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SYNTHESIS AND CHARACTERIZATION OF SILVER NANOPARTICLES BY THERMAL TREATMENT METHOD

LEILA GHARIBSHAHI

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By

LEILA GHARIBSHAHI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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May 2017

Chairman: **Professor Elias Saion, PhD**
Faculty: **Science**

Silver nanoparticles have many technological applications, for instance in biosensing, photonics, electronics, catalysis and antimicrobial applications. Various methods of synthesizing silver nanoparticles by using inorganic salts as metal precursors have been reported which are mostly complicated in preparation procedure, difficult to attain pure particles, and the methods produced toxic by-products that may harm the environment. In this study, a simple thermal treatment method was employed and successfully produced pure silver nanoparticles. An aqueous solution containing silver nitrate as a metal precursor and polyvinyl pyrrolidone (PVP) as capping agent, which was dissolved in deionized water at the room temperature, were prepared. This solution was dried at 80˚C for 24 h to form brown colored transparent solid remained before it was crushed and ground in a mortar to form powder before calcination at 400, 500, 600, 700, and 800˚C in the oxygen and nitrogen atmosphere for 3 h in succession to decompose organic matters and crystallized the silver nanoparticles.

The Fourier transforms inferred spectroscopy (FT-IR) and the corresponding peaks of silver, which observed in the EDX analysis of the sample, confirmed the formation of pure silver nanoparticles. The silver nanoparticles have a cubic structure determined from the XRD spectra. The average particle size determined from a prominent XRD peak by the Scherer's formula showed that the change in particle size was in a good agreement with the particle size determined by TEM images. The spherical silver nanoparticles have uniform morphology and particle size distribution. When the sample containing 50 mg metal precursor and 2% PVP calcined at 400, 500, 600, 700, and 800℃, the particles size were 7.88, 5.57, 4.61, 3.75, and 3.29 nm respectively. The electrostatic repulsive force and thermal vibration are the main factors that silver nanoparticles become smaller not larger at higher calcination temperatures. At calcination temperature 600˚C, the particles size decreased at 4.61, 2.92, and 2.49 nm when varied the PVP concentration at 2%, 3%, and 4% respectively and the size

increased at 2.93, 3.73, and 4.61 nm when varied the silver concentration at 30, 40, and 50 mg respectively.

The optical properties of silver nanoparticles were measured by means of UV-visible absorption spectrophotometer, which revealed the absorption peaks shifted between 407 and 450 nm depends on the calcination temperatures, PVP and silver nitrate concentrations. The conduction band energy of silver nanoparticles was calculated from the absorption peaks and was found the conduction band decreased with increasing particle size of the silver nanoparticles. Increasing the calcination temperature from 400˚C to 800˚C, the conduction bands were 2.75, 2.81, 2.83, 2.95, and 3.94 eV for the particle size at 7.88, 5.57, 4.61, 3.75, and 3.29 nm, respectively. The conduction band increased with decreasing particle size due to weaker electrical attraction between conduction electrons and positively ionic core as the number of atoms or protons to form the smaller particle is fewer. By varying the PVP concentration from 2% to 4%, the conduction bands were 2.83, 2.88, and 2.94 eV for the particle size at 4.61, 2.92, and 2.49 nm, respectively. The conduction band due to change in precursor concentration at 30, 40, and 50 mg silver nitrate were 2.94, 2.92, and 2.83 eV for the particle size at 2.93, 3.73, and 4.61 nm.

Therefore, it was concluded that modified thermal treatment method is a proper method to produce pure silver nanoparticles in which, the size and conduction band energy of produced silver nanoparticles can be controlled by controlling the calcination temperature, PVP concentration, and metal precursor concentration. The silver nanoparticles' size decreases and the conduction band energy increases by increasing the calcination temperature and PVP concentration and by decreasing metal precursor concentration. The thermal vibration of silver nanoparticles increases by increasing the calcination temperature and since electrons surround silver nanoparticles, therefore, the electrostatic repulsive force between the metal particles and the thermal vibration of nanoparticles are the main factors of size decreasing at higher calcination temperature. Since the size decreases the number of atoms or protons, which form the particle decrease, therefore, the conduction band energy increases by increasing the calcination temperature due to the weaker electrical attraction between conduction electrons and positively ionic core of nanoparticle.

