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An Investigation on Synthesis of Silver Nanoparticles

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAA designed the work-plan, discuss the acquised data and wrote the original document. Authors SAM and RKB co-operate to write the manuscript. Author SM shares the intellectual knowledge for this research. Author SAJ supervised the overall work and assisted in writing the document. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Introduction: Nano science and nano biotechnology provided enormous opportunities for exploring the bactericidal and fungicidal activities. Since ancient times, silver was known for its anti-bacterial effects and for centuries it has been used for prevention and control of disparate infections. On the effective use silver nanomaterials synthesized and characterized play a vital role of the modern science.
Aims: Our goal is to prepare silver nanomaterials since studies have shown that silver nanoparticles have efficient activity against bacterial biofilms.
Methodology: The silver nanoparticles were generally synthesized by non-aqueous sol-gel technique in the presence of different precursor by chelating agent.

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Results: Here found a cubic unit cell with miller indices (111) (200) (220) (311) (222) and crystallite size around 50.00nm by XRD. The morphology of the prepared nano particles has been revealed by SEM below 10.00 nm and TEM is below 5.00nm in size of graphical presentation such as size, shape, surface etc. of the nanoparticles. DLS is a unique technique to discern particle size around 65.00nm and size distributions in aqueous or physiological solutions of the nanoparticles.
Conclusion: The studies on the combined synthesized and use of AgNPs with other antimicrobial agents generally help reduce the problem of toxicity and to avoid the potential for development of resistance and strongly enhance the microbicidal effect. This paper describes a short and very precise description about the chemical synthesis process of silver nanoparticles like no aqueous SGM. Also, this paper contains a brief description about different characterization technique of nanoparticles like X-ray Diffraction review the shape of crystal a cubic unit cell with miller indices (111) (200) (220) (311) (222) where crystallite size around 50.00nm, the morphology of the prepared nanoparticles has been revealed with size 10.00nm by SEM, Dynamic Light Scattering discern particle size around 65.00nm and Transmission Electron Microscope review the spherical shape of the nanomaterials. Further investigation will be continuing the antimicrobial activity test of AgNPs with ceramic coating.

Keywords: Cell destruction (CD); silver nanoparticles (AgNPs); sol-gel method (SGM); TEM analysis (TA); XRD technique (XRDT).

1. INTRODUCTION

"Recently there has been a great scientific and technological interest in the synthesis and characterization of nano-sized materials of various ranges for diverse applications" [1-7]. "Nanotechnology is the study, control and manipulation of materials at the nanoscales, typically having dimensions less than 100 nm at least one dimension" [8]. "Metal nanoparticles have been enormously investigated because of their unique optoelectronic properties that are substantially different from bulk materials" [9].

From Fig. 1. nanomaterials of silver species, both in pure and composite form have different graphical property as size (1 to 100 nm), materials (different structure), shape (such as cube, rod, plate etc.) and surface properties are of particular interest due to their field of applications from chemical catalysis [10,11] to health care [12-17], or solar cells [18] to mention a few. Various routes have been employed to synthesize these compounds such as through impregnation [19,20], co-precipitation [19,21,22], sugar reduction [23] and sol-gel process [24-28], etc. This paper gives a short review including the convenient way of synthesizing AgNPs that are generally practiced within the researchers in this relevant field focusing on SGM.

