International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

Synthesis and Characterization of Silver Nanoparticles from Ecofriendly Materials: A Review

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***Abstract*:- Recently, silver nanoparticles have been investigated by various researchers due to their unusual optical, electronic and chemical properties. Likewise, depending on their size and shape, many possibilities with respect to technological applications have been advanced. Silver nanoparticle has been discovered as one of the inorganic nano-materials suitable as antimicrobial agents. Hence, synthesis of silver nanoparticles from leaf extracts of numerous plants has been evolving as a cost effective and environmental friendly alternative to chemical and physical methods. The use of plants as major materials for the synthesis of nanoparticles is a green chemistry approach that interconnects nanotechnology and plant biotechnology. The focus of the present review is to examine the various means of synthesis of silver nanoparticles (Ag-NP) using different methods, plant extracts and their characterization as appropriate materials for diverse engineering applications.**

Keyword: Renewable materials, ecofriendly, pollution control, adaptation and vegetables

1. INTRODUCTION

Nanotechnology (NT) is the engineering of functional systems at the molecular scale which is the ability to work at the atomic, molecular and supra molecular levels (on a scale of 1 to 100 nm) in order to understand, create and use material structures, devices and systems with fundamentally new properties and functions resulting from their small structure [1].

The term “nanotechnology” can also be defined as the controlled manipulation of materials with at least one dimension less than 100 nm. This technology attempts to integrate chemistry, physics, materials science, and biology to create new material properties that can be exploited to develop facile processes for the production of electronic devices, biomedical products, high performance materials and consumer articles. The commercialization of nanotechnology is expected to boost wide technological development, improve quality of life and societal benefits around the world [2].

The main driver in the field of nanotechnology is not only the small size dimension that can be created with any type of material (metal, ceramic, polymer, glass or composite), but also the unique characteristics of such material, whose size might be controlled to only a few atomic layers in thickness, yet display physical properties which can be very different from the macro scale properties of the same substance. These special and highly fascinating attributes can be accredited to the shape, spacing, confined sizes [3] and also the exceptionally large surface area to volume ratio which has been identified as the key reason for the properties that nanoparticles exhibit as shown in Figure 1 and their dimensions as shown in Table 1 [4-5].

[redacted]

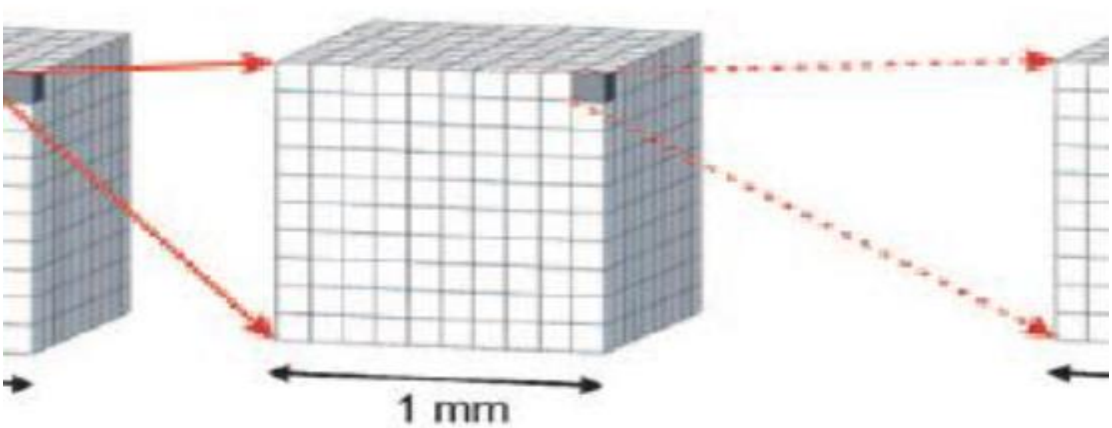

Figure 1: A simple model of the surface area of nanoparticles [5]

Table 1: Nanoparticles dimension [5]

Edge length of cubes	Number of cubes	Volume of cubes (cm^3)	Surface area of cubes (m^2)
1cm	1	1	0.0006
1mm	10^3	1	0.006
1um	10^{12}	1	6
1nm	10^{21}	1	6000

Nanoparticles are the simplest form of structures with sizes in the nanometer range. In principle, any collection of atoms bonded together with a structural radius of < 100 nm can be considered a nanoparticle [6]. Currently there are more than 1,317 nanotechnology-based consumer products according to an analysis by Nanotechproject.com [7]. Compared to their counterparts in bulk states, manufactured nanomaterials have the merits of better adjustable electronic properties, better tunable optical properties, and higher reactivity.

Nanostructure materials have existed, and used for specific applications throughout history without knowledge of the small size of the particles involved. An example of the use of nanoparticles can be traced as far back as Roman times, 4th century AD, when the unique properties of colloidal silver and gold were used to produce an array of colours in the Lycurgus cup. The glass of the cup is dichroic; in direct light it turns an opaque greenish-yellow tone resembling jade, and alternatively when light is shown through the glass it turns to a translucent ruby colour [8].

Alongside the advancement into the various disciplines in the recent years, nanoparticles have also been the subject of sporadic research interest for many years, focusing on understanding the origin of these new properties along with the implementation of new instruments and techniques to observe, measure, manipulate and synthesise high quality nanoparticles with desired morphologies that would offer even more manifold perspectives, knowledge and insight into the ever increasing miniaturisation and complexity of technical developments [9].

Silver has over the years provided a very exciting research field due to its interesting optical [10], electronic [11], magnetic [12] and catalytic properties alongside the ability to exhibit the highest electrical and thermal conductivity among all the metals. For this reason, silver nanoparticles are the nanoparticles of choice to use throughout this project [13].

Among all the nano-products, 313 products (23%) are impregnated with nano-sized silver. Silver nanoparticles (AgNP) are used in a wide range of applications, including pharmaceuticals, cosmetics, medical devices, foodware, clothing and water purification, among others uses, due to their antimicrobial properties [14].The extensive application of the silver nanoparticle (AgNP) results in their inevitable release into the environment. Silver nanoparticles are known as excellent antimicrobial agents, and therefore they could be used as alternative disinfectant agents [15].

Silver NPs are of interest because of the unique properties which can be incorporated into antimicrobial applications, biosensor materials, composite fibers, cryogenic superconducting materials, cosmetic products, and electronic components [16].

There are two major approaches used in synthesizing silver nanoparticles which are top to bottom approach and bottom to top approach, these approaches are made used of in the three methods of synthesizing silver nanoparticles [17], the three methods are physical, chemical and biological reduction method, Silver nanoparticles (AgNPs) are synthesized by using physical method including laser ablation [18, 19], ball milling [20], evaporation/ condensation [21], sputtering [22], lithography [23], arc discharge, electrodeposition, pulse wire discharge and sonochemical method [24].

Chemical method is based on reduction of silver ions in aqueous or non-aqueous solutions using reducing agents, Silver nitrate, silver acetate, silver citrate and silver chlorate are usually used as silver source, this method employs three main components; (1) metal precursors, (2) reducing agents and (3) stabilizing/capping agents [25] Chemical and physical methods lead to the presence of some toxic chemical species adsorbed on the surface that may have adverse effects in medical applications. Silver nanoparticles could be produced by using biological agents, which is very helpful for reducing and stabilizing of

AgNPs with peculiar properties. Biological agents are having antioxidant or reducing properties and thus easily reduce silver ions into metallic silver. These biological agents are free from toxic chemicals as well as offering natural capping agents for the stabilization of AgNPs. For example, Wang *et al*. [26] have synthesized silver nanoflowers by using leaf extracts. Jayaprakash *et al*. [27] have produced AgNPs by using the extract of *Piper nigrum* (black pepper) as a reducing as well as capping agent in aqueous medium without addition of any other chemicals. Hence, the focus of the present review is to examine the various means of synthesis of silver nanoparticles (Ag-NP) using different methods, plant extracts and their characterization as appropriate materials for diverse engineering applications.

2. SYNTHESIS OF SILVER NANOPARTICLES

There are various methods for synthesis of silver nanoparticles with different shapes like spherical, octahedral, tetrahedral, hexagonal, cubic, wire, coaxial cable, triangular prism, disc, triangular mark, belt, and shell shapes which has effect on the uses of these particles.

Syntheses of silver nanoparticles are of two major approaches which are top to bottom and bottom to top approaches. The three methods of synthesis which are physical, chemical and biological reduction method employ these two approaches.

International Journal of Engineering Research & Technology (IJERT)
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2.1 Physical Approach

Silver nanoparticles (AgNPs) are synthesized by using physical methods like laser ablation, ball milling, evaporation/condensation, sputtering, lithography, arc discharge, electrodeposition, pulse wire discharge and sonochemical methods. The following are brief description of these processes.

Laser ablation

In this method, silver target is ablated by pulsed laser beam in liquid medium [28-32]. The ablation efficiency and the characteristics of produced nano-silver particles depend upon many parameters, including the wavelength of the laser impinging the metallic target, the duration of the laser pulses (in the femto-, pico- and nanosecond regime), the laser fluence, the ablation time duration and the effective liquid medium, with or without the presence of surfactants [33-36]. One important advantage of laser ablation technique compared to other methods for production of metal colloids is the absence of chemical reagents in solutions. Therefore, pure and uncontaminated metal colloids for further applications can be prepared by this technique [37]. For instance, Sportelli *et al*. [38] have synthesized AgNPs by using laser ablation in the presence of isopropanol without any additional capping agents. The synthesized AgNPs were more stable over several months due to coating of isopropanol molecules with the pulsed, high-energy laser beam. This coating prevents any chemical reaction on colloidal AgNPs and thus achieved larger stability than naked metallic nanoparticles. Boutinguiza *et al*., [39] have deposited AgNPs on titanium substrates by using laser ablation in open air. The AgNPs were obtained by ablating silver foil using two different lasers. One was an inert gas jet to prevent oxidation and another one was to direct the ablated material to the substrate. Alva *et al*., [40] have produced AgNPs in ethanol by laser ablation method with pulsed photoacoustic technique, which is used to determine the production rate per laser pulse and concentration of synthesized AgNPs. Amendola *et al*., [41] have been produced AgNPs without using any reducing and stabilizing/capping agents in presence of pure acetonitrile and *N,N*-dimethylformamide by laser ablation of the bulk metal. They had synthesized AgNPs with a carbon shell or included in a carbon matrix.