It was also found that the nanoparticles' size decreases by increasing the PVP concentration due to increasing the capping ability of PVP to stabilize the silver atoms and ions strongly and therefore reduce the agglomeration speed. Since the size decreases, the numbers of atoms or protons, which compose the nanoparticle decrease, therefore, the electrostatic attraction between conduction electrons and the positively ionic core of nanoparticle becomes weaker and the conduction band energy increase by increasing the PVP concentration.

It was concluded that the nanoparticles' size increases by increasing the silver nitrate concentration due to increasing Ag^+ ions and the agglomeration speed in the samples according to decreasing the capping ability of PVP to stabilize the silver atoms and ions strongly. Since the size increases, the numbers of atoms or protons, which compose the nanoparticle increase, therefore, the electrostatic attraction between conduction electrons and the positively ionic core of nanoparticle becomes stronger and the conduction band energy decrease by increasing the silver nitrate concentration.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SINTESIS DAN PENCIRIAN NANOPARTIKEL AGENTAM DENGAN KAEDAH RAWATAN TERMA

Oleh

LEILA GHARIBSHAHI

Mei 2017

Pengerusi : Profesor Elias Saion, PhD
Fakulti : Sains

Nanopartikel agentam mempunyai banyak aplikasi teknologi, misalnya dalam penderiaan bio, fotonik, elektronik, pemangkinan dan aplikasi anti-mikrob. Pelbagai kaedah sintesis nanopartikel agentam dengan menggunakan garam bukan organik sebagai prekursor logam telah dilaporkan yang kebanyakannya adalah rumit dalam prosedur penyediaan, sukar untuk mencapai zarah tulen, dan kaedahnya menghasilkan produk asing toksik yang boleh memudaratkan alam sekitar. Dalam kajian ini, kaedah mudah rawatan digunakan dan berjaya menghasilkan nanopartikel agentam tulin. Larutan akueus yang mengandungi agentam nitrat sebagai pelopor logam dan polyvinyl pyrrolidone (PVP) sebagai ejen pembalut telah dilarutkan dalam air ternyahion pada suhu bilik dan kering pada 80˚ C selama 24 jam untuk membentuk pepejal coklat berwarna lutsinar sebelum ia dihancurkan dan digilis di mortar untuk membentuk serbuk sebelum ia dikalsinan pada 400, 500, 600, 700, dan 800˚ C dalam oksigen dan nitrogen atmosfera selama 3 jam berturut-turut untuk menguraikan bahan organik dan menghablurkan nanopartikel agentam.

Spektroskopi tranformasi Fourier inframerah (FT-IR) dan puncak yang sepadan agentam, yang diperhatikan dalam analisis EDX sampel itu, mengesahkan pembentukan nanopartikel agentam tulin. Nanopartikel agentam mempunyai struktur padu ditentukan dari spektrum XRD itu. Saiz zarah purata ditentukan dari puncak XRD dengan formula Scherer menunjukkan bahawa perubahan dalam saiz zarah adalah setuju dengan saiz zarah yang ditentukan oleh imej TEM. Nanopartikel agentam sfera mempunyai morfologi seragam dan taburan saiz zarah. Apabila sampel mengandungi 50 mg pelopor logam dan 2% PVP dikalsinan pada 400, 500, 600, 700, dan 800 C, saiz zarah yang masing-masing 7.88, 5.57, 4.61, 3.75, dan 3.29 nm. Daya tolakan elektrostatik dan getaran haba adalah faktor utama yang menjadikan nanopartikel agentam lebih kecil tidak lebih besar pada suhu pengkalsinan yang lebih tinggi. Pada suhu pengkalsinan 600˚ C, saiz zarah yang menurun pada 4.61, 2.92, dan 2.49 nm

apabila kepekatan PVP diubah masing-masing pada 2%, 3%, dan 4% dan peningkatan saiz pada 2.93, 3.73, dan 4.61 nm apabila kepekatan agentam diubah pada 30, 40, dan masing-masing 50 mg.