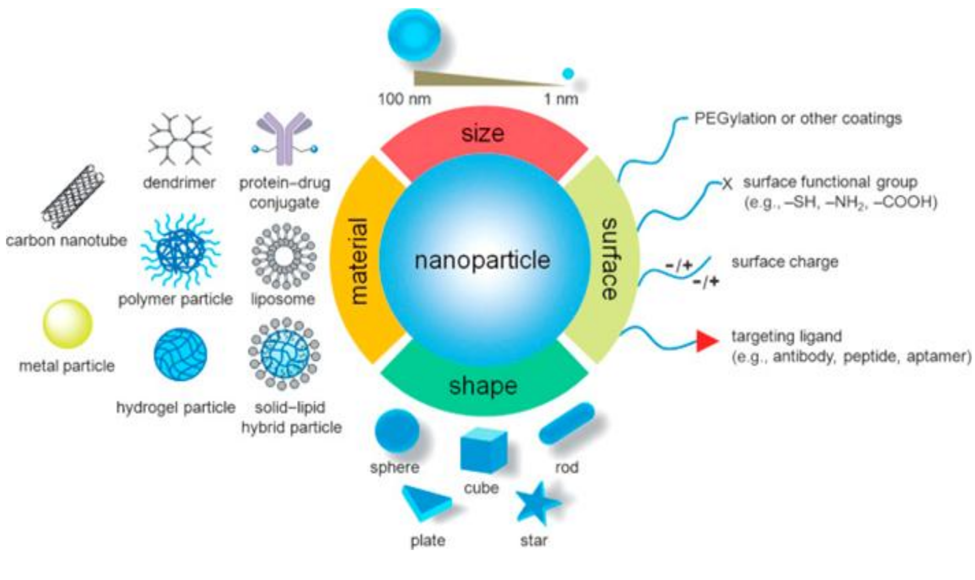

Fig. 1. Over all graphical view of nanoparticle

2. INVESTIGATION OF ANTIBACTERIAL ACTIVITY MECHANISM

"Antimicrobial resistance is a complex mechanism whose etiology depends on the individual, the bacterial strains and resistance mechanisms that are developed" [29]. "Non-traditional antibacterial agents are thus of great interest to overcome resistance that develops from several pathogenic microorganisms against most of the commonly used antibiotics" [30]. "In the past, silver found its uses as an antiseptic and antimicrobial efficacy against Gram-positive and Gram-negative bacteria [31-33] due to its low cytotoxicity" [34]. "In fact, the potent antibacterial and broad-spectrum activity against morphologically and metabolically different microorganisms seems to be correlated with a multifaceted mechanism by which nanoparticles interact with microbes" [35]. "AgNPs are capable to physically interact with the cell surface of various bacteria. In fact, the bactericidal activity of AgNPs of smaller dimensions (<30 nm) was found to be optimal against *Staphylococcus aureus* and *Klebsiella pneumoniae"* [36].

"AgNPs have a surface to volume ratio much greater than the corresponding bulk material; therefore, modalities and amount of the interactions with the bacterial surfaces are facilitated and determine a higher antibacterial activity with penetration the cell wall with disrupted" [35]. From the Fig. 2. shows generally how AgNPs can damage and bacterial cell disruption. "The antibacterial effect appears to be conferred by their ultra-small size and increased surface area, through which they destroy the membrane, cross the body of the microbe and create intracellular damage. Silver ions (Ag^+), released by AgNPs, are likely to interact with chloride (Cl^-) which is often present in bacterial growth media and exhibits a strong affinity for oxidized silver to damage" [35].

3. EXPERIMENTAL PROCEDURE

3.1 Materials

Reagent used as silver nitrate (99%+ metals basis Alfa-Aesar, used as a precursor), citric acid (99+% Alfa-Aesar, used as a chelating agent) and ethanol (Fisher Scientific, used a s a medium) and De Ionized water (used as a solvent).

3.2 Method and Preparation

The experiment proceeds to the following reagent and condition, silver nanoparticles had been synthesized through a non-aqueous SGM [37]. Typically, silver nitrate was dissolved in about 100 mL of ethanol and stirred until complete dissolution. Citric acid was then added in a 1:1 molar ratio to allow complexation. Under constant stirring, the solution was then heated at about 120℃ until the formation of a gel. The latter was then heated under different atmospheres at different temperatures with variable dwelling times.