Evaporation-condensation

In this method, bulk silver is heated at high temperature to produce silver vapours which are condensed as nanoparticles by flowing in inert gas. This method is limited because of large space occupied by the tube furnace, great amount of energy consumption by the furnace while raising the environmental temperature around the source material and a lot of time required achieving thermal stability [42]. Raffi *et al*., [43] have synthesized AgNPs by using an inert gas condensation method, in which helium was flowing in the process chamber. Nucleation, growth mechanism and the kinetics of nanoparticles formation in vapour phase were also discussed. Harra *et al*. [44] had generated AgNPs with an evaporation-condensation technique followed by size selection and sintering with a differential mobility analyzer and a tube furnace.

Ball milling method

In this method, size reduction is achieved by dropping a ball from near the top of the container. This container is cylindrically hollow, which rotates about its horizontal axis. The inner surface of the cylindrical container might be lined up with abrasion-resistant material (*i.e*. rubber). The diameter of the ball mill is approximately equal, which is filled partially in the cylindrical container to grind the bulk silver. The quality of the dispersion is affected by rotational speed, milling time and size of balls. In certain conditions, the particles could be prepared as small as 100 nm [17]. Silver nanoparticles were also prepared by mechanochemical reduction of Ag_2O along with graphite. Silver nanoparticles with average crystallite size of 28 nm was achieved after 22 h of milling process [45]. Yadav *et al*. [46] reviewed the details of the ball milling methods.

Sputtering method

Direct current (DC) magnetron sputtering has long been used to fabricate thin films, nanostructured coatings, and nanoparticles of various materials, including metallic oxide,

nitride, and carbide films [47-53]. To produce silver nanoparticles by this process, silver target was bombarded by inert gas ions and silver particles emerged. Chandra *et al.* [54] have used high pressure sputtering method to fabricate silver nanoparticles (3-60 nm).

Recently, Liu *et al.* [55] reported on growth of metal nanoparticles, for example, Au and Ag, using DC sputtering systems. The metal targets were sputtered onto ionic liquids to form self-assembly of metal nanoparticles on carbon supports in the liquid. Thus, DC magnetron sputtering could be a potential technique for synthesizing metal nanoparticles. The technique also reduces the complexity of synthesis processes and facilitates control over size, shape, and aggregation of the nanoparticles [56]. However, little research to date has focused on using this technique to synthesize Ag nanoparticles.

Electric discharge method

In this method, pulse voltage is applied between an electrode and a workpiece that are kept close to each other. Dielectric breakdown takes place at a certain distance between the work piece and electrode which causes high heating of the workpiece to melt away small amount. The excess workpiece material is removed with the help of steady flow of the dielectric fluid and also cooling in the machining. If current flows through a workpiece, even a hard metal can be machined [57].

Sonochemical method

Sonochemical effects are the phenomenon of acoustic cavitation in liquids. Cavitation is the formation, growth and collapsing of bubbles in a liquid. Cavitational collapse gives up an intense heating. Vinoth *et al*. [58] have reported sonochemical method for AgNPs containing reduced grapheme oxide.

Physical methods have some advantages such as less time consuming for preparation, and no hazardous chemicals. However, it requires some special devices, high temperature and pressure, longer time for thermal stability, light energy which requiring high energy for production of AgNPs [59, 60]. Hence, alternative methods are being sought for cost effective synthesis with large scale production of the nanoparticles.

2.2 Chemical Approach

Chemical reduction is the most common used method for synthesis of silver nanoparticles due to its convenience and simple equipment. Control over the growth of metal nanoparticles is required to obtain nanoparticles of small size with a spherical shape and narrow distribution in diameter. It is well known that silver nanoparticles can be produced by chemical reaction at low cost with high yield.

Chemical synthesis process of AgNPs in solution usually employs the following three main components which are: metal precursors, reducing agents and stabilizing/capping agents. The formation of colloidal solutions from the reduction of silver salts involves two stages which are nucleation and subsequent growth. It has been revealed that size and shape of synthesized AgNPs are strongly dependent on these two stages. Besides, for the synthesis of monodispered AgNPs with uniform size distribution, all nuclei are required to form at the same time. In this case, all the nuclei are likely to have the same or similar size, and then they will have the same subsequent growth. The initial nucleation and the subsequent growth of initial nuclei can be controlled by adjusting the reaction parameters such as reaction temperature, pH, precursors, reduction agents (sodium borohydride, ($NaBH_4$), ethylene glycol and glucose) and stabilizing agents (polyvinyl alcohol (PVA), polyvinyl pyrrolidone (PVP) and sodium oleate) [61-63].

This method is based on reduction of silver ions in aqueous or non-aqueous solutions using reducing agents. Depending on the conditions, silver ions may favour either the process of nucleation or aggregation to form nanoparticles. Silver nitrate, silver acetate, silver citrate and silver chlorate are usually used as silver source. Numerous researchers have synthesized silver nanoparticles using chemical reduction approach, for example, Zaheer *et al*. [64] have prepared AgNPs by reduction of $AgNO_3$ solution with aniline in presence of CTAB. They suggested experimentally that concentration of aniline does not have appreciable effect on the shape, size and the size distribution of AgNPs The most frequently used reducing agents among various ones are sodium borohydride, citrate, ascorbate and compounds containing hydroxyl or carbonyl groups like alcohol, aldehydes, carbohydrates and their derivatives [65]. During preparation of nanoparticles, it is paramount to use protective or stabilizing or capping agent which will stabilize dispersed AgNPs in order to prevent agglomeration. Hence, polymeric compounds like polyvinyl pyrrolidone (PVP), polyethylene glycol (PEG), poly (methyl methacrylate) (PMMA), poly(N-isopropylacrylamide) (PNIPA) and poly(methacrylic acid) (PMAA) were used as a capping or stabilizing agents for synthesis of AgNPs.

Khatoon *et al*. [66] synthesized colloidal AgNPs by using NaBH4 as reducing agent and trisodium citrate as a stabilizing agent. Different stabilizing agents like gelatin, polyvinyl alcohol (PVA) and polyvinyl pyrrolidone (PVP) were used by Chahar *et al*. [67] to synthesize colloidal AgNPs. Ye *et al*., [68] had synthesized AgNPs by using gelatin as a reducing agent and stabilizing agent. The obtained AgNPs were mixed with chitosan (CS),
cross linked tannic acid and then freeze-dried to obtain a new composite gelatin/CS/Ag, which has a dense pore structure with a pore size of about 100-250 m. Gelatin/CS/Ag composite could have antibacterial and wound healing properties and found to be good biocompatible material [68].

Nersisyan *et al*., [69] had prepared nanosized uniform silver powders and colloidal dispersions from $AgNO_3$ by a chemical reduction method in the presence of sodium dodecyl sulfate as a surfactant. Wang *et al*. [70] have discussed to produce AgNPs from
silver nitrate and glucose as a reducing agent in presence of polyvinyl pyrrolidone (PVP) solution, whereas NaOH was used to enhance the reaction rate.

Radziuk *et al.*, [71] prepared AgNPs by reduction of silver nitrate in an excess of aqueous sodium borohydride which be used as a reducing agent. The nanoparticles with a diameter
of 20 nm are obtained. Luo *et al*., [72] reported AgNPs prepared under mild conditions by exploiting polyethylene glycol (PEG), and the dramatic effect of PEG to the formation of AgNPs.

The main advantage of chemical reduction method is that large quantity of nanoparticles can be synthesized within a short period of time. However, the limitations involve the usage of toxic chemicals, costlier chemicals and production of toxic by-products. Hence, there is a need to develop eco-friendly and cost effective route for synthesis of AgNPs. In this regard, green synthesis of AgNPs has being gaining significant importance.

2.3. Biological Approach

The biological synthesis or green synthesis of silver nanoparticles using various leaf revealed a rapid and fairly uniform size particles and shape in an environmental friendly mode. Bioinspired synthesis of nanoparticles provides advancement over chemical and physical methods [73]. Biosynthesis of nanoparticles has been proposed as a cost effective and environmental friendly alternative to chemical and physical methods. Plant mediated synthesis of nanoparticles is a green chemistry approach that interconnects nanotechnology and plant biotechnology [74].

Silver nanoparticles could be produced by using biological agents, which are very helpful for reducing and stabilizing of AgNPs with peculiar properties. Biological agents are having antioxidant or reducing properties and thus, easily reduce silver ions into metallic silver. These biological agents are free from toxic chemicals as well as offering natural capping agents for the stabilization of AgNPs. Various parts of plant like seed, stem, leaf and flower are extensively used for production of AgNPs

[27], as polysaccharides, biological microorganism such as bacteria and fungus are also used in biosynthetic method which have also emerged as a simple and viable alternative to more complex chemical synthetic procedures to obtain AgNPs.

Bacteria are known to produce inorganic materials either intra- or extracellularly. This makes them potential biofactories for the synthesis of nanoparticles like gold and silver. Particularly, silver is well known for its biotical properties [75]. Wang *et al*. [76] have synthesized silver nanoflowers by using leaf extracts. Jayaprakash *et al*. [77] have produced AgNPs by using the extract of *Piper nigrum* (black pepper) as a reducing as well as capping agent in aqueous medium without addition of any other chemicals. Rolim *et al*. [78] have biogenically synthesized AgNPs using a commercial green tea extract (*Camellia sinensis*), which acts as a reducing and stabilizing agents for AgNPs due to presence of polyphenols in green tea. Again Jayaprakash *et al*. [79] had produced AgNPs using *Tamarindus indica* fruit extract, which acts as a reducing and capping agent. Carbone *et al*. [80] have prepared AgNPs using white grape pomace aqueous extract (WGPE) as both reducing and capping agent, Laura *et al*., [81] had biosynthesized silver nanoparticles using *Murraya koenigii* (curry leaf) extract as the reduction and stabilizing agent.

Microorganisms like bacteria, fungi, yeasts and actinomycetes have been used for synthesis of silver nanostructures. Khan *et al*. [82] have recently produced AgNPs by using bacterial mediated synthesis. This kind of bacterial mediated synthesis could be an alternative approach for chemical (toxic) and physical (high energy required) synthesis methods.

