Review on Green Synthesis of Silver Nanoparticles by Physical, Chemical and Biological Methods

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Abstract— This report is focused on a brief review on methods of synthesis of silver nanoparticles through green process which are being performed in the recent decade. Nano chemistry being a revolutionary change in the research areas from last few decades has wide range of applications starting from the use of semiconductors to biomedical. The synthesis process of nanoparticles mostly involves hazardous chemicals which are a great threat to the existence of human kind and environment. The development of efficient green chemistry methods for synthesis of nanoparticles has become a major focus of researchers. The beginning of green chemistry is considered to reduce the hazardous effects created by the man-made materials and the processes used to produce them. A quick review on green chemistry issues in the last few decades shows many ways that is ecofriendly, efficient and beneficial for researches.

Index Terms— Biological Synthesis, Chemical Synthesis, Green Chemistry, Physical Synthesis, Reductant, Silver Nanoparticles, Synthesis of Nanoparticles.

1 Introduction

Among metallic nanoparticles; silver nanoparticles has gained an advanced and important position due its various applications among different science branches starting from a semiconductor up to medicine by inhibiting some virus and bacteria. Silver nanoparticles have been synthesized from silver metals which have been attracted many considerable scientific fields such as medical science, biotechnology, material science and also in photonics and electronics.

Nanoparticle can be synthesized different ways mechanically, chemically, hydrothermally, sol-gel, chemical deposition. Nanoparticles are synthesized by various method depending upon the various dimensions of nanoparticle such as size, shape, surface functionality etc.

Basically for metals generally wet chemical method is being used. Silica coating method using PVP can also applicable for synthesis nanoparticles directly. Later a brief table was given on the synthesis of silver nanoparticles.

2 Methods to Synthesize Nanoparticles

There are many methods to synthesize silver nanoparticles depending upon various factors of the particles to be formed such as size, shape, stability etc. However, the methods are broadly categorized into physical, chemical and biological.

2.1 Physical Methods

These synthesis process mainly depends upon the instruments used in the experiments. Various methods with their advantages has been cited below in the Table 1.

Nanoparticles	Methods	Advantages	Remarks
Ag	Tube furnace [1], [2]	Occurs at atmospheric pressure	Requires large space and time for thermal stability, heats up the environment
	Ceramic heater [3]	Use local heat source, prepared in high concentrations, can be used for calibration for nanoparticle measuring device	Requires rapid cooling
	Laser ablation [4], [5]	Absence of chemical reagents in soltions Gives pure and uncontaminated nanoparticle	Can be affected by various factors such as wavelength, timing, influence of ablation for perfect nanoparticle structure.
	Arc discharge [6]	Silver wires are used up as electrodes by providing DC voltage between them.	Performed at room temperature and 1atm pressure.

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2.2 CHEMICAL METHODS

These synthesis process mainly depends upon chemicals used i.e. the reducing agents and the capping agents used along with an optimum condition of temperature and pressure.

