biosynthesis of metal nanoparticles have interested researchers to investigate mechanisms of metal ions uptake and bioreduction by plants, and to understand the possible mechanism of metal nanoparticle formation in plants. In this work most of the plants used in metal nanoparticle synthesis are shown.

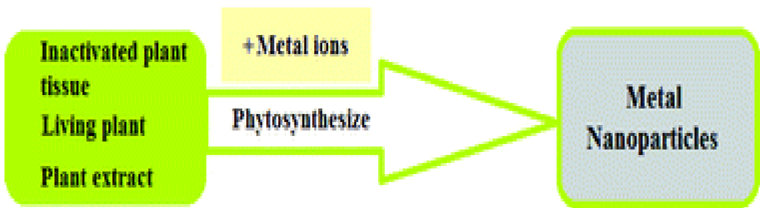

Figure (1.1) Synthesized Nano-Particles Using Green Method

The precepts of green chemistry have been spreading since the mid-1990s, concomitant with advances in nanomaterial synthesis. Recently these two communities have begun to significantly converge. Nanomaterial synthesis groups are developing greener, more sustainable production methods, while nanoparticle application groups are exploring sustainable energy sources and environmental remediation as end goals.

The roles of green chemistry in nanotechnology and nanoscience fields are very significant in the synthesis of diverse nanomaterials Nanotechnology and especially nanomaterials have received much consideration because their structure and properties differ appreciably from those of molecules, atoms, and bulk materials. The synthesis of metal nanoparticles has been widely discussed in the literature due to their distinctive chemical and physical properties, which have many potential purposes.(Shameli et al., 2012)

Herein, we report a green chemistry method for synthesized colloidal zinc oxide nanoparticles (Zn NPs).

1.3 Problem Statement

Green nanotechnology has been described as the development of clean technologies, "to minimize potential environmental and human health risks associated with the manufacture and use of nanotechnology products, and to encourage replacement of existing products with new Nano-products that are more environmentally friendly throughout their lifecycle.

1.4 Aim of Study

The aim of this study is using tomato extract to Prepare zinc oxide nanoparticles.

1.5 Objectives

- Synthesize of Zinc oxide Nano particles using tomato extract.
- Characterization the obtained Nano particles using scanning electron microscope (SEM).

Chapter Two

Literature Review

2.1 Nanotechnology

Over the last few years, nanotechnology is increasingly developing in scientific sector, which has attracted a great deal of interest because of its abundant applications in almost all the areas. Nanomaterials have an enormously wide range of possible applications from nanoscale optics and electronics to nano-biological systems and nano-medicine. However, the study and applications of nanomaterials rely powerfully on the effective synthesis of nanomaterials. In addition, progress of simple and economical impending for the preparation of nanomaterials is vital for the applications of nanomaterials and the progress of nanotechnology.(Ganachari et al., 2017)

Survey that done in America expected benefits of nanotechnology to be more prevalent than risks, and they reported feeling hopeful about nanotechnology rather than worried. Their most preferred potential benefit of nanotechnology is “new and better ways to detect and treat human diseases,” and they identified “losing personal privacy to tiny new surveillance devices” as the most important potential risk to avoid (Macoubrie, 2004). A wide range of nanostructured materials (NSMs), from inorganic metal, metal oxides, and their nanocomposites to nano-organic materials with bioactive agents, has been applied to the food industry (Bajpai et al., 2018). Numerous novel nanomaterials have been developed for improving food quality and safety, crop growth, and monitoring environmental conditions (Özogul et al., 2019). In medicine Nanotechnology has a great potential to affect the treatment of neurological disorders, mainly Alzheimer’s disease (Saeedi et al., 2019). Nanotechnology also is one of most effective ways to remove heavy metal ions (Liu et al., 2019).

2.2 Metal oxides

Metal oxides are crystalline solids that contain a metal cation and an oxide anion. They typically react with water to form bases or with acids to form salts. What would metal oxides do? To answer this question, we will have to focus on the nature of the metal–oxygen bond as it can vary between being ionic, highly covalent, or metallic; because of unique nature of their outer d-electrons.

2.2.1 Metal Oxide Nano-Particles and its Applications

Studies on nano-sized particles have been the range for the past 10–15 years. With rapid growth of metal oxide nanotechnologies during the last decades, the application of this material in the field of catalysis has become a substantial research area. In the past decades, the utilization of transition metal oxide nanoparticle catalysts for industrial application in the synthesis of important chemical intermediates has been investigated by industrial and academic communities. Compared to other catalysts, one of the outstanding properties of metal oxide nanoparticles in catalysis is represented by the high selectivity which allows discrimination within chemical groups and geometrical positions, favoring high yields of the desired product (Chaturvedi et al., 2012). We can see that clearly in synthesized MO nanoparticles were used as catalysts for the reduction of aromatic aldehydes. The reduction was done at mild reaction conditions using ammonium formate as a green hydrogen donor and the corresponding alcohols were obtained in 2–24 h with excellent yields.(Muthuvinothini and Stella, 2019) metal oxide nanoparticle are used also for detecting heavy metal ions (Cheng et al., 2019).