Ciri-ciri optik nanopartikel agentam diukur menggunakan spektrofotometer penyerapan UV-sinar tampak, yang mendedahkan puncak penyerapan beralih antara 407 dan 450 nm bergantung kepada suhu pengkalsinan dan kepekatan agentam nitrat dan PVP. Jalur konduksi tenaga nanopartikel agentam dikira dari puncak penyerapan dan mendapati jalur konduksi menurun dengan peningkatan saiz zarah nanopartikel agentam. Peningkatan suhu pengkalsinan dari $400^{\circ}C$ hingga $800^{\circ}C$, jalur konduksi adalah 2.75, 2.81, 2.83, 2.95, dan 3.94 eV untuk saiz zarah pada 7.88, 5.57, 4.61, 3.75, dan 3.29 nm, masing-masing. The jalur konduksi meningkat dengan mengurangkan saiz zarah disebabkan tarikan elektrik lemah antara elektron konduksi dan teras positif ionik sepadan dengan bilangan atom atau bilangan proton untuk membentuk zarah adalah lebih kecil. Dengan mengubah kepekatan PVP dari 2% hingga 4%, jalur konduksi adalah 2.83, 2.88, dan 2.94 eV untuk saiz zarah pada 4.61, 2.92, dan 2.49 nm, masing-masing. The jalur konduksi disebabkan perubahan dalam kepekatan pelopor pada 30, 40, dan 50 mg agentam nitrat adalah 2.94, 2.92, dan 2.83 eV untuk saiz zarah pada 2.93, 3.73, dan 4.61 nm.

Oleh itu, boleh dibuat kesimpulan bahawa kaedah rawatan haba yang diubah suai adalah kaedah yang betul untuk menghasilkan nanopartikel perak murni di mana, saiz dan jalur tenaga prngaliran nanopartikel perak dihasilkan boleh dikawal dengan mengawal suhu pengkalsinan, kepekatan PVP, dan kepekatan logam pelopor. Nanopartikel perak berkurangan saiz dan jalur pengaliran tenaga meningkat dengan meningkatkan suhu pengkalsinan dan dengan mengurangkan kepekatan PVP dan kepekatan logam pelopor. Getaran haba perak nanopartikel meningkat dengan meningkatkan suhu pengkalsinan dan oleh kerana elektron mengelilingi nanopartikel perak, daya tolakan elektrostatik antara zarah logam dan getaran haba nanopartikel adalah faktor utama saiz berkurangan pada suhu pengkalsinan yang lebih tinggi. Oleh kerana saiz berkurangan bilangan atom atau proton, yang membentuk zarah menurun, oleh itu, jalur konduksi tenaga meningkat dengan meningkatkan suhu pengkalsinan disebabkan tarikan elektrik yang lebih lemah antara elektron konduksi dan teras positif ionik nanoparticle.

Keputusan juga mendapati bahawa saiz nanopartikel 'berkurangan dengan meningkatkan kepekatan PVP kerana meningkatkan keupayaan menutup PVP untuk menstabilkan atom perak dan ion kuat dan oleh itu mengurangkan kelajuan pembentukan zarah. Oleh kerana saiz berkurangan, bilangan atom atau proton, yang membentuk penurunan nanopartikel, oleh itu daya tarikan elektrostatik antara elektron konduksi dan teras positif ionik nanoparticle menjadi lemah dan peningkatan tenaga jalur konduksi dengan meningkatkan kepekatan PVP.

Juga dibuat kesimpulan bahawa saiz nanopartikel meningkat dengan meningkatkan kepekatan nitrat perak berikutan peningkatan ion Ag^+ dan kelajuan penumpuan dalam sampel mengikut mengurangkan keupayaan menutup PVP untuk menstabilkan atom perak dan ion kuat. Sejak kenaikan saiz, bilangan atom atau proton, yang mengarang peningkatan nanoparticle, oleh itu daya tarikan elektrostatik antara elektron konduksi dan teras positif ionik nanopartikel menjadi lebih kuat dan tenaga pengurangan jalur konduksi dengan meningkatkan kepekatan nitrat perak. Oleh itu boleh dibuat kesimpulan kaedah rawatan haba yang diubah suai adalah kaedah yang betul untuk menghasilkan nanopartikel perak murni di mana, saiz dan pengaliran jalur tenaga nanopartikel perak dihasilkan boleh dikawal dengan mengawal suhu pengkalsinan, kepekatan PVP, dan kepekatan logam pelopor. Nanopartikel perak 'saiz berkurangan dan jalur pengaliran tenaga meningkat dengan meningkatkan suhu pengkalsinan dan dengan mengurangkan kepekatan PVP dan logam pelopor. Getaran haba perak nanopartikel meningkat dengan meningkatkan suhu pengkalsinan dan sejak elektron mengelilingi nanopartikel perak, oleh itu, daya tolakan elektrostatik antara zarah logam dan getaran haba nanopartikel adalah faktor utama saiz berkurangan pada suhu pengkalsinan yang lebih tinggi. Oleh kerana saiz berkurangan bilangan atom atau proton, yang membentuk penurunan zarah, oleh itu, jalur konduksi tenaga meningkat dengan meningkatkan suhu pengkalsinan yang disebabkan tarikan elektrik yang lebih lemah antara elektron konduksi dan teras positif ionik nanoparticle.

