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BIOLOGICAL SYNTHESIS AND APPLICATIONS OF GOLD AND SILVER NANOPARTICLES–A REVIEW

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ABSTRACT

Nanotechnology is the science and engineering of creating structures in the nanometer scale which have been applied in the field of drug delivery, catalysis, optical devices and nanoelectronics. Although nanomaterials may be synthesized using chemical approaches it is now possible to use biological materials for the same. Biological systems, masters of ambient condition chemistry, synthesize inorganic materials that are hierarchically organized from the nano to the macroscale. Recent studies on the use of microorganisms in the synthesis of nanoparticles are a relatively new and exciting area of research with considerable potential for development. In this review, we critically asses the role of biological entities such as plants and microorganisms in the synthesis of gold and silver nanoparticles and their advanced applications in the field of medicine and catalysis.

KEYWORDS : Nanotechnology, Microorganisms, Catalysis

I. INTRODUCTION

Synthesis of noble metal nanoparticles using biological entities has great interest due to their physico-chemical properties which are not observed either in individual molecules or in bulk metals. Nature has devised various processes for the synthesis of nano and micro scaled inorganic materials which have contributed to the development of relatively new and largely unexplored area of research based on biosynthesis of nanomaterials[1]. Gold and silver nanoparticles exhibit strong absorption of electromagnetic waves in the visible range due to Surface Plasmon Resonance (SPR) which is highly influenced by shape and size of the nanoparticles. Various synthesis procedures for gold and silver nanoparticles have been explained by many scientists around the globe. The special interest on noble metal has been taken since they don't undergo corrosion or oxidation easily.

II. PLANT EXTRACTS IN THE SYNTHESIS OF GOLD AND SILVER NANOPARTICLES

Gold nanoparticles were synthesized using various plant extracts, leaves and their biomasses. The size of the nanoparticles obtained from each plant was different from others. Gold nanotriangles formed were of 50 nm size from Aloe vera[2]. The pH dependent binding trend of Au(111) ions to Avena sativa[3] biomass and subsequent formation of Au nanoparticles of variable size were common during all pH level. Gold nanoparticles were 50-100 nm which were synthesized using Azadirachta indica[4]. Extracellular synthesis of gold nanoparticles occurred while using Emblica Officinalis[5] fruit extract as reducing agent. Similarly the size of gold nanoparticles formed were 50 nm of Pelargonium graveolens [6], 55nm of Cinnamomum camphora [7], 100 nm while using Lemon grass [8] and 20-40 nm of Tamarind [9] leaf extract. The surface plasmon resonance of gold nanoparticles will correspond to 520 nm and 420 nm for silver nanoparticles in a UV-visible spectral study also the wavelength may differ from +20 nm based on the size and shape of the nanoparticles formed. Silver nanoparticles are also synthesized using Aloe vera [2], Azadirachta indica [4], Cinnamomum camphora [7] and Pelargonium graveolens [10]. The main difference in controlling the size and shape of gold and silver nanoparticles was due to protective biomolecules and reductive biomolecules. The stabilization and reduction of nanoparticles were mainly due to water-soluble heterocyclic components and polyphenolic components. Gold nanoparticles are also synthesized extracellularly using marine alga Sargassum Wightii[24] Greville. Different scale of monodisperse TEM images of gold nanoparticles synthesized using this alga are presented in Fig1.

III. BACTERIA IN THE SYNTHESIS OF AU AND AG NANOPARTICLES

Pseudomonas stutzeri AG259 isolated from silver mines has shown to produce silver nanoparticles [11]. Nair and Pradeep reported that common Lactobacillus [12] strains found in buttermilk assisted the growth of gold and silver crystalline nanoparticles of well-defined morphology. Recently, bacterial cell supernatant of Pseudomonas aeruginosa was used for the reduction of gold ions resulting in the extracellular biosynthesis of gold nanoparticles[13]. This will help us to understand the biochemical and molecular mechanism of nanoparticles synthesis. Morphological control over the shape of gold nanoparticles has been achieved by using Plectonema boryanum[14] UTEX485 a filamentaeous cyanobacterium. When it is reacted with aqueous Au(S2O3)2 3- and AuCl4 - solutions at 25-100 o C for upto one month resulted in the precipitation of cubic gold nanoparticles and octahedral gold platelets.