The thermal conductivity of metal oxide can prove as a best additive for the higher thermal conductivity enhancement at very low concentrations for various instruments and device cooling applications(Parashar et al., 2014).

Also there is a study shows the anti-inflammatory activities of various metal and metal oxide nanoparticles synthesized by green routes (Agarwal et al., 2019).

2.3 Zinc Oxide

Recently (ZnO) has attracted much attention within scientific community as a future material with a wide band gap of 3.4eV and a large exciton bending energy of 60 me V at room temperature ZnO will be important in blue and ultra-violate optical devices. Zinc oxide in the form of Nano-scale materials can be regarded as one of the most important semiconductor oxides at present.

ZnO as mineral zincite is present in the earth's crust and has been extensively used as an additive in different products such as rubber, ceramics, pigments, cement, sealants, plastic and paint , ZnO is also an attractive material for biomedical applications, because it is a bio-safe material (Hussain, 2014) ,like using synthesized ZnO Nano particles for the removal of phenol from synthetic and industrial wastewater (Sridar et al., 2018).

Zinc oxide (ZnO) nanostructures are the forefront of research due to their unique properties and wide applications. It has many technological applications, because of its exceptional optical and electrical properties, such as thin-film transistors, gas sensors, transparent conductors, biomedical and piezoelectric applications.

2.3.1 Characteristics of ZnO

Some of the basic characteristics of ZnO have also been highlighted in Table:(2.1)

Table (2.1) Basic Characteristics of ZnO

Property	Value
Molecular Mass	81.37 g/mol
Crystal Structure	Wurtzite
Density	5.606 g/cm3
Melting Point	1975°C
Boiling Point	2360°C
Solubility in water	0.16 g/100 mL
Thermal Conductivity	0.6 ; 1-1.2
Energy gap	3.37 eV
Exciton binding energy	60 mV
Electron effective mass	0.24m0
Hole effective mass	0.59m0
Static dielectric constant	8.656
Bulk effective piezoelectric	constant 9.9pm/V
Bulk hardness; H(GPa)	5.0±0.1

2.3.1.1 Piezoelectric properties

The polarity present in the ZnO crystal is because of its tetrahedral structure in which oppositely charged ions produce positively charged zinc and negatively charged oxygen polar surfaces, that creates conventional dipole moment and spontaneous polarization along the c-axis. Therefore one can say that piezoelectricity initiates from the polarization of the tetrahedrally coordinated unit (Hussain, 2014) .

2.3.1.2 Optical properties

ZnO holds some exceptional properties which make ZnO an excellent luminescent material. These properties include direct and wide band gap, large excitons binding energy and deep level defect emission. As direct band gap is good for short wavelength photonics, high excitons binding energy permits effective excitonic emission at ambient temperature and deep level defect emission is responsible for covering the whole visible region beside ultra violet emission(Hussain, 2014)

2.3.1.3 Electrical properties

It is very much essential to realize the electrical properties of ZnO nanostructures for different applications especially in electronics. It is believed that current transport properties have been strongly affected by the concentration of intrinsic defects. It is considered that oxygen vacancies and zinc interstitials are responsible for the n-type electrical behavior of un-doped ZnO (Hussain, 2014).

2.4 Synthesis Techniques for the Preparation of Nanomaterials

How to get at nano scale?

There are two general approaches to the synthesis of nanomaterials and the fabrication of nanostructures.

2.4.1 Bottom-up approach

These approaches include the miniaturization of materials components (up to atomic level) with further self-assembly process leading to the nanostructures. During self-assembly the physical forces operating at nanoscale are used to combine basic units into larger stable structures. Many of these techniques are still under development or are just beginning to be used for commercial production of Nano powders and some of the well-known bottom–up techniques reported for the preparation of luminescent nanoparticles. Examples of such techniques are shown in figure (2.1).