Yin *et al.* [83] have reported that biosynthesis of AgNPs by human gut microbiota. In this route, human gut microbiota is exposed to aqueous $AgNO_3$ solution which resulted in the intracellular reduction of silver (I) ions and led to the formation of approximately spherical AgNPs with dimensions of 34 ± 10 nm. Al-Dhabi *et al*. [84] have produced AgNPs by biosynthetically using the extracellular metabolites of marine derived actinomycetes. The reducing potential of *Streptomyces* sp. Al-Dhabi-89 cell surface extracts was involved for the green synthesis of AgNPs without any external capping substances or agents. They concluded that AgNPs produced from marine *Streptomyces* sp. Al-Dhabi- 89 has shown potential activity against both standard and clinical drug resistant microbial pathogens [84].

Advantages of the biological methods are low cost, ecofriendly, easily scaled up for large scale synthesis and moreover no need of high temperature, pressure, energy and toxic chemicals while the major setbacks of the method was that synthesis of microbe mediated silver nanoparticles (AgNPs) is not industrial feasibility due to their maintenance and highly aseptic conditions.

Table 2: Plant extracts used for silver synthesis and their potential activity [85]

Plant extracts	Potential activity	Ref
Alternanthera dentate – leaves extract	Antibacterial & antimicrobial	[86]
Acorous calamus – rhizome	Antioxidant,antimicrobial, anticancerous	[87]
Abutilon indicum – leaves extract	Antibacterial, antimicrobial	[88]
Cymbopogan citratus – leaves extract	Antibacterial, antimicrobial, antifungal	[89]
Thevetia peruviana – latex	Antimicrobial	[90]
Vitis vinifera – fruit extract	Antimicrobial, antibacterial	[91]
Musa paradisiacal – peel extract	Antimicrobial	[92]
Tribulus terrestris – fruit extract	Antimicrobial	[93]
Cocous nucifera –inflorescence extract	Antibacterial	[94]
Pistacia atlantica – seeds extract	Antibacterial	[95]
Citrus sinensis – peel extract	Antibacterial	[96]

Table 3: Green synthesis of silver nanoparticles by different researchers using plant extracts, with the size and shape [97]

Plant	**Size, nm**	**Shape**	**Ref.**
Calotropis procera	150–1000	Spherical	[98]
Anana comosus	12	Spherical, fcc	[74]
Murraya Koenigii	10-25	Spherical, fcc	[81]
Emblica officinalis, Terminalia catappa & eucalyptus Hybrid	20-80	Fcc	[1]
Azadirachta indica	146	Spherical	[99]
Eucalyptus hybrid	50–150	Spherical	[100]
Psoralea corylifolia	100–110	Spherical	[101]
Aloe Vera	50–350	Spherical, triangular	[102]
Alternanthera dentate	50–100	Spherical	[103]
Memecylon edule	20–50	Triangular, circular, hexagonal	[104]
Cinnamomum camphora	48–67	Spherical	[105]
Dioscorea bulbifera	35–60	triangles, pentagons, hexagons	[106]
Melia azedarach	78	Spherical	[107]
Datura metel	16–40	Quasilinear superstructures	[108]
Nelumbo nucifera	25–80	Spherical, triangular	[109]
Rosa rugosa	30–60	Spherical	[110]
Tea extract Leaves	20–90	Spherical	[111]
Chenopodium album	10–30	quasi-spherical	[112]
Vitex negundo	5 & 10–30	Spherical & FCC	[113]
Cinnamomum camphora	3.2–20	cubic hexagonal crystalline	[74]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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3. CHARACTERIZATION OF SILVER NANOPARTICLES

Characterization of silver nanoparticle is important in other to understand and control nanoparticles synthesis and applications. Different techniques such as transmission and scanning electron microscopy (TEM, SEM), atomic force microscopy (AFM), dynamic light scattering (DLS), X-ray photoelectron spectroscopy (XPS), powder X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), and UV–Vis spectroscopy are used to determine various parameters of the synthesized nanoparticles [114-124]. These techniques are used for determination of different parameters such as particle size, shape, crystallinity, fractal dimensions, pore size and surface area. Moreover, orientation, intercalation and dispersion of nanoparticles and nanotubes in nanocomposite materials could be determined by these techniques.

The surface morphology and particle size of AgNPs is observed using transmission electron microscopy, scanning electron microscopy and Atomic force microscopy, (TEM, SEM, AFM). The size distribution of AgNPs can be measured with a Zetasizer Nano Series analyzer. Energy dispersive X-ray spectroscopy (EDS) measurements are used with an emission scanning electron microscope equipped with an EDS instrument for the determination of the purity of synthesized nanoparticle. X-ray photoelectron spectroscopy (XPS), X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), and UV-Vis spectroscopy are also used to characterize AgNPs. Dynamic light scattering is used for determination of particle size distribution. UV-Vis spectroscopy is used to confirm AgNPs formation by showing the Plasmon resonance. Moreover, XRD is used for the determination of crystallinity. Figures 2-8 showed some of the results obtained from these characterizations.

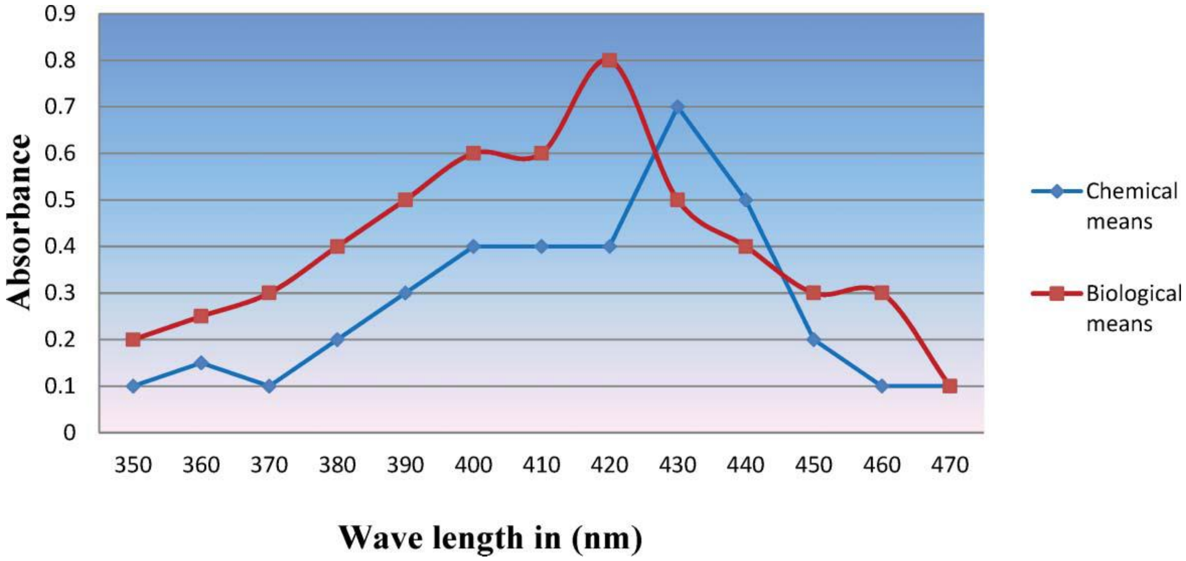

Figure 2: UV-Vis absorption spectra of silver nanoparticles synthesised by both chemical and biological means Gudikandula and Maringanti [125]

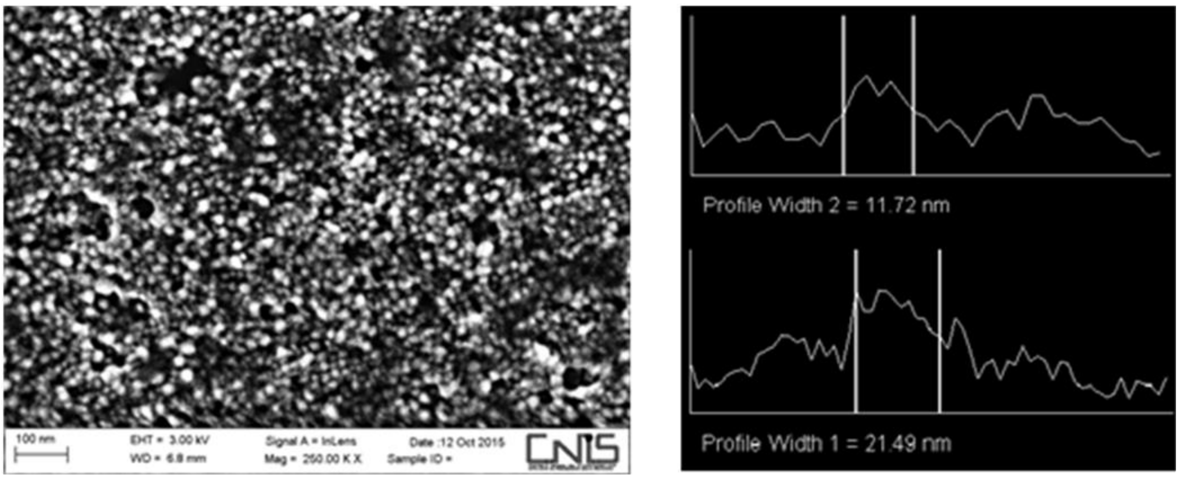

Figure 3: Imaging of Ag NPs and evaluation of NP size from SEM measurements Daniele Baiocco et al., [126]