IV. ROLE OF FUNGI

The use of fungi is potentially exciting since they secrete large amount of enzymes. Nanoparticles with well defined dimensions and good monodispersity can be obtained using fungi. Bioreduction of aqueous $AuCl_4$ - ions was carried out using fungus Verticillium[15] sp led to the formation of nanoparticles with fairly well defined dimensions. In this reaction it was concluded that surface trapping of chloroaurate ions occur in fungal cells by electrostatic interaction with positively charged groups in enzymes that are present in the mycelia cell wall. Fungi are known to secrete higher amounts of proteins thus might have significantly higher productivity of nanoparticles in biosynthetic approach using Fusarium oxysporum[16]. The fungus Aspergillus flavus[17] also resulted in the accumulation of silver nanoparticles on the surface of its cell wall when incubated with silver nitrate solution. Endophytic fungus Colletotrichum[6]sp. grows in the leaves of geranium has been used for the synthesis of stable and various shaped gold nanoparticles. When gold ions were incubated with Trichothecium[18] sp biomass under stationary led to the formation of extracellular nanoparticles. During shaking conditions the same resulted in intracellular synthesis, since enzyme and proteins could be responsible for the synthesis. Aspergillus fumigatus[19] fungus resulted in the rapid synthesis of silver nanoparticles and the particles formed were monodisperse which can be used in bacterial applications.

V. APPLICATION OF NANOPARTICLES

Development of nano-devices using biological materials and their use in wide array of applications on living organisms has recently attracted the attention of biologists towards nanobiotechnology. Here we have mentioned few applications based on biological concepts as foremost focus on living organisms. Gold nanoparticles based probes have been used in the identification of pathogenic bacteria in DNA-microarray technology. Silver nanoparticles have antibacterial effects, it has been reported that extracellularly synthesized silver nanoparticles using Fusarium oxysporum can be incorporated in several kinds of dressing materials. These clothes with silver nanoparticles are sterile and can be useful in hospitals to minimize infection with pathogenic bacteria such as Staphylococcus aureus [20]. Silver nanoparticles have applications in spectrally selective coatings and for biolabelling techniques. Currently, positive results have been achieved to control HIV-1 virus via preferential binding to the gp120 glycoprotein knobs. Due to this interaction, silver nanoparticles inhibit the virus from binding to host cells[21]. Gold nanoparticles have a good tunable shape and size dependent optical property which has been exploited in various surface coatings and biomedical applications. They are biocompatible, non toxic, bind readily to a large range of biomolecules such as amino acids, proteins/enzymes and DNA and expose large surface areas for the immobilization of such biomolecules. The ability to modulate the surface chemistry of gold nanoparticles by binding suitable ligands has important applications in many areas such as novel organic reactions, sensors (both inorganic and biological entities), drug/ DNA delivery and imaging.

Branched polyethylenimine covalently attached to gold nanoparticles has been investigated for the delivery of plasmid. The antitumor drug cisplatin was adsorbed on Au- Au_2S nanoparticles via 11-mercaptoundecanoic acid (MUA) layers. Gu et al., have shown that gold nanoparticles in toluene react with bis(vancomycine) cystamide in water under vigorous stirring conditions to form vancomycin-capped gold nanoparticles; the antibiotic-capped gold nanoparticles showed enhanced antibacterial activity against E. coli strains. Analytical detection and biological assay of antileukemic drug 5-fluorouracil[22] using gold nanoparticles as probe. Gold nanoparticles could serve as excellent carriers for insulin in the treatment of diabetes mellitus[23]. Proteins are the important part of cell's structure and machinery, understanding their functionalities is extremely important for further progress in human's welfare. Gold nanoparticles are also widely used in immunohistochemistry to identify protein-protein interaction.

VI. CONCLUSION AND FUTURE EXPLORATION

Biological resources are gaining importance in the synthesis and applications of the nanomaterials. Nanobiotechnology is at its infancy but the examples of the synthesis methods and their applications explained in the above article will magnetize the attention of people to proceed their research towards the endless biotechnology. In future the main focus is to elucidate the mechanism of the biomolecules which are exactly responsible for reduction and to find more applications in the area of drug delivery to support the medicine field to find solutions for the unanswered questions.