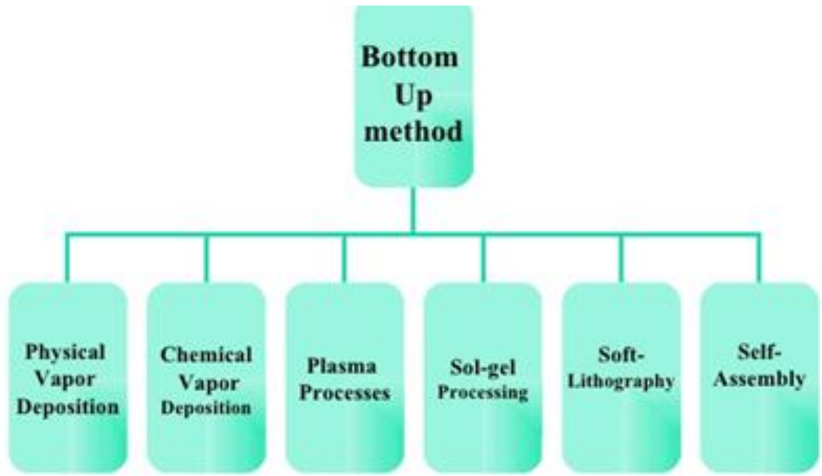

Figure (2.1) Types of bottom up method

2.4.2 Top-down approach

These approaches use larger (macroscopic) initial structures, which can be externally-controlled in the processing of nanostructures.

Top-down approaches are inherently simpler and depend either on removal or division of bulk material or on miniaturization of bulk fabrication processes to produce the desired structure with appropriate properties. The biggest problem with the top-down approach is the imperfection of surface structure. For example, nanowires made by lithography are not smooth and may contain a lot of impurities and structural defects on its surface. Examples of such techniques are shown in figure (2.2).

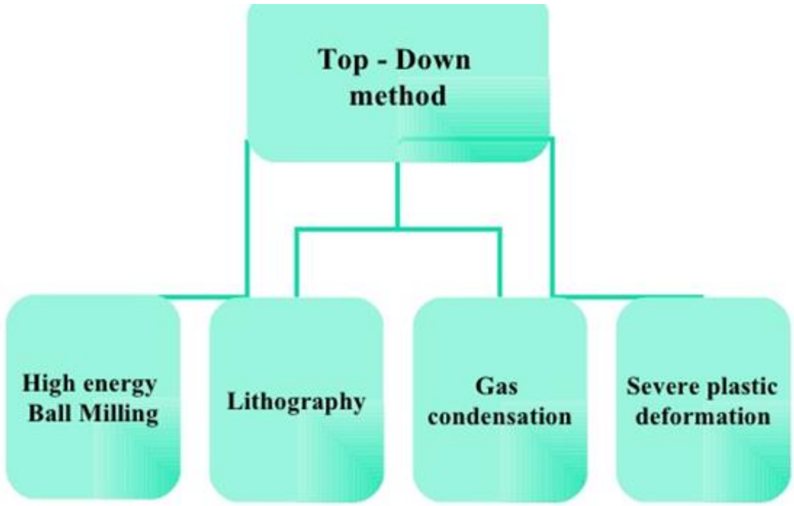

Figure (2.2) Types of Top Down Method

2.5 Green method and Chemical method

Green synthesis is an emerging area in the field of bio nanotechnology and provides economic and environmental benefits as an alternative chemical and physical methods. Many researchers have reported the synthesis of metal oxide nanoparticles from plant extracts as shown below and presented good results.

ZnO NPs in mass level, using tomato extract by both thermal method and under microwave irradiation using different power.(Sutradhar and Saha, 2015) The synthesized ZnO NPs have good crystalline and are of high purity.

The biological synthesis using plant extracts is performed using compounds, which are extracted from different parts of the plant such as leaves, roots, stem, fruit and flowers. Some of the plant extracts tend to have complex phytochemical compounds that act as reducing and capping agent in the synthesis process such as phenol, alcohol, terpenes, saponins and protein(Mohd Yusof et al., 2019)

There was study tell that The antimicrobial effect of ZnO nanoparticles synthesized by the green method using *Juglans Regia* leaf extract was more effective .(Darvishi et al., 2019)

Nanostructured materials have a larger percentage of atoms at their surface which lead to high surface reactivity. Thus, nanomaterials have witnessed recently significant importance in the basic and applied sciences as well as in bio nanotechnology. So Antibacterial activity of zinc oxide nanoparticles (ZnO-NPs) has received significant interest worldwide particularly by the implementation of nanotechnology to synthesize particles in the nanometer region Many microorganisms exist in the range from hundreds of nanometers to tens of micrometers. ZnO-NPs exhibit attractive antibacterial properties due to increased specific surface area as the reduced particle size leading to enhanced particle surface reactivity. ZnO is a bio-safe material that possesses photo-oxidizing and photocatalysis impacts on chemical and biological species.