Ia juga mendapati bahawa saiz nanopartikel 'berkurangan dengan meningkatkan kepekatan PVP kerana meningkatkan keupayaan menutup PVP untuk menstabilkan atom perak dan ion kuat dan oleh itu mengurangkan kelajuan penumpuan. Oleh kerana saiz berkurangan, bilangan atom atau proton, yang mengarang penurunan nanoparticle, oleh itu daya tarikan elektrostatik antara elektron konduksi dan teras positif ionik nanoparticle menjadi lemah dan peningkatan tenaga jalur konduksi dengan meningkatkan kepekatan PVP.

Ia telah membuat kesimpulan bahawa nanopartikel 'saiz meningkat dengan meningkatkan kepekatan nitrat perak berikutan peningkatan ion Ag + dan kelajuan penumpuan dalam sampel mengikut mengurangkan keupayaan menutup PVP untuk menstabilkan atom perak dan ion kuat. Sejak kenaikan saiz, bilangan atom atau proton, yang mengarang peningkatan nanoparticle, oleh itu daya tarikan elektrostatik antara elektron konduksi dan teras positif ionik nanoparticle menjadi lebih kuat dan tenaga pengurangan jalur konduksi dengan meningkatkan kepekatan nitrat perak.

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I certify that a Thesis Examination Committee has met on 23 May 2017 to conduct the final examination of Leila Gharibshahi on her thesis entitled "Synthesis and Characterization of Silver Nanoparticles by Thermal Treatment Method" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Azmi bin Zakaria, PhD
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Faculty of Science
Universiti Putra Malaysia
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Universiti Putra Malaysia
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Ahmad Umar, PhD
Professor
Najran University
Saudi Arabia
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 6 July 2017

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Elias Bin Saion, PhD
Professor, Ir
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Abdul Halim Shaari, PhD
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Faculty of Science
Universiti Putra Malaysia
(Member)

Khamirul Amin Matori, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
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PVP	polyvinyl pyrrolidone
FWHM	Full Width at Half Maximum
M	Molar (mol per litre)
mM	milliMolar
EDX	Energy Dispersive X-ray spectra
TEM	Transmission Electron Microscopy
SEM	Scanning Electron Microscopy
FTIR	Fourier transform infrared spectroscopy
XRD	X-Ray Diffraction
TGA	Thermo Gravimetric Analysis
LSP	Localized Surface Plasmon
DFT	Density Functional Theory
E_{cb}	conduction band Energy

CHAPTER 1

INTRODUCTION

1.1 Introduction on nanomaterials

The main goal of nanotechnology is to make devices that are small, fast, light and cheap but have superior functions. Therefore, nanomaterial's research is to achieve this goal and in the process reduce using raw materials and energy consumption considerably (Schmid et al., 2003). Researcher of fundamental science such as physics, chemistry, and biology can make a huge impact to this area for nanotechnological applications in many fields. Nanomaterials are made from up to tens of thousands of atoms, but their dimensions 1–100 nm have a very significant due to their strong chemical and optical properties.

Metal nanoparticles display remarkable unique properties such as nonlinear optical characteristics, improved mechanical strength, high specific heat, etc. These properties arise from the smaller size of the nanoparticles and their large surface to volume ratio(Gleiter, 2000). Researchers have found various applications for metallic nanoparticles in biotechnology (Mirkin et al., 1996), sensors (Taton et al., 2000), medical diagnostics (Storhoff et al., 1998), catalysis (Toshima, 2004), high performance engineering materials, optics and conducting adhesives (Dagani, 1999; Hamilton & Baetzold, 1979; Schmid, 1992).

Various physical and chemical methods have been proposed to synthesize metal nanoparticles, including physical vapour deposition, chemical vapour deposition, aerosol processing, sol-gel process, wet chemical synthesis, mechanical alloying/milling, and gamma radiation. These methods can have some disadvantages such as impurities, toxic solvent and difficult preparation procedure, which restricts their commercial benefits. The researcher has been trying to find an alternative method that overcomes these inappropriate attributes such as time-consuming process, low adoption, insoluble, expensive and small production commonly applied for the chemical and electrochemical methods in nanoparticles synthesis. In this work, attempts are made to synthesize silver nanoparticles via thermal treatment method and at the same time to overcome several drawbacks encountered through other approaches.