Nanoparticles	Methods	Advantages	Remarks
Ag	Reduction [7], [8]	Used reducing agents are sodium citrate, DMF, $NaBH_4$, poly block polymers, curcumin, phloroglucinol etc	Requires stabilizing agents for long term stability (polymeric compounds)
	UV photoreduction [9]	Performed at room temperature, various sized nanoparticle can be formed using certain reagents	Generally large sized nanoparticles formed, time taking reaction
	Sono electrochemical [10]	Less time taking, depends mainly on uv sonication pulses, nano spheres can be produced	Reaction temperature should keep in a limit unless it will heat up by UV sonication.
	Photo induced reduction [11]	Polymeric compounds as micro reactors, can convert nanoparticles in to nano crystals of 30-120nm length	Requires stabilizing agents for long term stability (polymeric compounds, citrate)
	Electro chemical synthetic method [12]	Homogeneity and various sized nanoparticle can be formed	Polymeric compounds must require for stabilizing
	Laser irradiation [13]	Perfect sized and shaped nanoparticles formed. Requires few chemical reagents.	
	Microwave [14]	Size and shape of nanoparticles depends upon the concentration of the silver nitrate and carboxymethyl cellulose, stability for 2 months	Amino acids and starch required for reducing and stabilizing agent. PVP can act as a stabilizing agent Reaction time: 5-10 hours
	Radiolysis, γ-radiolysis, pulse radiolysis [15], [16]	Ethylene glycol required along with specific maintenance of pH	Oligochitosan is used as a stabilizer.
	Polysaccharide method [17]	Polysaccharides used as reducing and capping agent with water as solvent	Binding interactions are weak between nanoparticles and can be denatured in higher temperature.
	Using Heparin [18]	Heparin used as reducing, capping and nucleation agent. Solution of heparin and silver nitrate needed to heat at 700c.	Time taking process(up to 7hours)
	Autoclave method [19]	Silver nitrate along with starch as reducing and capping agent at 15 psi and 121^0c for 5 mins. Stability holds for 3 months.	
	Tollen method [20]	$Ag(NH_3)^{2+}$ being reduced by an aldehyde or saccharides. Size and morphology of nanoparticles depends upon concentration of ammonia and silver nitrate.	
	Electrolysis [21]	Reduction of silver nitrate by polyol solution in presence of PVP and KNO_3. Cathode: rotating Ti disk of 6mm diameter Anode: Pt plate of 2cm radius	Performed at room temperature and 1atm pressure. 10-12 nm sized nanoparticles formed.
	Using Ascorbic Acid [22]	Flowered shaped nanoparticles formed of 20nm at room temperature. Ascorbic Acid as reducing agent and citric acid played a major role in controlling the structure of nanoparticle.	Reaction time is almost 1.5 hours.
	Aqueous Chemical Method [23]	Silver nanoparticles of 40-80nm size has been prepared by oxidation of glucose to gluconic acid that acts as capping agent.	No external capping agent required.
	Spray pyrolysis [24]	336 mL h_{-1} flux of AgNO3 solution,0.32 MPa flux of carrier gas and at 720 °C furnace temperature able to give 100nm sized nanoparticles.	Requires high temp of 620^0c-820^0c and pressure of 0.28-0.32MPa

2.3 BIOLOGICAL METHODS

The biological methods are as similar as chemical methods but the only different is here the biological products/extracts are used as the reducing agents and the capping agents. These are mainly green processes of nanoparticle synthesis.

Nanoparticles	Organisms	Experimented Examples	Process
Ag	Bacterial [25], [26], [27]	*Bacillus licheniformis*, *Bacillus licheniformis*, *B. subtilis*, *Pseudomonas stutzeri*, *Klebsiella pneumonia*, *E. coli*, *and Enterobacter cloacae*, *Aeromonas sp. SH10 and Corynebacterium sp. SH09*, *Lactobacillus*	Bio reduction and microwave irradiation
	Fungal [28], [29], [30]	*Fusarium oxysporum, Fusarium acuminatum, Phanerochaete chrysosporium, Plectonema boryanum, Aspergillus flavus, Aspergillus fumigatus, Penicillium fellutanum, Coriolus versicolor*	Bio reduction and extracellular synthesis, mostly protein used as a capping agent, Stabilization achieved by surface binding nature of fungus
	Plants [31], [32], [33], [34]	*Green tea, black tea, water melon, sandal wood, alfalfa, lemon grass, geranium, Datura metel, Pinus desiflora, Diospyros kaki, Ginko biloba, Magnolia Kobus, Platanus orientalis, Nelumbo nucifera,*	Mostly used as reductants and capping agents in the synthesis process by reduction methods.

3. CONCLUSION

From the studies we came to know about the production of ecofriendly green methods of silver nanoparticles which applications has great impact on the environment.
In this review report entitled "Review on Green Synthesis of Silver Nanoparticles by Physical, Chemical and Biological Methods" different methods are listed which had been performed in the past decades with their advantages and remarkable process. However, the chemical methods are being studied comparatively more as compared to other procedures.

4. REFERENCES

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