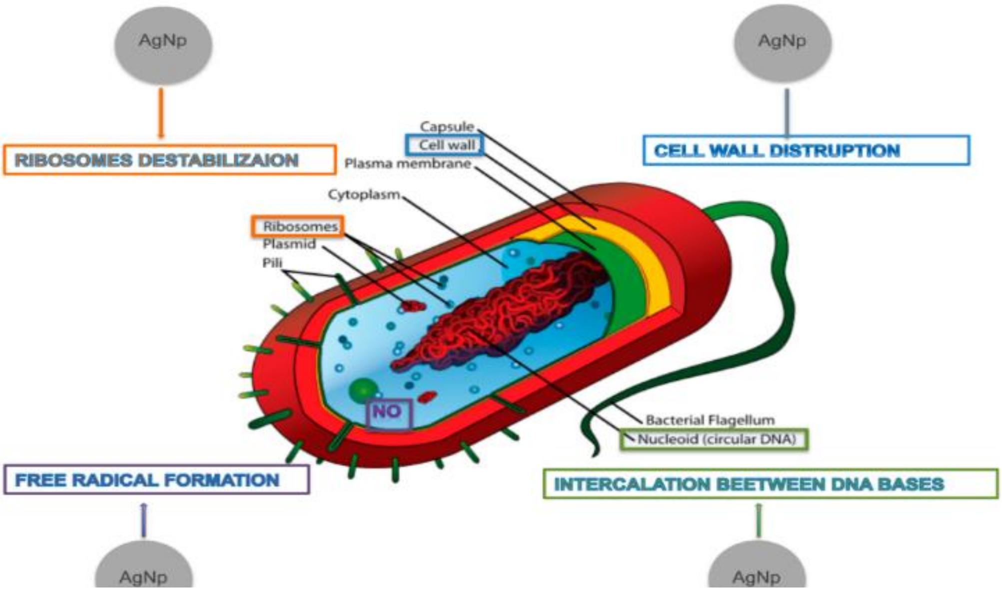

Fig. 2. Mechanisms of silver nanoparticles actions on a bacterial cell disruption

4. RESULTS AND DISCUSSION

4.1 X-ray Diffraction

"X-ray diffraction (XRD) is a popular analytical technique which has been used for the analysis of both molecular and crystal structures [38,39], qualitative identification of various compounds [40], quantitative resolution of chemical species [41], measuring the degree of crystallinity [42], isomorphous substitutions [43], crystallite sizes [44], etc". "Each material like organic and inorganic crystalline substances has a unique diffraction beam which can define and identify it by comparing the diffracted beams with the reference database in the Joint Committee on Powder Diffraction Standards (ICDD) library" [45].

"The working principle of X-ray diffraction is Bragg's law" [39,46]. "Typically, XRD is based on the wide-angle elastic scattering of X-rays" [39,47,48]. From Fig. 3, Main four diffraction was observed on the AgNPs diffractogram of reflection angle with miller indices is (111), (200), (220) and (311) that was conformed the formation of crystalline phase of AgNPs. shows the comparison between the experimental and standard data from ICDD (PDF-4+) [Card No: 00-004-0783]. The values of diffraction angles (2 theta) of synthesized nanomaterials (38.13, 44.37, 64.55, 77.44, 81.59) are mostly similar to the standard data (38.1538, 44.3454, 64.5147, 77.4886, 81.6385) [ICDD Card No: 00-004-0783] which confirmed the synthesis of purer crystalline phase of metallic silver nanomaterial. The values of interplanner distance of nanomaterials (2.351, 2.038, 1.444, 1.215, 1.196 nm) are more similar (2.3568, 2.0410, 1.4432, 1.2308, 1.1784nm) of standard data[Card No: 00-004-0783] which confirmed the of purer silver nanomaterial. The normal intensity of the AgNPs is main five refelction was 100.00, 42.6, 29.5, 36.9, 9.00% which was similar to (100.00, 40.00, 25.00, 26.00, 12.00%) standard data [ICDD Card No: 00-004-0783]. It's found a cubic unit cell with miller indices (111) (200) (220) (311) (222) [ICDD Card No: 00-004-0783]. So the purer cystalline phase obserbved that performed a unite antimicrobial property.