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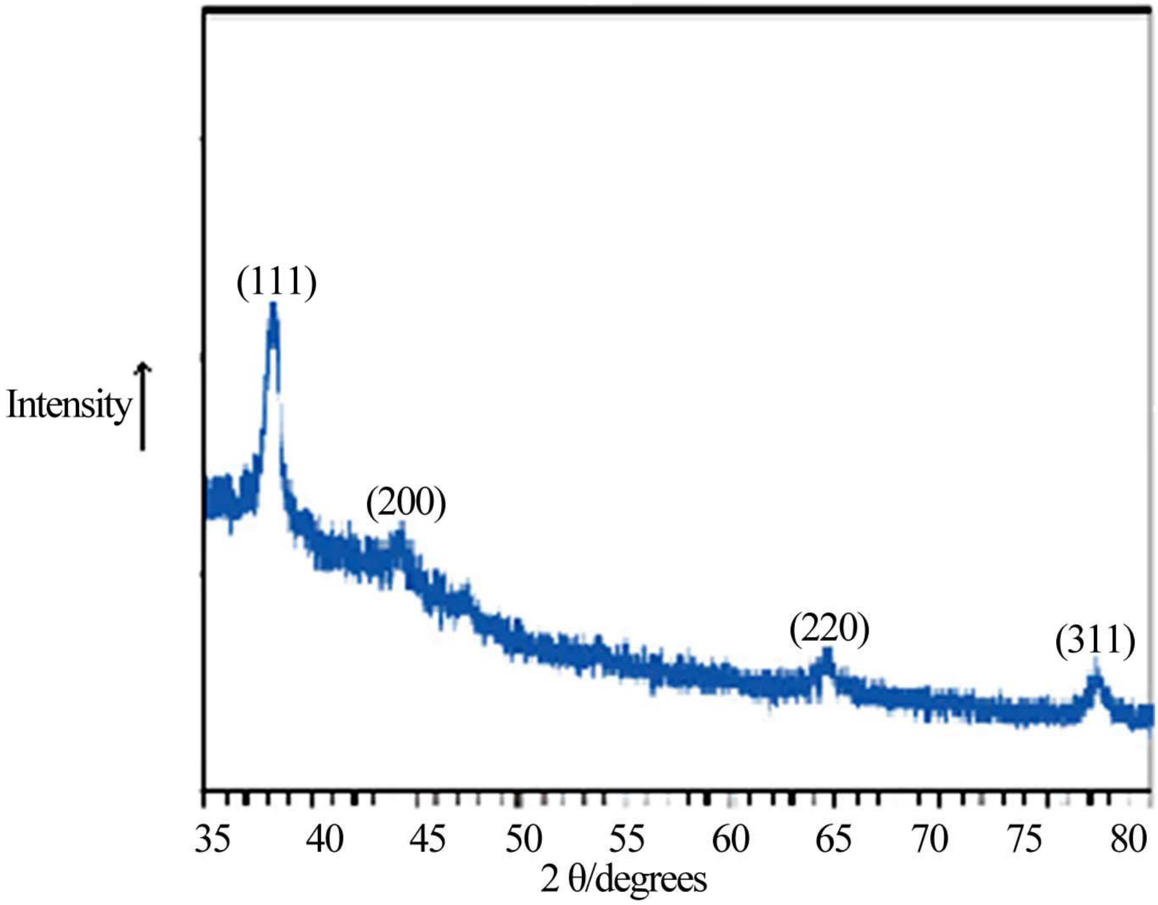

Figure 4: XRD spectrum of AgNp synthesized from extract of Ananas comosus [74]

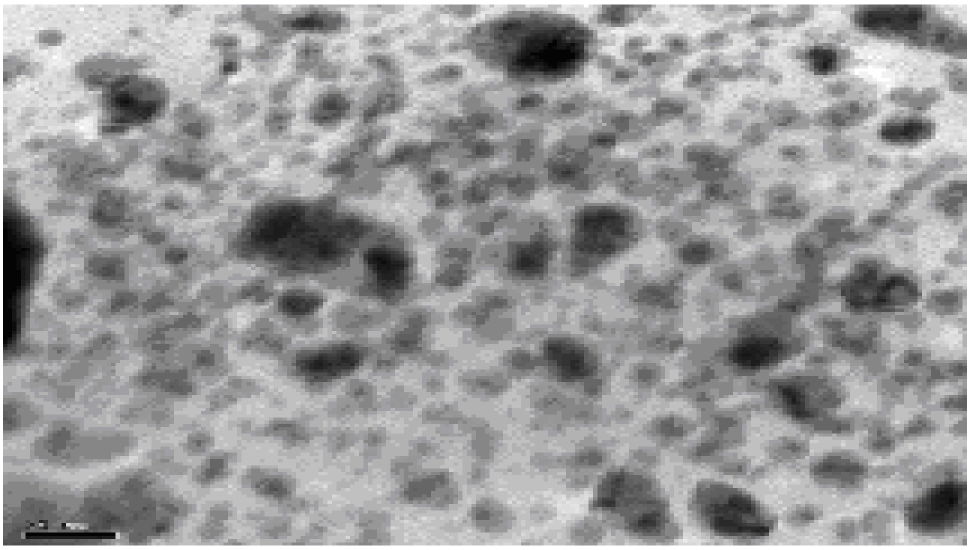

Figure 5. HRTEM micrograph recorded on a drop-coated film with *Ananas comosus* fruit extract and AgNPs aqueous suspension [74]

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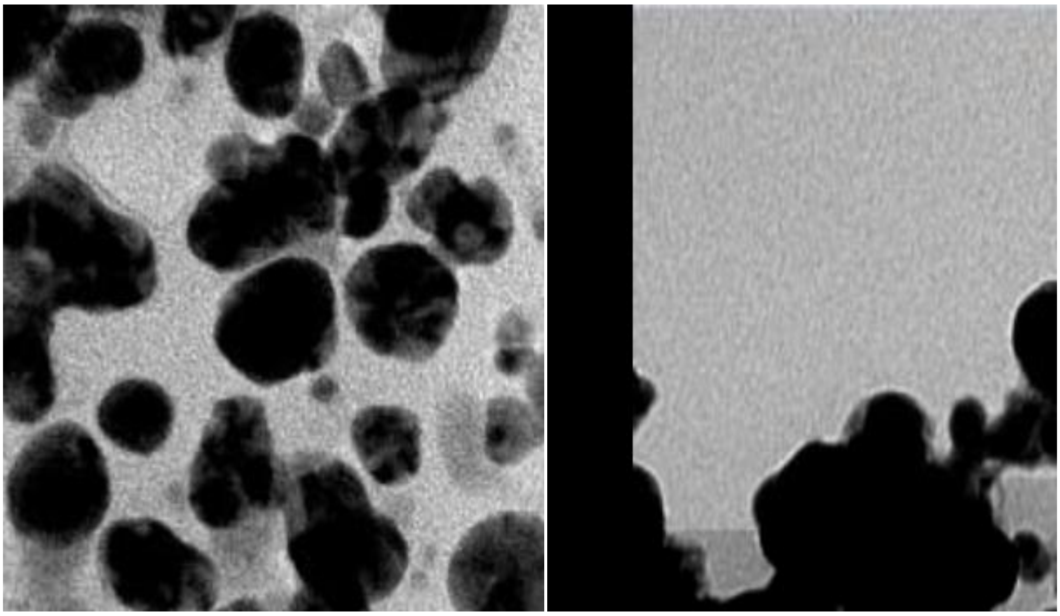

Fig. 6: TEM images of the biosynthesized silver nanoparticles using concentrations of leaf broth (curry leaf) [81]

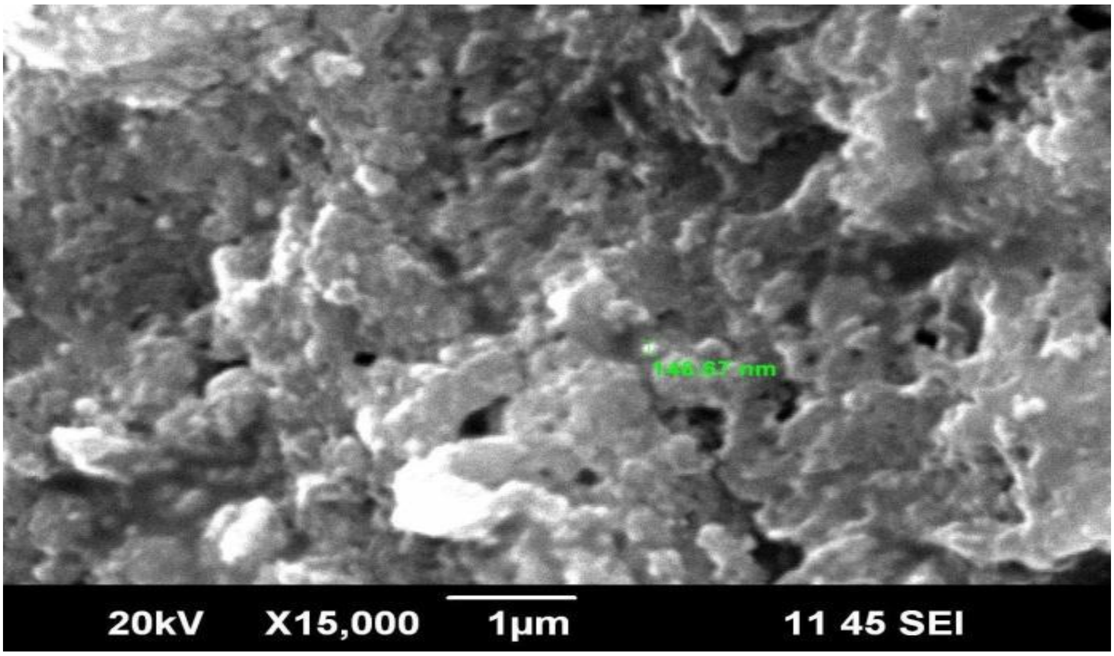

Figure 7: SEM micrograph of sliver nanoparticles synthesized *with azadirachta indica* plant exract [17]