1.2 Metal nanoparticles

Nanomaterials are characteristically intermediate between atomic/molecular and bulk structure with the size of less than 100 nm. Nanomaterials can be divided into four branches,

1) Nanotubes (Carbon nanotubes CNTs), which are three-dimensional systems.

2) Nanothin films, which are two-dimensional systems.
3) Nanowires, which are one-dimensional systems.
4) Nanoparticles, which are zero-dimensional systems.

Metallic nanoparticles include small metallic clusters of transition atoms such as silver and gold atoms with sizes of less than 100 nm. Due to the small size of particles, metal nanoparticles have a large surface to volume ratio and quantum effects exhibit interesting novel characteristics differed from bulk structures and isolated molecules properties (Banyai et al., 1988; Takagahara, 2005; Takagahara, 1989). Due to their electronic structure, transition metal nanoparticles absorb electromagnetic radiation with the wavelength in the range of ultra-violate, visible and near infrared rays. Classically, when metal nanoparticles interact with light, the incident light will excite the free electrons on the surface of the particles, which produce the secondary electromagnetic particle-wave on the surface of the particles that called plasmons. The optical characteristic of metallic nanoparticles is based on the surface plasmon resonance (Rastar et al., 2013). The surface plasmon resonance occurs when the frequency of the incident light to metal nanoparticles and the surface plasmon frequency is equal. This phenomenon depends on the size and shape and chemical composition of the particles and on the dielectric constant of the surrounding medium (Becker et al., 2010; Ghaforyan et al., 2015; Hutter & Fendler, 2004; Lu et al., 2009; Pan et al., 2003; Slistan-Grijalva et al., 2005).

For the first time in 1908, Gustav Mie resolved the optical absorption of spherical metal nanoparticles by considering the interaction between electrical field of light and free electrons on a metal surface using the classical electrodynamics theory of Maxwell's equations. The optical absorption is described as a summation of electron conduction oscillator on the metal surface by incident electromagnetic field, which polarized the particles and is known as the localized surface Plasmon resonance (LSPR). The plasmonic theory cannot explain the quantum nature of the electronic structure of metal nanoparticles. Therefore, perhaps the best description of the optical absorption of metal nanoparticles is by the quantum mechanical approach.

The Time-Dependent Density Functional Theory (TD-DFT) was used to explain these plasmonic properties of metals (Gonzalez & Noguez, 2007; Huang & Carter, 2008; Negrut et al., 2007; Zheng et al., 2009). The optical properties of metal nanoparticles based on the geometrical and electronic structures of nanoparticles can be explained by using quantum mechanics. Only recently the optical absorption of metal nanoparticles was calculated by using a quantum mechanics principle (Gharibshahi & Saion, 2010). In this theory, fundamentally based on DFT principle, conduction electrons of metal nanoparticle experience a potential at the ground energy of the conduction band assigned by their quantum numbers. The quantum theory of metal nanoparticles describes the excitation of these conduction electrons to higher energy near the Fermi energy when absorbed photon energy from UV light. As a result, it is necessary to consider the electronic structure of metal nanoparticles, which is similar in the electronic structure of an atom of a given metal. According to this theory, the size of nanoparticles depends on N atoms which establish by using the crystal structure that made up the geometrical structure of the particle (Saion & Gharibshahi, 2014; Saion et al., 2013).

1.3 Significance of silver nanoparticles

Silver with the symbol of Ag is a novel heavy metal. The atomic number of the Ag is 47 with the electronic configuration structure Ag: [Kr] $4d^{10}$ $5s^{1}$. It has the melting point temperature of 961.8 ˚C. Silver nanoparticles have unique physical, chemical, optical, electronic and antibacterial characteristics, differed from molecules and bulk properties. Because of these properties, silver nanoparticles are widely used in area such as bio sensing, photonics, electronics catalysts, as optical sensors, in textile engineering, in optics, and in the medical field as a bactericidal and as a therapeutic agent. Also they are used in the formulation of dental resin composites; in coatings of medical devices; as a bactericidal coating in water filters; as an antimicrobial agent in air sanitizer sprays, pillows, respirators, socks, wet wipes, detergents, soaps, shampoos, toothpastes, washing machines, and many other consumer products; as bone cement; and in many wound dressings (Prabhu & Poulose, 2012). Thus, silver nanoparticles have important roles in the present nanoscience and nanotechnology era.