4.2 Dynamic Light Scattering

"Dynamic light scattering is a method that depends on the interaction of light with particles" [45]. "This method can be used for the measurement of narrow particle size distributions, like in the range of 2–500 nm" [49]. "DLS is mainly used to determine particle size and size distributions in aqueous or physiological solutions, that are around mostly below 100.00nm" [50]. "DLS measures the light scattered from a laser that passes through a colloid, that relies on Rayleigh scattering from the suspended nanoparticles" [51].

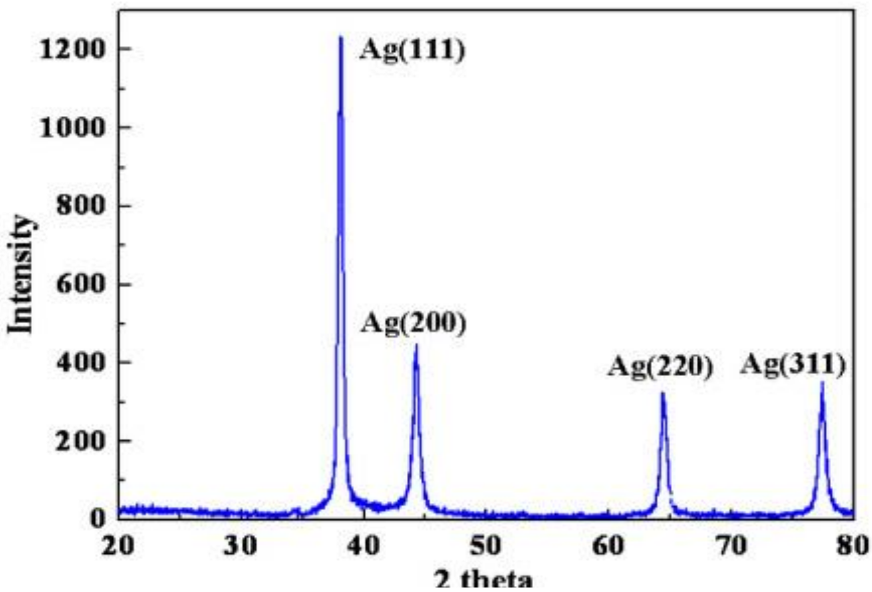

Fig. 3. X-ray diffraction pattern of silver nanoparticles

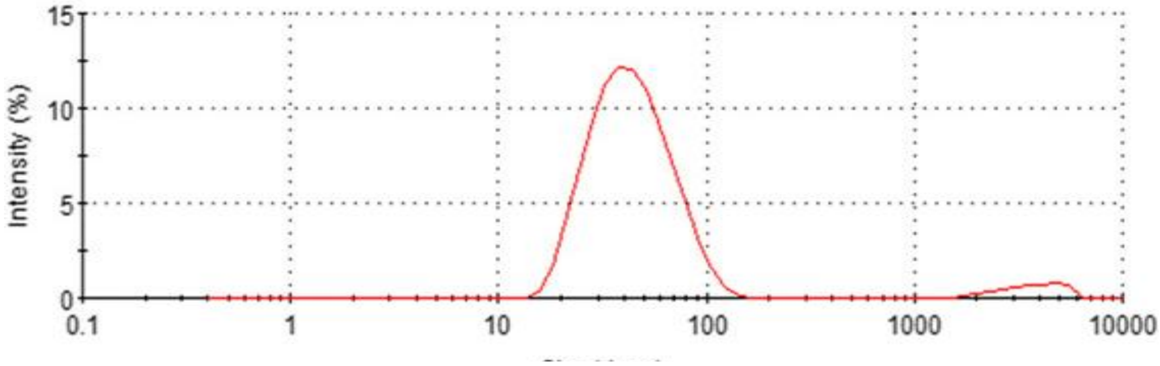

Fig. 4. Silver nanoparticles size showing in dynamic light scattering

Zeta potential is the electrical potential at slipping plane (the slip plane is the plane defined by the distance at which the structure with its chemically bounded water and ions moves in bulk through the solution). Only the slipping plane where the zeta potential is valid. This plane is the interface which separates mobile fluid from fluid that remains attach to the surface. It is usually denoted by Greek letter zeta (ζ) and its units are volt (V) or more commonly milivolt (mV). So which colloids ζ value is high (positive or negative) are electrically stabalized. Zeta potential in milivolt (mV) units its value 0 to 5 then its occurs rapid coagulation as well as 10 to 30 is incipient instability, 30 to 40 is moderate stability, 40 to 60 is good stability, more than 61 is excellent stability of the colloidal particleCharacterization of any nanomaterial in solution is essential to evaluate the toxic potential [52]. On Fig. 4, DLS is a nondestructive method used to obtain the average diameter of nanoparticles dispersed in liquids as well as the zeta potential that was conformed the stability of nanoparticles in a solution or medium. The AgNPs average size around 65.00nm conformed the formation of nano in size. Highest formation of AgNPs was found around 65.00nm (intensity 12.00%) that was surface to volume ratio was higher than bulk materials.