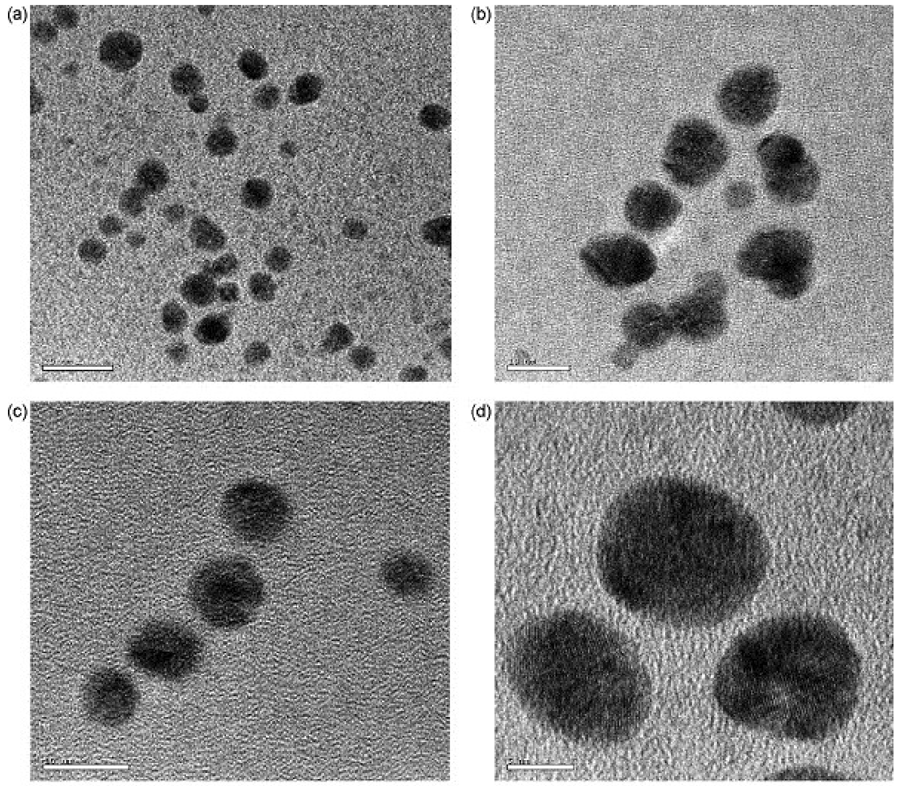

Fig .1 (a-d). The various TEM images of gold nanoparticles synthesized using Sargassum wightii Greville ranging from (a) 20 nm, (b)10 nm, (c)10 nm to (d)5 nm.

REFERENCES

[1] Deendayal Mandal. Mark E. Bolander .Debabrata Mukhopadhyay. Gobinda Sarkar .Priyabrata Mukherjee, “The use of microorganisms for the formation of metal nanoparticles and their application” ,Applied Microbiology and Biotechnology. 2006, vol.69, pp.485 - 492.

[2] S. Prathap Chandran, Minakshi Chaudhary, Renu Pasricha, Absar Ahmad, and Murali Sastry, “Synthesis of Gold Nanotriangles and Silver Nanoparticles Using Aloe vera Plant Extract” Biotechnology progress. 2006.vol 22(2), pp.577 – 583.

[3] Veronica Armendariz, Isaac Herrera, Jose R. peralta-videa, Miguel Jose-yacaman, Horacio Troiani, Patricia Santiago and Jorge L. Gardea-Torresdey “Size controlled gold nanoparticle formation by Avena sativa biomass: use of plants in nanobiotechnology” J. Nanoparticle Res.pp 2004.vol 6(4) pp.377 – 382.

[4] S. Shiv Shankar, Akhilesh Rai, Absar Ahmad, Murali Sastry “Rapid synthesis of Au, Ag, and bimetallic Au core–Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth” J. Colloid and Interface Science. 2004, Vol.275 (2), pp.496 – 502.

[5] Balaprasad Ankamwar, Chinmay Damle, Absar Ahmad, and Murali Sastry “Biosynthesis of Gold and Silver Nanoparticles Using Emblica Officinalis Fruit Extract, Their Phase Transfer and Transmetallation in an Organic Solution” J. Nanosci Nanotechnology. 2005.vol.5(12), pp.1665–1671.

[6] S. Shiv Shankar, Absar Ahmad, Renu Pasricha and Murali Sastry “Bioreduction of chloroaurate ions by geranium leaves and its endophytic fungus yields gold nanoparticles of different shapes” J. Materials chemistry. 2003. 13. 1822 – 1826.

[7] Jiale Huang, Qingbiao Li, Daohua Sun, Yinghua Lu, Yuanbo Su, Xin Yang, Huixuan Wang, Yuanpeng Wang, Wenyao Shao, Ning He, Jinqing Hong and Cuixue Chen “Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf” Nanotechnology. 2007. vol.18(10) pp.05104 – 105114.

[8] S. Shiv Shankar, Akhilesh Rai, Balaprasad Ankamwar, Amit Singh, Absar Ahmad and Murali Sastry “Biological synthesis of triangular gold nanoprisms” Nature Materials. 2004.vol.3. pp. 482 – 488.