The green ZnO NPs were synthesized using plant leaf extract (Aloe barbadensis Mill). Their formation was validated using a number of optical spectroscopic and electron microscopic techniques. The particle size of green ZnO NPs averaged as 35 nm which was far smaller than that prepared by conventional chemical methods for comparison purpose (e.g., 48 nm). Zinc oxide (ZnO) nanoparticles (NPs) are well-known for their versatile functionalities.

ZnO NPs prepared by both green and conventional methods were compared in various respects. The results confirmed the great potential of green ZnO NPs as a nano-fertilizer. As such, the potential of green synthesized ZnO NPs has been recognized as a nano-based nutrient source for agricultural applications (Singh et al., 2019).

Synthesis of ZnO nanoparticles by a green process via Agathosma betulina leaves' extract. It was used as an effective reduction/oxidizing agent. Pure ZnO nanoparticles were confirmed via HRTEM, EDS, XRD (Thema et al., 2015). Nanosize particles of zinc oxide have gained much attention due to several applications which includes bacterial inhibition. The below studies evaluate zinc oxide properties synthesized using reduction (chemical) and bio-reduction (green) processes and their corresponding inhibition potentials. The antimicrobial activity property of the nanoparticles was tested against Pseudomonas aeruginosa, Salmonella typhi and Shigella dysenteriae. The degree of susceptibility of ZnO nanoparticles was higher in the bio-reduction process than chemically synthesized for selected microorganisms. A sustainable pathway for development of bio-antibiotic is presented that how clearly in synthesis of zincoxide nanoparticles employing aqueous flower extract of *Nyctanthes arbor-tristis*. Flower extract was used as the biological reduction agent for synthesizing zinc oxide nanoparticles from zinc acetate dihydrate and it was used as antifungal (Jamdagni et al., 2018).

Another example synthesized ZnO nanoparticles with quartzite hexagonal structure using green synthesis. Method is simple, novel, nontoxic and cost effective and environment friendly. A current study has clearly demonstrated that the particle size variations and surface area to volume ratios of ZnO NPS are responsible for significant higher antibacterial activities. Further, the investigation suggests that ZnO NPs has the potential applications for various medical and industrial fields so, that the investigation is so useful and helpful to the scientific communities.(Ramesh et al., 2015)

In recent times, green nanotechnology is a relative and multidisciplinary field that has emerged as a rapidly developing research area(Saratale et al., 2018) . ZnONPs in mass level, using tomato extract by both thermal method and under microwave irradiation using different power the synthesized ZnONPs have good crystallinity and are of high purity (Sutradhar and Saha, 2015) .

Chapter Three

Materials and methods

3.1 Materials

The tomatoes were purchased from the central market (Khartoum). After cutting and squeezing them, they were filtered using medium-sized low-purity filter papers. After adding the rubber solution to the zinc nitrate solution (HDC production) the separation formed using the Fixed Angle General Purpose Centrifuge was separated. The sample was dried In a Dogmatic Drying oven. The sample was weighed and examined using Scanning Electron Microscope.

3.2 Methods

3.2.1 Tomato Extracts

The tomatoes were brought from the central market (Khartoum). They were thoroughly washed with distilled water, their skin was removed and then squeezed and filtered using filters papers (Grade 1).

The highly purified filtrate was heated up to 30 ° C for 30 minutes by water path .

3.2.2 Zinc Nitrate Solution

20g of zinc nitrate hex hydrate ($Zn(NO_3)_2 . 6H_2O$) was dissolved in a distilled water until the morality becomes 1.3 M.

3.2.3 Synthesis of ZnO Nanoparticles

When exposing the solution resulting from mixing tomato juice and nitrate solution (3:1) to microwave waves for 5 min, the color change is observed to yellow-orange with no precipitate. Microwave irradiation accelerated the synthesis but the yield of the nanoparticles was very poor.

Therefore, exposure to direct heat or using a water bath showed positive results. So the nitrate solution was added to the tomato extract (1:3) [Sutradhar, 2016 #31].

The final solution was put for one hour in a water path at 80 °C (slowly shake and stir) after that an absolute alcohol (potassium hydroxide**)** was added drop by drop (2-3) until the pH become 10 (pH papers) then a collide was observed; left 24 hours at room temperature.

The colloid was separated using centrifugation (4000 rpm, VWR® company, Digital and dimension 11 x 14.3 x 10.4) as is shown in figure (3.1) after washed it three times by water and absolute alcohol. The sample was dried by oven (NL Scientific Instruments Sdn Bhd company, model number NL 1017 X / 007 & 008) as is shown in figure (3.2)   at 200 °C. getting 1.07 g of participate.