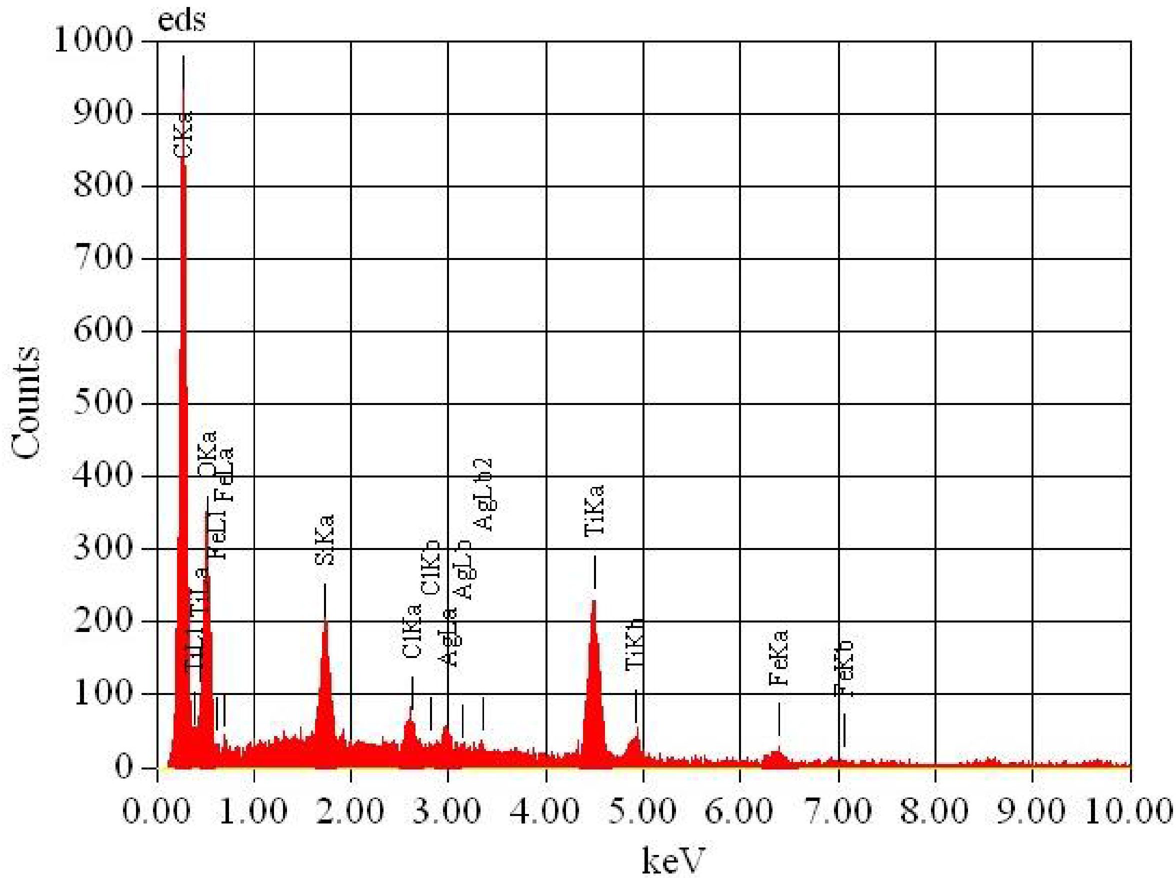

Figure 8: EDX spectra of sliver nanoparticles synthesized *with azadirachta indica* plant extract [17]

4. APPLICATION OF SILVER NANOPARTICLES

Silver nanoparticles have found applications in many field due to its unique properties. Some of its areas of applications are follows;

4.1 Medical Science Applications

Application of Ag NPs in medical can be divided into two types, namely diagnostic and therapeutic uses. Lim *et al* found that Surface Enhanced Raman Spectroscopy (SERS) based on Ag NPs can be used in cancer detection in non-invasive way [127]. This process of cancer detection will be inevitable part of cancer detection in near future.

Now a days silver nanoparticle is widely used in medical science. It is used for wound dressing, scaffolds, eye treatment and dental hygiene [128] bone substitute biomaterials [129]. By Incorporating Silver Nanoparticles at surface antibacterial properties can be increased without affecting biocompatibility [128] and also provides superior cosmetic after wood healing and better efficacy. Silver contained materials are used for surgical meshes. Central venous catheters (CVC) contained silver nanoparticles are less infective in blood stream [130]. According to Sun *et al.* [131] human serum contains albumin stabilized silver nanoparticle which provides antiviral properties.

Recent studies of Ag NPs lead to utilization in some important applications such as diagnostic imaging, therapy, bio-sensing and cancer diagnosis. [132]. Ag NPs are considered to be used as drug delivery vehicles and cancer therapeutic agents. Interferon gamma and tumor necrosis can also be inhibited by Ag nano-particles [133]. Nano silver can be used for destroying unwanted cells due to its plasmonic nature. This operation can be done by absorbing light from target cell and then converting to thermal energy. The plasmonic nature of Nano silver can also be used to destroy unwanted cells. The cells can be conjugated to the target cells and then be used to absorb light and convert it to thermal energy; the thermal energy can lead to thermal ablation of the target cells [134].

Silver nanoparticles (AgNPs) loaded in chitosan/gelatin blend: Ag NPs-containing chitosan/gelatin (CS/G) polymers exhibit strong antibacterial activity against Staphylococcus aureus strains and Escherichia coli strains, limited cytotoxicity, good bond strength with metal substrate and good biodegradability [135]. It is also important to mention that the initial burst release of Ag ions prevent the initial adhesion of bacterial strains while exhibiting relatively low cytotoxicity to healthy cells creating the premises of reduce implant-associated infections. Also, these formulations can be used in wound dressing for preventing or eradicating infection [136]

4.2 Textile Applications

Nano materials are now commercially used in textile industries [137]. Nanoparticles are incorporated into fiber or coated on fiber. Silver nanoparticles are used in T shirt, sporting clothes, underwear, socks etc. [138].

Various textiles were functionalized by silver to induce antimicrobial surfaces. After the functionalization, the Ag NPs-fabrics exhibited antimicrobial properties in the order silk> linen> nylon> PET. The morphology of the silver nanoparticles is substrate-dependent, but also the content of silver differs considerably, the highest amount of silver can be found on silk (12.05 ±0.41g AgNPs/kg) followed by PET (5.77±0.21gNPs/kg), linen (4.37±0.89gAgNPs/kg) and finally nylon (2.65±0.05g AgNPs/kg) [139]

4.3 Energy applications

$AgSiO_2$ nanospheres were designed to obtain Plasmonic Organic solar cells. The optimization was done considering the periodicity of the array, the Ag core diameter, the active layer thickness, the shell thickness, and the refractive index of the shell materials. Based on the study realized by N'Konou *et al*. [140] it was found that the optimal periodicity of the $AgSiO_2$ nanospheres (50mm) can improve the optical absorption with 24.7% (comparing to the similar structure without $AgSiO_2$ nanospheres).

Wearable supercapacitors with core/shell hierarchical structure based on silver coated textile and nanostructured active materials were obtained using metal hydroxide (e.g. $Ni(OH)_2$, NI-Co layered double hydroxide(LDH)), hydrates (e.g. $NiMoO_4$ hydrate), and sulphides (e.g. $Ni(Fe)Co_2S_4$) with three typical nanostructures of a 1D nanotube array, a 1D nano rod array, 2D nanosheet network. As a general conclusion of the work published by Li *et al*. [141], both the nature of the active materials but also the morphology is critical factors affecting the performances of the wearable super capacitor.

4.4 Food Industry Applications

Silver nanoparticles are widely used in food industry reported by Cushen [142] mainly due to antibacterial actions and free of preservative. Small concentration of Ag NPs is harmless for human cell but deadly for majority of viruses and bacteria. For this reason it is extensively used in decontamination of food and water in day to day lifecycle and infection resistor in medicine. Nanoparticles are added into food packages. Sunriver industrial Nano silver fresh food bag is one of commercially available bag in which silver nanoparticles are added [143]. Ag NPs are widely used in consumer product namely soaps, food, plastics, pastes and textiles due to their anti-fungicidal and anti-bactericidal activities.

*4.5 **Anti-Parasitic and Anti-Fouling Action***

The Silver nanoparticles have been found to be effective larvicidal agents against dengue vector Aedes aegypt and Culex quinquefasciatus, filariasis vector C. quinquefasciatus and malarial vector A. subpictus, Aedes aegypti, A. subpictu and other parasites.

The Silver nanoparticles synthesized from Rhizopus oryzae fungal species have been used for treating contaminated water and adsorption of pesticides and that from Lactobacillus fermentum cells have been used as anti-bio fouling agent. The Silver nanoparticles are being used to treat many environmental concerns like; air disinfection, water disinfection, ground water and biological water disinfection and surface disinfection [144].

5. CONCLUSION

In this paper, review on the existing methods, characterization and applications of silver nanoparticles has been carried out. Biological method of synthesis for silver nanoparticle was noticed to be the best compared to physical and chemical methods. The work reveals a future prospect for the use of silver nanoparticle in particular from the biological method of production. The various areas of application of silver nanoparticle also contribute to the interest in the advancement of its manufacturing process. Hence, more attention needed to be given to synthesis of the nanoparticle from this approach in other to overcome the present limitations. This became necessary due to environmental benefits unlike chemical approach that produce toxic material that is hazardous to the environment.

REFERENCE

[1] Vishwajeet S., Ankita S. and Nitin W. (2015): Biosynthesis of silver nanoparticles by plants crude extracts and their characterization using UV, XRD, TEM and EDX, *African Journal of Biotechnology,* Vol. 14 (33) pp 2554 – 2567
[2] Okpala, C.C. (2013). Nanocomposites – An Overview**,** *International Journal of Engineering Research and Development,* Vol. 8 (11), pp. 17-23.
[3] Nuffer, J.H. and Siegel R.W, Nanostructure-Biomolecule Interactions: Implications for Tissue Regeneration and Nanomedicine. Tissue Engineering Part A, 2010. 16(2): pp 423-430.
[4] Sau, T.K. (2010). Properties and Applications of Colloidal Nonspherical Noble Metal Nanoparticles. *Advanced Materials*, 22(16): p. 1805-1825.
[5] Goesmann, H and Feldmann C. (2010) Nanoparticulate Functional Mterials, Angewandte Chemie International. Vol.49 (8); pp 1362-1395.
[6] Sreeram K. J., Nidhin M. and Nair B. U. (2008). Microwave Assisted Template Synthesis of Silver Nanoparticles. *Bull. Material Science Academy of Sciences.* Vol.31(7) pp 937-942.
[7] Raid S. J., Khalid F. S. and Ali H. Al- Hamadani (2014): Synthesis of Silver nanoparticles *Journal of Engineering and Applied Sciences* Vol. 9, (4), pp 586
[8] *Woodrow Wilson Center*. 2011; Available from: http://www.nanotechproject.org/inventories/consumer/analysis_draft/.
[9] Christian P.K.F (2008) Nanoparticles: Structure, properties, penetration and behaviorin environmental media 17
[10] Giorgetti, E.(2009) In Situ Production of Polymer-Capped Silver Nanoparticles for Optical Biosensing. Macromolecular Symposia, 283–284(1): p. 167-173.
[11] Natsuki, J. and T. Abe.(2011) Synthesis of pure colloidal silver nanoparticles with high electroconductivity for printed electronic circuits: The effect of amines on their formation in aqueous media. J. Colloid Interface Sci., 359: p. 19-23. 61
[12] Gao, J., H. Gu, and B. Xu, Multifunctional Magnetic Nanoparticles: Design, Synthesis, and Biomedical Applications. Accounts of Chemical Research, 2009. 42(8): p. 1097-1107.
[13] Sun, Y. and Xia Y. (2002) Large-scale synthesis of uniform silver nanowires through a soft, self-seeding, polyol process. Advanced Materials, 14(11): pp 833-837.