[9] Balaprasad Ankamwar; Minakshi Chaudhary; Murali Sastry "Gold Nanotriangles Biologically Synthesized using Tamarind Leaf Extract and Potential Application in Vapor Sensing" Synth React Inorg Metal – Org Nanometal Chem. 2005.vol. 35 pp.9 – 26.

[10] S. Shiv Shankar, Absar Ahmad, and Murali Sastry "Geranium Leaf Assisted Biosynthesis of Silver Nanoparticles" Biotechnology Progress. 2003. vol.19(6),pp.1627 – 1631.

[11] R. Joerger, T. Klaus, C. G. Granqvist "Biologically Produced Silver-Carbon Composite Materials for Optically Functional Thin-Film Coatings",Adv. Mater. 2000, 12(6), 407 – 409.

[12] Binoj Nair and T. Pradeep "Coalescence of Nanoclusters and Formation of Submicron Crystallites Assisted by Lactobacillus Strains" Crystal growth design. 2002,vol.4(12). pp. 295– 298.

[13] M.I. Husseiny, M. Abd El-Aziz, Y. Badr, M.A. Mahmoud "Biosynthesis of gold nanoparticles using Pseudomonas aeruginosa" Spectrochim Acta A. 2007.vol.67(3-4) pp.1003– 1006.

[14] Maggy F. Lengke, Michael E. Fleet, and Gordon Southam "Morphology of Gold Nanoparticles Synthesized by Filamentous Cyanobacteria from Gold(I)-Thiosulfate and Gold(III)-Chloride Complexes" Langmuir. 2006.vol.22(6), pp.2780 – 2787.

[15] Mukherjee P, Ahmad A, Mandal D, Senapati S, Sainkar SR, KhanMI, Ramani R, Parischa R, Ajayakumar PV, Alam M, Sastry M,Kumar R "Bioreduction of AuCl4 - ions by the fungus, Verticillium sp. and surface trapping of the gold nanoparticles formed". Angew Chem Int Ed 2001vol.40, pp.3585–3588.

[16] Mukherjee P, Senapati S, Mandal D, Ahmad A, Khan MI, Kumar R, Sastry M. "Extracellular synthesis of gold nanoparticles by the fungus Fusarium oxysporum" Chembiochem. 2002 May 3;3(5):461-63.

[17] N. Vigneshwaran, N.M. Ashtaputre, P.V. Varadarajan, R.P. Nachane, K.M. Paralikar and R.H. Balasubramanya "Biological synthesis of silver nanoparticles using the fungus Aspergillus flavus" Materials Letters Vol. 61 (6), 2007, pp.1413-1418.

[18] Absar Ahmad, Satyajyoti Senapati, M. Islam Khan, Rajiv Kumar, and Murali Sastry "Extra-/Intracellular Biosynthesis of Gold Nanoparticles by an Alkalotolerant Fungus, Trichothecium sp" Journal of Biomedical nanotechnology 2005 vol.1(1),pp.47-53

[19] Bhainsa KC, D'Souza SF "Extracellular biosynthesis of silver nanoparticles using the fungus Aspergillus fumigatus" Colloids Surf B Biointerfaces. 2006, vol.47(2), pp.160-164.

[20] Dura´n N, Marcato PD, De S, Gabriel IH, Alves OL, Esposito E "Antibacterial effect of silver nanoparticles produced by fungal process on textile fabrics and their effluent treatment. J Biomed Nanotechnol 2007, vol.3, pp.203–208.

[21] Jose Luis Elechiguerra, Justin L Burt, Jose R Morones, Alejandra Camacho-Bragado, Xiaoxia Gao, Humberto H Lara and Miguel Jose Yacaman "Interaction of silver nanoparticles with HIV-1", J Nanobiotechnology 2005, vol.3, pp.6-16.

[22] Vaithilingam Selvaraj and Muthukaruppan Alagar, "Analytical detection and biological assay of antileukemic drug 5-fluorouracil using gold nanoparticles as probe", Pharmaceutical Nanotechnology,2007 vol.337(1-2), pp.275-281.

[23] Hrushikesh M. Joshi, Devika R. Bhumkar, Kalpana Joshi, Varsha Pokharkar, and Murali Sastry, "Gold Nanoparticles as Carriers for Efficient Transmucosal Insulin Delivery" Langmuir 2006, 22 (1), pp.300 -305.

[24] G. Singaravelu, J.S. Arockiamary, V. Ganesh Kumar, K. Govindraju "A novel extracellular synthesis of monodisperse gold nanoparticles using marine alga, Sargassum wightii Greville" Colloids and Surfaces B: Biointerfaces 2007, 15(1), pp. 97-101

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