1.4 Problem Statement

Different methods have been used for the synthesis of silver nanoparticles such as, chemical method, microwave method, sol-gel method, ball milling method, gamma radiation synthesis that all have some disadvantages such as impurities problem, solvent toxicity, and complex procedures in their preparation that limits their commercialization potential.

In order to overcome some of these disadvantages the thermal treatment method was introduced, initially to prepare metal ferrites such as $NiFe_2O_4$ (Mahmoud Goodarz Naseri et al., 2011a) $ZnFe_2O_4$ (Mahmoud Goodarz Naseri et al., 2011b), $MnFe_2O_4$ (Goodarz Naseri et al., 2011), $CoFe_2O_4$ (Naseri et al., 2010), metal chromic $ZnCr_2O_4$ (Gene et al., 2014) nanoparticles, and semiconductor nanoparticles such as ZnO (Al-Hada et al., 2014), CdO (Al-Hada et al., 2015), TiO2 and ZrO2 (Keiteb et al., 2016a; Keiteb et al., 2016b) that let oxygen introduced into the samples and all the products were metallic oxides. In this method, nanoparticles will be prepared from an aqueous solution containing metal nitrates, poly (vinyl pyrrolidone) (PVP), and deionized water followed by drying, grinding and calcination by thermal treatment. No other chemicals will be added to the solution. In contrast with the original thermal treatment method, in this work, for the first time, we have introduced the modified thermal treatment method to synthesise pure silver nanoparticles by removing oxygen from the sample during calcination.

1.5 Significant of the Study

Silver nanoparticles because of their unique properties differed from the molecules and bulk silver characteristics, are widely used in areas such as biosensing, photonics, electronics, catalysis and antimicrobial applications.

In this study, the silver nanoparticles synthesizing via the modified thermal treatment method, from a water-based solution consist of metal nitrates, polyvinyl pyrrolidone (PVP), and deionized water was described. The solution was heated at 80ºC to dry for 24 h before grinding and calcination at different temperatures from 400 to 800ºC for 6 hours by using oxygen and nitrogen gas respectively. This method has the advantages of simplicity, environmentally friendly, no produces toxic substances and low cost.

1.6 Scope of this Study

The limitation of this study is included to the modified thermal treatment synthesis of pure silver nanoparticles. In the modified thermal treatment method, aqueous solutions are prepared from silver nitrate ($AgNO_3$), PVP as the capping agent and deionized water as solvent followed by drying in the oven and calcination by using oxygen and nitrogen gases in the furnace to produce pure silver nanoparticles. Environmentally friendly, no produces toxic substances, simplicity and low-cost features of modified thermal treatment synthesis are useful in determining underlying physical principles controlling the nucleation and aggregation of metal nanoparticles, thus the size of nanoparticles. The influences of calcination temperatures, initial precursor concentration, and PVP concentrations on the particle size and optical property of silver nanoparticles are the scopes of this research. The investigation of electric, magnetic, and chemical properties of silver nanoparticles are out of the scope of this study.

1.7 Objectives of the Study

Different methods are used to synthesize nanoparticles. One of these methods, which recently are used to produce nanoparticles is thermal treatment method. Metal ferrites nanoparticles and semiconductor nanoparticles are already produced by this method. Different parameters of synthesis procedure of this method are variable, such as calcination temperature, capping agent, and metal concentration, which change in each of them can have an effect on the properties of produced nanoparticles. Therefore, the aims of this study are to synthesize silver nanoparticles by modified thermal treatment method and to characterize the structural and optical properties of the produced nanoparticles. The objectives of this work are as follows:

1. To synthesise pure silver nanoparticles by modified thermal treatment method.
2. To study the influence of calcination temperatures on the structural and optical properties of silver nanoparticles.

3. To study the influence of PVP concentrations on the structural and optical properties of silver nanoparticles.
4. To study the influence of metal precursor concentrations on the structural and optical properties of silver nanoparticles.

1.8 Thesis Outline

This thesis includes six chapters. Chapter 1 consists the information about the research, scope, problem statement, and objectives of the study. Chapter 2 includes the history of nanoscience, nanostructures, metal nanoparticles, the literature about the definition, synthesizing and characterization methods of silver nanoparticles and their applications. Chapter 3 describes the classical and quantum theories of metal nanoparticles and their optical of metal nanoparticles. Chapter 4 deals with the methodology of our study, including materials, sample preparation and measurement. Chapter 5 shows the results and discussion on the chemical contents, structural, and optical properties of the synthesized sample by using FTIR, EDX, TEM, XRD and, UV-visible spectroscopy. Chapter 6 includes the conclusions and future works.

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