Figure (3.1) Fixed Angle General Purpose Centrifuge

Figure (3.2) Digimatic Drying Oven

3.3 Characterization

Nanoparticles are characterized for various purposes, including Nano toxicology studies and exposure assessment in workplaces to assess their health and safety hazards, as well as manufacturing process control There is a wide range of instrumentation to measure these properties, including microscopy and spectroscopy methods as well as particle counters. Microscopy methods generate images of individual nanoparticles to characterize their shape, size, and location.

3.3.1 Scanning Electron Microscope (SEM)

The sample was examined by a scanning electron microscope (SEM) as is shown in figure (3.3). A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.

Figure (3.3) Scanning Electron Microscope (SEM)

Chapter Four

Results and discussion

4.1 Results

When adding the tomato solution to the nitrate solution, the color was yellow. When the heating started, there was a slight change in color from yellow to yellow-orange, which indicated the beginning of the formation of nanoparticles.

The precipitate obtained after separation and drying is yellowish-white.

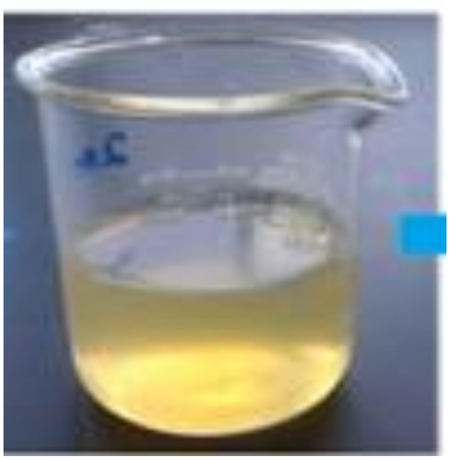

Figure (4.2 ） zinc oxide Nano particles _day 1

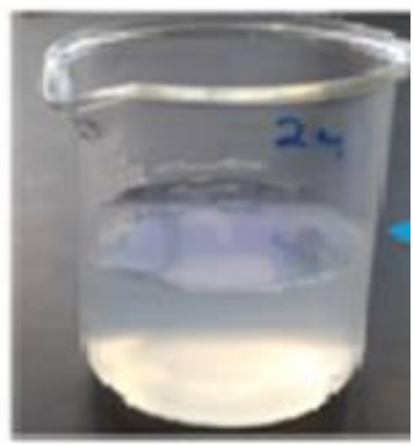

Figure (4.1 ） zinc oxide nanoparticles_ after week

Image using a device Scanning Electron Microscope (SEM) showing three different sectors of the sample (Spectrum1, 4 and 6)

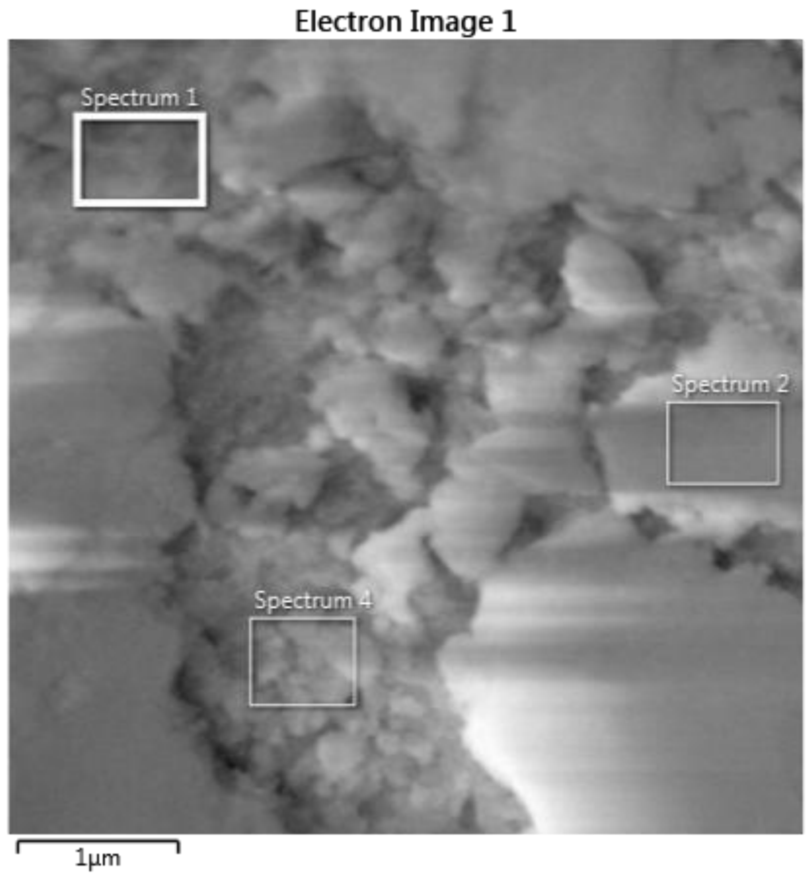

Figure (4.3) sectors of the sample (Spectrum1, 4 and 6)