[14] Choi, O., (2008). The inhibitory effects of silver nanoparticles, silver ions, and silver chloride colloids on microbial growth. Water Res, Vol. 42 (12): pp. 3066-3074.
[15] Hongyin Z. (2013). Application of Silver Nanoparticles in Drinking water Purification. University of Rhode Island, Open Acces Dissertation.
[16] Iravani S., Korbekandi H., Mirmohammadi S.V. and ZolfaghariB. (2014) Synthesis of silver nanoparticles: chemical, physical and biological methods. Research in Pharmaceutical Sciences, 9 (6): 385 -406
[17] Jayaprakash1 N, Suresh R, Rajalakshmi S, Raja S and Sundaravadivel E (2019). An Assortment of Synthesis Methods of Silver Nanoparticles: A Review. *Asian Journal of Chemistry; Vol. 31, No. 7 (2019), 1405-1412*
[18] Sportelli M.C, Clemente M., Izzi M, Volpe A., Ancona A., Picca R.A., Palazzo G. and Cioffi N.(2018) *Colloids Surf. A Physicochem. Eng. Asp.*, **559**, 148
[19] Mafune F., Kohno J., Takeda Y., Kondow T. and Sawabe H. (2000) "Formation and size control of silver nanoparticles by laser ablation in aqueous solution", J. Phys. Chem. B, vol.104, pp.9111-9117, 2000
[20] Yadav T.P., Yadav R.M. and D.P. Singh (2012), *Nanosci. Nanotechnol.*, **2**, 22
[21] Raffi M., Rumaiz A.K, Hasan M.M and Shah S. (2007); *J. Mater. Res.*, **22**, 3378 https://doi.org/10.1557/JMR.2007.0420.
[22] Chandra R., Taneja P., John J., Ayyub P., Dey G.K. and Kulshreshtha S. K.(1999) *Nanostruct. Mater.*, **11**, 1171 https://doi.org/10.1016/S0965-9773(99)00408-0.
[23] Zhang X. , Hicks E.M., Zhao J., Schatz G.C. and Van Duyne R.P.(2005) *Nano Lett.*, **5**, 05); https://doi.org/10.1021/nl050873x
[24] Vinoth V., Wu J.J. Asiri A.M and Anandan S. (2017) *Ultrason. Sonochem.*, **39**, 363 https://doi.org/10.1016/j.ultsonch.2017.04.035.
[25] Zaheer, S.A. Al-Thabaiti, A.Y. Obaid and A.O. Al-Youbi, (2011) *Colloids Surf. B Biointerfaces,* 82, 513 https://doi.org/10.1016/j.colsurfb.2010.10.008.
[26] Wang L., Lu Z., Lin F., Qin H., Zhang Z., Zhang J., Lei X., Dai P. and Zhang X. (2018) *Mater. Lett.*, **233**, 184 (2018) https://doi.org/10.1016/j.matlet.2018.09.018.
[27] Jayaprakash N., Judith J., Vijaya, L. John Kennedy, Priadharsini K.and Palani P. (2014) *Mater. Lett.*, **137**, 358 https://doi.org/10.1016/j.matlet.2014.09.027.
[28] Mafune F, Kohno J, Takeda Y, Kondow T and Sawabe H. (2000). Structure and stability of silver nanoparticles in aqueous solution produced by laser ablation. J Phys Chem B. 104:8333-8337.
[29] Mafune F, Kohno J, Takeda Y, Kondow T and Sawabe H. (2001) Formation of gold nanoparticles by laser ablation in aqueous solution of surfactant. J Phys Chem B.;105:5114-5120.
[30] Kabashin A.V. and Meunier M. (2003). Synthesis of colloidal nanoparticles during femtosecond laser ablation of gold in water. J Appl Phys.;94:7941-7943.
[31] Sylvestre J.P, Kabashin A.V, Sacher E, Meunier M, and Luong JHT. (2004) Stabilization and size control of gold nanoparticles during laser ablation in aqueous cyclodextrins. J Am Chem Soc.;126:7176- 7177.
[32] Dolgaev S.I, Simakin A.V, Voronov V.V, Shafeev G.A. and Bozon-Verduraz F.(2002) Nanoparticles produced by laser ablation of solids in liquid environment. Appl Surf Sci.;186:546-551
[33] Kim S, Yoo B, Chun K, Kang W, Choo J. and Gong M. (2005) Catalytic effect of laser ablated Ni nanoparticles in the oxidative addition reaction for a coupling reagent of benzylchloride and bromoacetonitrile. J Mol Catal A: Chem.;226:231-234
[34] Link S, Burda C, Nikoobakht B, El-Sayed M (2000). Laser- Induced shape changes of colloidal gold nanorods using femtosecond and nanosecond laser pulses. J Phys Chem B. ;104:6152–6163.
[35] Tarasenko N, Butsen A, Nevar E, Savastenko N. (2006)Synthesis of nanosized particles during laser ablation of gold in water. Appl Surf Sci.;252:4439-4444.
[36] Kawasaki M and Nishimura N. (2006) 1064-nm laser fragmentation of thin Au and Ag flakes in acetone for highly productive pathway to stable metal nanoparticles. Appl Surf Sci. ;253:2208-2216
[37] Tsuji T, Iryo K, Watanabe N. and Tsuji M.(2002) Preparation of silver nanoparticles by laser ablation in solution: influence of laser wavelength on particle size. Appl Surf Sci. ;202:80-85
[38] Sportelli M.C., Clemente M., Izzi M., Volpe A., Ancona A., Picca R.A, Palazzo Gand Cioffi N. (2018) *Colloids Surf. A Physicochem. Eng. Asp.*, **559**, 148 https://doi.org/10.1016/j.colsurfa.2018.09.046.
[39] Boutinguiza M., Fernández-Arias M., del Val J., Buxadera-Palomero J., Rodríguez D., Lusquiños F., Gil F.J. and Pou J. 2018), *Mater. Lett.*, **231**, 126 https://doi.org/10.1016/j.matlet.2018.07.134.
[40] Valverde-Alva M.A., García-Fernández T., Villagrán-Muniz M., Sánchez-Aké C., . Castañeda-Guzmán R. and Esparza-Alegría E. C.F (2015). *Surf. Sci.*, **355**, 341 https://doi.org/10.1016/j.apsusc.2015.07.133.
[41] Amendola V. Polizzi S. and Meneghetti M. (2007) *Langmuir*, **23**, 6766 https://doi.org/10.1021/la0637061.
[42] Kruis F, Fissan H. and Rellinghaus B. (2000) Sintering and evaporation characteristics of gas-phase synthesis of size-selected PbS nanoparticles. *Mater Sci Eng B*.;69:329-334.
[43] Raffi M., Rumaiz A.K., Hasan M.M. and Shah S.I. (2007), *J. Mater. Res.*, **22**, 3378 https://doi.org/10.1557/JMR.2007.0420.
[44] 44. Harra J., Maitalo J., Siikanen R, Virkki M., Genty G., Kobayashi T., Kauranen M. and Ma¨kela J.M. (2012), *J. Nanopart. Res.*, **14**, 870 https://doi.org/10.1007/s11051-012-0870-0.
[45] Khayati G.R. and. Janghorban K (2013), *Trans. Nonferrous Met. Soc. China*, **23**, 1520 https://doi.org/10.1016/S1003-6326 (13)62625-4.
[46] Yadav T.P., Yadav R.M. and. Singh D.P (2012), *Nanosci. Nanotechnol.*, **2**, 22
[47] Safi I. (2000) "Recent aspects concerning DC reactive magnetron sputtering of thin films: a review," *Surface and Coatings Technology*, 127(2-3) pp. 203–219, 2000.
[48] Ziebert C. and Ulrich S. (2006) "Hardmultilayer coatings containing TiN and/or ZrN: a review and recent progress in their nanoscale characterization," *Journal of Vacuum Science and Technology A*, 24 (3) pp. 554–583.
[49] 49. Taneja P., Banerjee R., Ayyub P, and G. K. Dey (2001), "Observation of a hexagonal (4H) phase in nanocrystalline silver," *Physical Review B - CondensedMatter andMaterials Physics*, vol. 64 (3) Article ID 033405, pp. 0334051–0334054.
[50] Stueber M., Holleck H., Leiste H., Seemann K., Ulrich S. and Ziebert C. (2009) "Concepts for the design of advanced nanoscale PVD multilayer protective thin films," *Journal of Alloys and Compounds*, 483 (1-2), pp. 321–333.
[51] Bock F.X., Christensen T.M, Rivers S.B., Doucette L.D. and Lad R. J. (2004) "Growth and structure of silver and silver oxide thin films on sapphire," *Thin Solid Films*, 468 (1-2) pp. 57– 64.
[52] Pettersson L.A.A. and Snyder P.G. (1995) "Preparation and characterization of oxidized silver thin films," *Thin Solid Films*, 270 (1-2), pp. 69–72.
[53] Hou S.M., Ouyang M. and Chen H.F. (1998) "Fractal structure in the silver oxide thin film," *Thin Solid Films*, 315 (1-2), pp. 322–32.
[54] Chandra R., Taneja P., John J., Ayyub P., Dey G.K and. Kulshreshtha S.K (1999) *Nanostruct. Mater.*, **11**, 1171 https://doi.org/10.1016/S0965-9773(99)00408-0
[55] Liu C.-H.,. Mao B.-H Gao J. (2012) "Size-controllable self-assembly of metal nanoparticles on carbon nanostructures in room-temperature ionic liquids by simple sputtering deposition," *Carbon*, 50 (8) pp. 3008–3014.
[56] K¨orner E., Aguirre M.H., Fortunato G., Ritter A., R¨uhe J. and Hegemann D. (2010) "Formation and distribution of silver nanoparticles in a functional plasma polymer matrix and related Ag+ release properties," *Plasma Processes and Polymers*, 7 (7) pp. 619–625.