4.3 Scanning Electron Microscope

"Among various electron microscopy techniques, SEM is a surface imaging method, fully capable of resolving different particle sizes, size distributions, nanomaterial shapes, and the surface morphology of the synthesized particles at the micro and nanoscales" [51,53]. "The modern electron microscope as well as high-resolution SEM is able to identify the morphology of nanoparticles below the level of 10 nm, The limitation of SEM is that it is not able to study the internal structure, but it can provide valuable information regarding the purity and the degree of particle aggregation which a very less agglomeration was observed and the size in around 60.00nm" [45]. "Using SEM, we can prove the morphology of particles and derive a histogram from the images by either by measuring and counting the particles manually, or by using specific software" [49]. From Fig. 5, the image shows that, silver nanoparticles are mono-dispersive and highly crystalline. The grain sizes of the samples obtained from the SEM images are larger than that obtained from XRDT data (crystallite size around 50.00nm). From Fig. 5. showed that a very unified distribution of surface nanomaterials that are a very less agglomeration.

4.4 Transmission Electron Microscope

From the Fig. 6, the Transmission Electron Microscope (TEM) analyses showed the internal morphology of AgNPs. AgNPs particle size between 50 and 200 nm (histogram) and average size of silver nanoparticles between 5.00 and 40.00 nm with a spherical morphology, very a less agglomeration of the internal morphology and selected area electron diffraction (SAED) planes (111), (200), (220) and (311) observed which conform crystal planes of AgNPs [54]. Which was previously proved by X-ray Diffractometer (XRD) with miller indices of (111), (200), (220) and (311).