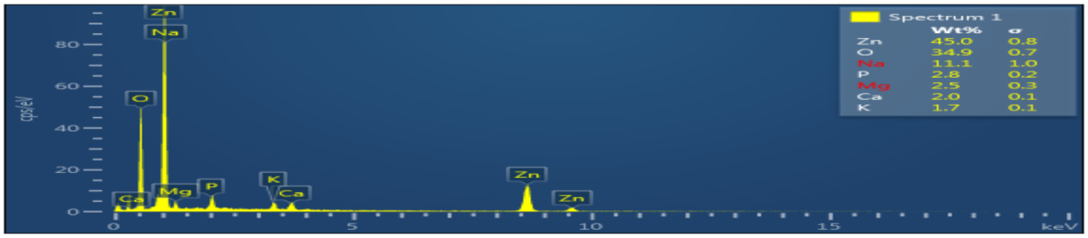

Figure (4.4) The Percentage of Minerals in the Spectrum one

The figure shows the percentage of minerals in the Spectrum one by weight, showing that the percentage of zinc and oxide is higher than the rest of the other elements

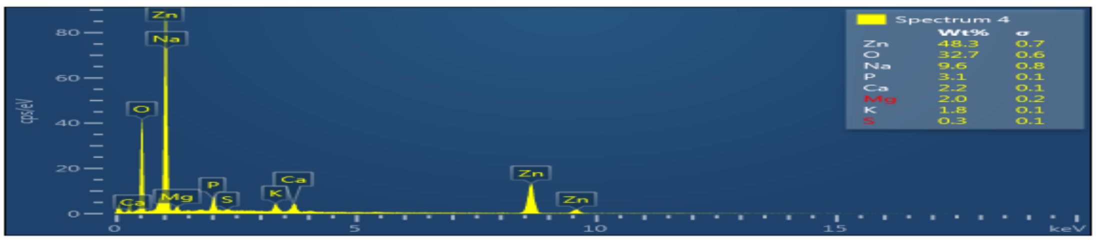

Figure (4.5) The Percentage of Minerals in the Spectrum four

The figure shows the percentage of minerals in the Spectrum four by weight, showing that the percentage of zinc and oxide is higher than the rest of the other elements

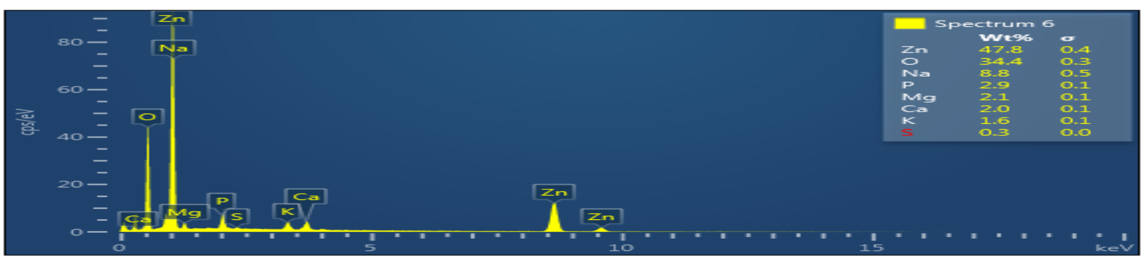

Figure (4.6) The Percentage of Minerals in the Spectrum six

The figure shows the percentage of minerals in the Spectrum six by weight, showing that the percentage of zinc and oxide is higher than the rest of the other elements

In figures below we can see different nanoparticles diameter. The particle size in the three sectors ranges between (172-78.5) D. The average size of nanoparticles 129.6 D

The figure below Shows Three Different Diameters of Nano-Particles (129.57-161.79-172.25) D in Nano-Scale.