[57] Kumar P., Singh P.K., Hussain M. .and Kumar Das A.(2016) , *Adv. Sci. Lett.*, **22**, 3 https://doi.org/10.1166/asl.2016.6772.
[58] Vinoth V., Wu J.J., Asiri A.M. and Anandan S. (2017) , *Ultrason. Sonochem.*, **39**, 363 https://doi.org/10.1016/j.ultsonch.2017.04.035.
[59] Ahmed S. Ahmad M.,Swami B.L and Ikram S. (2016), *J. Adv. Res.*, **7**, 17 https://doi.org/10.1016/j.jare.2015.02.007.
[60] Ullah Khan S., Saleh T.A., Wahab A., Ullah Khan M.H., Khan D., Ullah Khan W., Rahim A, Kamal S, Ullah Khan F and Fahad S. (2018), *Int. J. Nanomedicine*, **13**, 733 https://doi.org/10.2147/IJN.S153167.
[61] Chen . S. F. and Zhang H. (2012), "Aggregation kinetics of nanosilver in different water condition", Adv. Nat. Sci.: Nanosci. Nanotechnol. Vol.3, pp.035006-1-7,
[62] Dang T. M. D.,. Le T. T. T, Blance E. F. and Dang M. C (2012), "Influence of surfactant on the preparation of silver nanoparticles by polyol method", Adv. Nat. Sci.: Nanosci. Nanotechnol. Vol.3, pp.035004-1-4,
[63] Patil R. S., Kokate M. R, Jambhale C., Pawar S. M., Han S. H. and Kolekar S. S (2012), "One-pot synthesis of PVA-capped silver nanoparticles their characterization and biomedical application", Adv. Nat. Sci.: Nanosci. Nanotechnol. vol.3, pp.015013-1-7,
[64] Zaheer K,, Al-Thabaiti S.A.,. Obaid A.Y and Al-Youbi A.O. (2011), *Colloids Surf. B Biointerfaces*, **82**, 513; https://doi.org/10.1016/j.colsurfb.2010.10.008.
[65] Zhang S., Tang Y. and Vlahovic B. (2016) *Nanoscale Res. Lett.*, **11**, 80 https://doi.org/10.1186/s11671-016-1286-z.
[66] Khatoon U.T , Rao G.V.S.N., Mohan M.K., Ramanaviciene A. and Ramanavicius A. (2018) , *J. Environ. Chem. Eng.*, **6**, 5837 ;https://doi.org/10.1016/j.jece.2018.08.009.
[67] Chahar V, Sharma B., Shukla G., Srivastava A. and Bhatnagar A (2018), *Colloids Surf. A Physicochem. Eng. Asp.*, **554**, 149 https://doi.org/10.1016/j.colsurfa.2018.06.012.
[68] Ye H., Cheng J. and Yu K.(2019) *Int. J. Biol. Macromol.*, **121**, 633 https://doi.org/10.1016/j.ijbiomac.2018.10.056.
[69] Nersisyan H.H., Lee J.H.,. Son H.T,. Won C.W and. Maeng D.Y (2003), *Mater. Res. Bull.*, **38**, 949 https://doi.org/10.1016/S0025-5408(03)00078-3.
[70] Wang H., Qiao X., Chen J. and Ding S. (2005) *Colloids Surf. A Physicochem. Eng. Asp.*, **256**, 111 https://doi.org/10.1016/j.colsurfa.2004.12.058
[71] Radziuk D., Skirtach A., Sukhrukov G., and Shchukin D. (2007). "Stabilization of silver nanoparticles by polyelectrolytes and poly (ethylene glycol)", Macromol: Rapid. Commun. 28 pp.848-855,
[72] Luo C, Zhang Y., Zeng X., Zeng Y and Wang Y (2005), "The role of poly(ethylene glycol) in the formation of silver nanoparticles", *J. Colloi. Interface Sci.* Vol. 288(2), pp.444-448, 205.
[73] Raid S. J., Khalid F. S. and Ali H. Al- Hamadani (2014): Synthesis of Silver nanoparticles *Journal of Engineering and Applied Sciences* Vol. 9, (4), pp 586
[74] Naheed A. and Seema S. (2012) Green Synthesis of Silver Nanoparticles Using Extracts of *Ananas comosus Green and Sustainable Chemistry* , Vol.2 pp 141-147 http://dx.doi.org/10.4236/gsc.2012.24020
[75] Jun N., Toshiaki n. and Yoshio H (2015). A review of Silver Nanoparticles: Synthesis Methods, Properties and Applications, International Journal of Materials Science and Applications, Vol. 4 No 5, pp 325-332
[76] Wang L., Lu Z., Lin F., Qin H, Zhang Z, Zhang J, Lei X, Dai P. and Zhang X. (2018) , *Mater. Lett.*, **233**, 184 ;https://doi.org/10.1016/j.matlet.2018.09.018
[77] Jayaprakash N, Judith J. Vijaya, L. John Kennedy, Priadharsini K and Palani P. (2014), *Mater. Lett.*, **137**, 358 ;https://doi.org/10.1016/j.matlet.2014.09.027.
[78] Rolim W.R., Pelegrino B. de Araújo Lima, Ferraz L.S., Costa F.N., Bernardes J.S., Rodigues T., Brocchi M. and Seabra A.B. (2019), *Appl. Surf. Sci.*, **463**, 66 https://doi.org/10.1016/j.apsusc.2018.08.203.
[79] Jayaprakash N, Vijaya J.J., Kaviyarasu K., Kombaiah K., Kennedy L.J.,. Ramalingam R.JMunusamy , M.A. and Al-Lohedan H.A. (2017) , *J. Photochem. Photobiol. B*, **169**, 178 https://doi.org/10.1016/j.jphotobiol.2017.03.013.
[80] Carbone K, Paliotta M, Micheli L, Mazzuca C, Cacciotti I., Nocente F., Ciampa A. and M. Teresa M (2018) Dell'Abate, *Arab. J. Chem.*, (In press); https://doi.org/10.1016/j.arabjc.2018.08.001.
[81] Laura C, Singaravelu V., Manjusiri M and Amar K.M (2011). Biosynthesis of Silver nanoparticles using murraya koenigii (curry leaf): an investigation on the effect of broth concentration in reduction mechanism and particle size. *Adv Matt. Lett* 2011, Vol. 2(6), pp 429-434 DOI:10 5185/amiett.2011.4256.Khan M.H, Sneha U. and Karthikeyan R. (2018), *Biocatal. Agric. Biotechnol.* (In press); https://doi.org/10.1016/j.bcab.2018.12.004.
[82] Yin G, Gao R., Knowles B., Wang J., Wang P, Sun G. and Cui Y. (2019), *Sci. Total Environ.*, **651**, 1489 https://doi.org/10.1016/j.scitotenv.2018.09.312.
[83] Al-Dhabi N.A., Ghilan A.-K.M., Arasu M.V. and Duraipandiyan V. (21018) , *J. Photochem. Photobiol. B*, **189**, 176 https://doi.org/10.1016/j.jphotobiol.2018.09.012.
[84] Spoiala A., Ficai D., Ficai A, Craciun L., Titus A.M., and Andronescu E. (2020) Toward Synthesis-derived Applications of Silver Nanoparticles *Preprints* (www.preprints.org) d doi:10.20944/preprints202003.0272.v2
Kumar D.A, Palanichamy V. and Roopan S.M, (2014) Green synthesis of silver nanoparticles using Alternanthera dentata leaf extract at room temperature and their antimicrobial activity, Spectrochimica acta. Part A, Molecular and biomolecular spectroscopy 127 pp 168-71.
Nakkala J.R, Mata R, Gupta A.K and Sadras S. R (2014). Biological activities of green silver nanoparticles synthesized with Acorous calamus rhizome extract, *European journal of medicinal chemistry* 85 pp. 784-94.
[88] S. Ashokkumar S., Ravi S, Kathiravan V, and Velmurugan S. (2015). Synthesis of silver nanoparticles using A. indicum leaf extract and their antibacterial activity, Spectrochimica acta. Part A, Molecular and biomolecular spectroscopy 134 pp. 34-9.
[89] Shalaka P.R.C. Masurkar A , Vrishali B, Shidore, Suresh and Kamble P (2011) Rapid Biosynthesis of Silver Nanoparticles Using Cymbopogan Citratus (Lemongrass) and its Antimicrobial Activity, Nano-Micro Lett. 3 (3), pp189-194
[90] Rupiasih N.N, Aher A, Gosavi S, and Vidyasaga P. (2013). Green synthesis of silver nanoparticles using latex extract ofThevetia peruviana: a novel approach towards poisonous plant utilization, *Journal of Physics:* Conference Series 423. 012032.
[91] Gnanadhas Gnanajobitha K.P, Mahendran Vanaja, Shanmugam Rajeshkumar,
[92] Chelladurai Malarkodi G.A, and Cellapandian Kannan (2013) Fruit-mediated synthesis of silver nanoparticles using Vitis vinifera and evaluation of their antimicrobial efficacy, *Journal of Nanostructure in Chemistry* (3:67).
[93] Bankar A, Joshi B, Kumar A.R, and Zinjarde S. (2010) Banana peel extract mediated novel route for the synthesis of silver nanoparticles, Colloids and Surfaces A: Physicochemical and Engineering Aspects 368(1-3) pp58-63.
[94] Gopinath V, MubarakAli D, Priyadarshini S, Priyadharsshini N.M, Thajuddin N. and
[95] Velusamy P. (2012). Biosynthesis of silver nanoparticles from Tribulus terrestris and its antimicrobial activity: a novel biological approach, Colloids and surfaces. B, Biointerfaces 96 pp. 69-74.
[96] Mariselvam R, Ranjitsingh A.J, Usha Raja Nanthini A, Kalirajan K, Padmalatha C, and Mosae Selvakumar P.(2014), Green synthesis of silver nanoparticles from the extract of thinflorescence of Cocos nucifera (Family: Arecaceae) for enhanced antibacterial activity, Spectrochimica acta. Part A, Molecular and biomolecular spectroscopy 129 pp. 37-41.
[97] Sadeghi B, Rostami A, and Momeni S.S. (2015) Facile green synthesis of silver nanoparticles using seed aqueous extract of Pistacia atlantica and its antibacterial activity, Spectrochimica acta. Part A, Molecular and biomolecular spectroscopy 134 pp326-32.

[98] Kaviya S, Santhanalakshmi J, Viswanathan B Muthumary J. and Srinivasan K. (2011) Biosynthesis of silver nanoparticles using citrus sinensis peel extract and its antibacterial activity, Spectrochimica acta. Part A, Molecular and biomolecular spectroscopy 79(3) pp 594-8.

[99] Sheikh J.N, Chandan K.S. Md Arifur R.K and Sharif M.H.S (2015) Silver Nanoparticles, synthesis, properties, application and future perspective: A short review. *Journal of Electrical and Electronic Engineering (IOSR-JEEE)* (10)6 pp 117-126.

[100] Babu S.A and Prabu H.G (2011). Synthesis of AgNPs using the extract of Calotropis procera flower at room temperature, Mater Letter, (65), pp. 1675–1677.