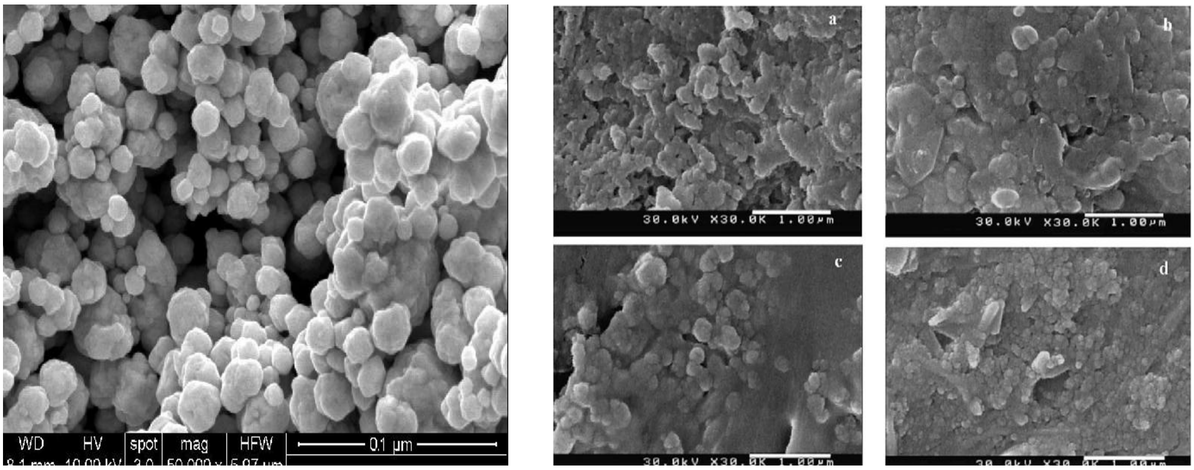

Fig. 5. Scanning electron microscope images of silver nanoparticles surface

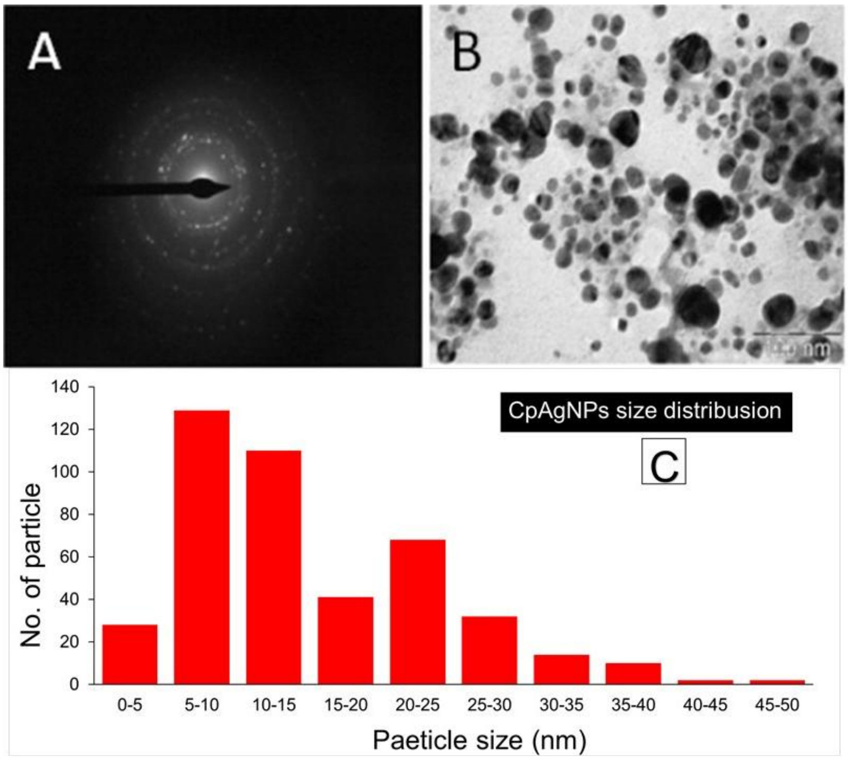

Fig. 6. Transmission electron microscope images silver nanoparticles

5. CONCLUSION

The studies on the combined synthesized and use of AgNPs with other antimicrobial agents generally help reduce the problem of toxicity and to avoid the potential for development of resistance and strongly enhance the microbicidal effect. This paper describes a short and very precise description about the chemical synthesis process of silver nanoparticles like no aqueous SGM. Also, this paper contains a brief description about different characterization technique of nanoparticles like X-ray Diffraction review the shape of crystal a cubic unit cell with miller indices (111) (200) (220) (311) (222) where crystallite size around 50.00nm, the morphology of the prepared nanoparticles has been revealed with size 10.00nm by SEM, Dynamic Light Scattering discern particle size around 65.00nm and Transmission Electron Microscope review the spherical shape of the nanomaterials. Further investigation will be continuing the antimicrobial activity test of AgNPs with ceramic coating.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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