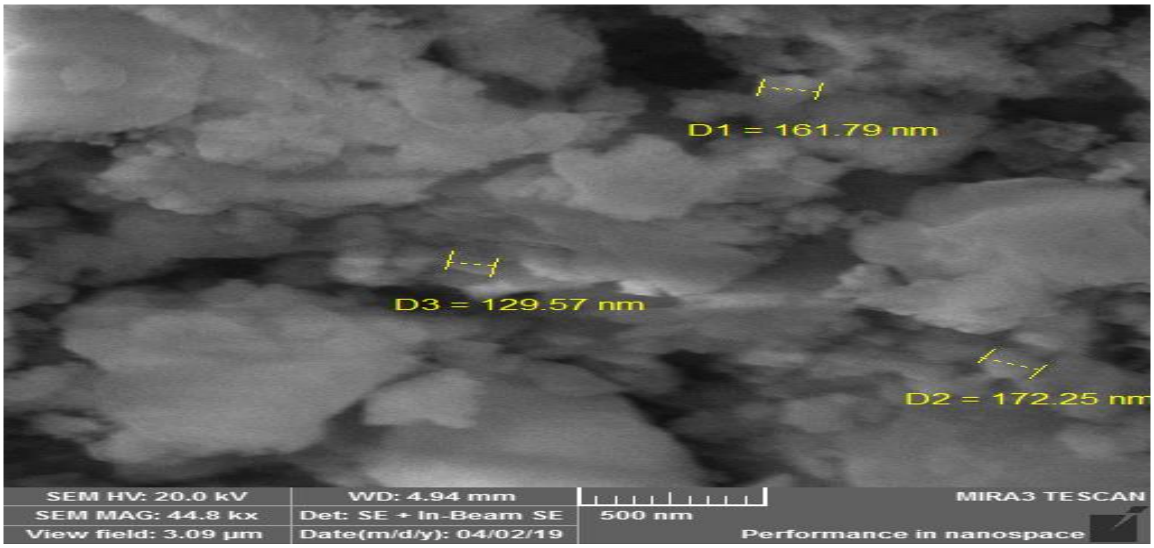

Figure (4.7) Diameters of Nano-Particles

The figure Shows Three Different Diameters of Nano-Particles (169.79-98.90-96.68-78.51) D in Nano-Scale.

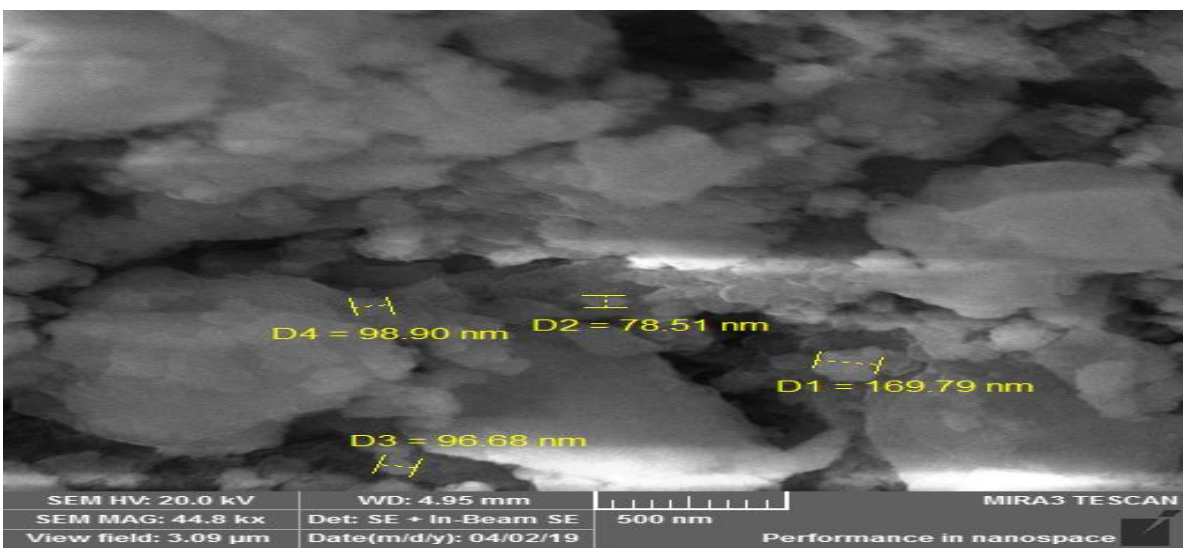

Figure (4.8) Diameters of Nano-Particles

4.2 Discussion

The tomato extract was used as reducing as well as stabilizing agent for the synthesis of ZnO NPs because of **Ascorbic Acid.**

Ascorbic acid is one form of vitamin C. It is a naturally occurring organic compound with antioxidant properties, although is commonly used as an antioxidant food additive. It can be oxidized by one electron to a radical state or doubly oxidized to the stable form called dehydroascorbic acid as is shown in figure (4.11). Because Ascorbic Acid is easily oxidized, it is used as a reductant in photographic developer solutions and as a preservative.

Also it's dissolves well in water to give mildly acidic solutions. It is a mild reducing agent. The redox reaction is accelerated by the presence of metal ions and light.

In order to optimize the reaction conditions and to get good yield of products, the synthesis have been carried out thermally.