[101]Sajesh Kumar N.K., Prem J.V., Jiby J.m and Jyothiomol (2015) Synthesis of Silver Nanoparticles from neem leaf (Azadirachta indica) extract and its antibacterial activity *CIBtech Journal of Biotechnology* 4(2) pp 20-31

[102] Dubey M, Bhadauria S, and Kushwah B (2009), " Green synthesis of nanosilver particles from extract of Eucalyptus hybrida (safeda) leaf", *Dig J Nanomater Biostruct*, (4) pp. 537–543,

[103] Sunita D, Tambhale D, Parag V, and Adhyapak A (2014) "Facile green synthesis of silver nanoparticles using Psoralea corylifolia. Seed extract and their in-vitro antimicrobial activities" Int J Pharm Biol Sci, (5) 1, pp. 457–67.

[104]Chandran S.P, Chaudhary M, Pasricha R, Ahmad A, and Sastry M (2006): Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract", Biotechnol Prog, (22) pp. 577–831.

[105]JNakkala J.R, Mata R, Kumar Gupta A, and Sadras S.R (2014), "Biological activities of green silver nanoparticles synthesized with Acorous calamusrhizome extract", Eur J Med Chem, (85) pp. 784–94,

[106]Elavazhagan T. and Arunachalam K.D (20110 "Memecylon eduleleaf extract mediated green synthesis of silver and gold nanoparticles", *Int J Nanomed*, (6) pp. 1265–78.

[107]105. Sirelkhatim A., Mahmud S., Seeni A, Kaus N.H.M, Ann L.C, Bakhori S.K.M, Hasan H. and Mohamad D (2015): Review on Zinc Oxide Nanoparticles: Antibacterial Activity and Toxicity Mechanism, *Nano-micro letters* 7(3) 219-242.

[108]Gupta M., Tomar R.S, Kaushik S, Mishra R.K, and Sharma D. (2018)Effective Antimicrobial Activity of Green ZnO Nano Particles of Catharanthus roseus, Frontiers in microbiology 9 pp 2030.

[109]Das B., Dash S. K., Mandal D., Ghosh T, Chattopadhyay S, Tripathy S, S. Das S, Dey S.K, Das D, and Roy S (2017): Green synthesized silver nanoparticles destroy multidrug resistant bacteria via reactive oxygen species mediated membrane damage, *Arabian Journal of Chemistry* 10(6) pp 862-876.

[110]Kesharwani J, Yoon K.Y, Hwang J. and Rai M.(2009) "Phytofabrication of silver nanoparticles by leaf extract of Daturametel: hypothetical mechanism involved in synthesis", J Bionanosci, (3), pp. 39–44.

[111]Santhoshkumar T., Rahuman A.A, Rajakumar G., Marimuthu S., Bagavan A. and C. Jayaseelan C. (2011) " Synthesis of silver nanoparticles using Nelumbo nucifera leaf extract and its lrvicidal activity against malaria and filariasis vectors", Parasitol Res, vol. 108, pp. 693–702.

[112]Dubey S.P., Lahtinen M. and Sillanpaa M (2010), "Green synthesis and characterizations of silver and gold nanoparticles using leaf extract of Rosa rugosa",Colloids Surf A, vol. 364, pp. 34–41.

[113]Nabikhan A., Kandasamy K., Raj A. and Alikunhi N.M (2010) " Synthesis of antimicrobial silver nanoparticles by callus and leaf extracts from saltmarsh plant, Sesuvium portulacastrumL", Colloids Surf B: Biointerfaces, vol. 79, pp. 488–93,

[114]Dwivedi A.D. and Gopal K (2010) "Biosynthesis of silver and gold nanoparticles using Chenopodium album leaf extract", Colloids Surf A, vol. 369, pp. 27–33.

[115]Zargar M., Hamid A. A., Bakar F. A, Shamsudin M.N., Shameli K. and Jahanshiri F. (2011) "Green synthesis and antibacterial effect of silver nanoparticles using Vitexnegundo L", Molecules, vol. 16, pp. 6667–76.

[116]Choi, Y., Ho, N. and Tung, C. (2007). *Angew. Chem. Int. Ed.* 707, 46.

[117]Yoosaf, K., Ipe, B., Suresh, C.H. and Thomas, K.G. (2007). *J. Phys. Chem.* C 1287, 111.

[118]Hutter, E. and Fendler, J.H., (2004). *Adv. Mater.* 1685, 16.

[119]Sun, S., Murray, C., Weller, D., Folks, L. and Moser, A., (2000). Science 1989, 287.

[120]Vilchis-Nestor, A., Sa´ nchez-Mendieta, V., Camacho-Lo´ pez, M., Go´ mez-Espinosa, R., Camacho-Lo´ pez, M. and Arenas-Alatorre, J., (2008) *Mater. Lett*. 62, 3103

[121]Yeo, S., Lee, H. and Jeong, S., 2003. *J. Mater. Sci*. 38, 2143.

[122]Zhang, J., Chen, P., Sun, C., Hu, X., 2004. Appl. Catal. A 266, 49.

[123]Chimentao, R., Kirm, I., Medina, F., Rodrı´guez, X., Cesteros, Y., Salagre, P. and Sueiras, J., (2004) *Chem. Commun*. 4, 846

[124]He, B., Tan, J., Liew, K. and Liu, H., (2004) *J. Mol. Catal.* A 221, 121.

[125]Khomutov, G. and Gubin, S. (2002) *Mater. Sci. Eng*. C 22, 141.

[126]Fatile B.O., Adewuyi B.O and Owoyemi H.T (2017) Synthesis and characterization of ZA-27 alloy matrix composites reinforced with zinc oxide nanoparticles. *Engineering Science and Technology, an International Journal* 20(2017) pp 1147-1154

[127]Krishna G. and Singara C. M. (2016). Synthesis of silver nanoparticles by chemical and biological methods and their antimicrobial properties *Journal of experimental nanoscience*, Vol. 11 (9) pp 714-721http://dx.doi.org/10.1080/17458080.2016.1139196

[128]Daniele Baiocco, Roberto Lavecchia, Stefano Natali and Antonio Zuorro (2016). Production of Metal Nanoparticles by Agro-Industrial Wastes:A Green Opportunity for Nanotechnology *Chemical engineering transactions Vol. 47,*

[129] Lin J., Chen R., Feng S., Pan J, Li Y. and Chen G. (2011) "A novel blood plasma analysis technique combining membrane electrophoresis with silver nanoparticle-based SERS spec-troscopy for potential applications in noninvasive cancer detection", Nanomedicine:Nanotechnology, Biology and Medicine, 7(5), pp. 655-663.

[130]Cao H., Liu X., Meng F. and Chu P.K (2010) "Silver nanoparticles-modified films versus biomedical device-associated infections", Wiley Interdiscip. Rev. Nanomed. Nanobiotechnol, (2) pp. 670–684.

[131]Rescignano N. and Armentano I.,"Biopolymeric Nanoparticles with a Silver Core for Biomedical Application, Institute of Polymer Science and Technology", pp. 301-318.

[132]Wong K.K.Y. and Liu X. (2010) "Silver nanoparticles—the real silver bullet in clinical medicine" *Med. Chem, Commun*, (1) pp. 125–131,

[133]Sun R.W.Y, Chen R., Chung N.P.Y., Ho C.M., Lin C.L.S. and Che C.M (2005) "Silver nanoparticles fabricated in hepes buffer exhibit cytoprotective activities toward HIV-1 infected cells" *Chem. Commun,* pp. 5059–5061,

[134]Majdalawieh A., Kanan M.C., Kadri O.E., and Kanan S.M. (2104)" Recent advances in gold and silver nanoparticles: synthesis and applications", *J Nanosci Nanotechnol*, 14(7), pp. 4757-4780,

[135]Shin S.H, Ye M.K., Kim H.S. and Kang H.S, (2007) "The effectsof nano-silver on the proliferation and cytokine expression by peripheral blood mononuclear cells*" Int. Immunopharmacol,* (7), pp. 1813–1818.

[136]Loo C., Lowery A. Halas N., West J, and Drezek R. (2005) ,"Immunotargeted nanoshells for integrated cancer imaging and therapy", Nano Lett, (5), pp. 709–711.

[137]Ma K.N, Gong L.L., Cai X.J, Huang P., Cai J., Huang D. and Jiang T. (2017) A green single-step procedure to synthesize Ag-containing nanocomposite coatings with low cytotoxicity and efficient antibacterial properties, *International journal of nanomedicine* (12) 3665-3679.

[138]Bin M., Ahmad, Lim L.L., Shameli K., Ibrahim N.A., and Tay M.Y. (2011) Synthesis of silver nanoparticles in chitosan, gelatin and chitosan/gelatin bionanocomposites by a chemical reducing agent and their characterization, Molecules 16(9) 7237-48.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

[139] Walser T., Demou E., Lang D.J, and Hellweg S. (2011) "Prospective environmental life cycle assessment of nanosilver t-shirts", *Environ. Sci. Technol*, (45) pp. 4570–4578.

[140] Benn T.M, and Westerhoff P. (2008) "Nanoparticle silver released into water from commercially available sock fabrics. *Environ" Sci. Technol,* (42) pp. 4133–4139.

[141] Emam H.E, Rehan M., Mashaly H.M. and Ahmed H.B. (2016) Large scaled strategy for natural/synthetic fabrics functionalization via immediate assembly of AgNPs, Dyes Pigments (133) pp. 173-183.

[142] N'Konou K., Peres L., and Torchio P. (2018) Optical Absorption Modeling of Plasmonic Organic Solar Cells Embedding Silica-Coated Silver Nanospheres, Plasmonics 13(1) pp.297-303.

[143] Li K.D, Zhao T., Wang H.F, Zhang S. and Deng C.(2018) From 1D nanotube arrays to 2D nanosheet networks on silver-coated textiles: new insights into the factors determining the performance of a core-shell hierarchical structure for wearable supercapacitors, *J Mater Chem A* 6(4) (2018) pp. 1561-1573.

[144] Cushen M., Kerry J., Morris M., Cruz-Romero M., and Cummins E. (2012) "Nanotechnologies in the food industry -recent developments, risks and regulation", *Trends Food Sci. Tech,* (24), pp. 30–46.

[145] Huang Y., Chen S., Bing X., Gao C., Wang T and Yuan B. (2011) "Nanosilver migrated into food—Simulating solutions from commercially available food fresh containers. Packag" *Technol. Sci,* (24) pp. 291–297.

[146] Haleemkhan A.A. (2015) Synthesis of Nanoparticles from Plant Extracts International *Journal of Modern Chemistry and Applied Science,* 2(3),195-203.