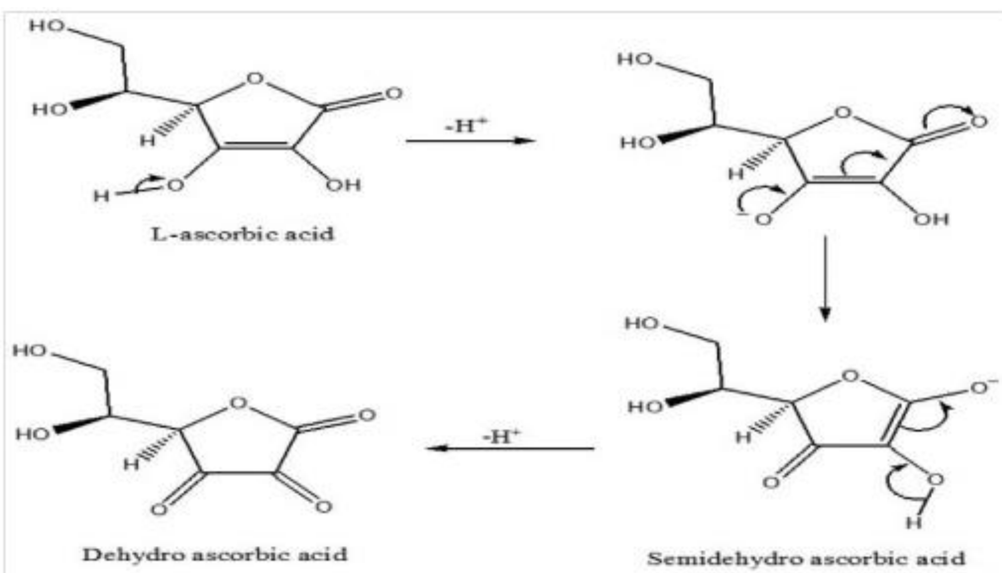

Figure (4.9) Ascorbic Acid Oxidation

If general heating is used (like here) the decomposition is relatively slow producing small amount of nuclei (which is very small nanocrystals) for longer durations. These will self-assemble and grow in to bigger particles due to continue supply of growth materials. This is the reason why bigger particles of ZnO are expected.

In very simple terms, Zinc Nitrate in this reaction system donates Zinc and tomato donates Oxygen to make Zinc Oxide (ZnO). Zinc Nitrate is a salt, and when added in to the water it dissociates in to Zinc (II) ion and Nitrate ion.

Tomato (**Ascorbic Acid)** however, is not salt and simply gets dissolved in the solution and float around. When a small amount of potassium hydroxide is added, hydroxyl groups in the solution shoot up. These hydroxyl groups will react with Zinc(II) ion to make Zinc hydroxide ($Zn(OH)_2$). This is the white precipitate we observed when we add a few drops of sodium hydroxide into the solution. When the solution is subjected to heat, it heats up rapidly and makes things even more interesting. First, Zinc hydroxide will be converted into Zinc oxide and first clusters of ZnO nanoparticles are born. Second the redox reaction is accelerated by the presence of metal ions and light here **Ascorbic Acid work again** with Zinc(II) ion.

When we left the solution a week the color of it become yellowish although it was yellow-orange; we returned that for photocatalytic activity. One of the most interesting Zinc oxide properties is photocatalytic activity. Zinc oxide nanoparticles can absorb UV light from the sunlight or from another light source to produce electrons and holes in its structure. These electrons and holes, migrate into the surface of the particles and react with water and oxygen in the surroundings of the nanoparticles to make highly unstable radicals. These radicals will then go and destroy any impurities like organic stains, dyes, bacteria, and toxic organic substances.

You can demonstrate the photocatalytic activity of the prepared nanoparticles simply by adding an organic stain like a dye to the diluted ZnO nanoparticles dispersion made according to the above method and keep it under sunlight. You can see that the color intensity of the dye in the Zinc oxide nanoparticle dispersion slowly reduces with the time and completely disappear subsequently.

Chapter Five

5.1 Conclusion

In this work, green chemistry has been used for the synthesis of ZnO NPs and were characterized by SEM. A facile approach has been reported using tomato extract, acting as reducing agent for the synthesis of ZnO NPs. This eliminated the need of toxic chemicals for the synthesis of nanoparticles. Besides, good reproducibility of these nanoparticles, without the use of any additional capping agent or stabilizer. The synthesis has been done by thermal method using the water path and the calculated average size of the prepared ZnO nanoparticles is found to be between (78.5_129.6) nm. These ZnO nanoparticles can be used in different industrial applications.

5.2 Recommendation

- It is better to use other heating sources to prevent bigger particles of ZnO nanoparticles.
- Tomato extract is weak oxidizer so it’s impractical in the case of mass production and the estimated time to form Zinc Oxide nanoparticles is relatively long without using catalysts.
- Eliminated the need of toxic chemicals for the synthesis of nanoparticles and the materials are not costly and available.

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