



Available Online through
www.ijptonline.com

USEFULNESS OF MARINE ALGA FOR NANO APPLICATIONS

P. Rajasulochana*, P. Krishnamoorthy[@] and R. Dhamotharan**

*Lecturer Dept .Bioinformatics., Bharath University, Chennai, India.

** Reader, Dept. Plant Biology & Plant Biotechnology, Presidency College, Chennai, India.

[@] Professor and Dean, Dept. Bioinformatics, Bharath University, Chennai, India.

Email: prs_nellore@yahoo.com

Received on 16-10-2013

Accepted on 05-11-2013

Abstract

The field of nanotechnology has recently witnessed spectacular advances in the methods of nanomaterial fabrication and utilizing their exotic physicochemical and optoelectronic properties. With the development of new chemical or physical methods, the concern for environmental contaminations is also heightened as the chemical procedures involved in the synthesis of nanomaterials generate a large amount of hazardous byproducts. Thus, there is a need for 'green chemistry' that includes a clean, nontoxic and environment-friendly method of nanoparticle synthesis. As an alternative to conventional methods, biological methods are considered safe and ecologically sound for the nanomaterial fabrication. This paper examines the applicability of marine algae for nano field.

Introduction

Some well-known examples of microbial systems synthesizing inorganic materials include magnetotactic bacteria for magnetite nanoparticles, S-layer bacteria for gypsum and calcium carbonate layers and silver mine-inhabiting *Pseudomonas* sp. that reduces silver ions to form silver nanoparticles [1]. Nanocrystals of gold, silver and their alloys have been synthesized within the cells of lactic acid bacteria [2]. Fungus and actinomycete species were reported to synthesize silver or gold nanoparticles of different shapes and sizes [3], but use of green plants for similar nanoparticle biosynthesis methodologies is an exciting possibility that is largely unexplored.

The first report of plants synthesizing gold or silver nanoparticles appeared when alfalfa seedlings were shown to uptake gold or silver from metals-enriched nutrient media [4]. These studies demonstrated that Au(III) or Ag(I) ions were reduced in the solid media to Au(0) or Ag(0) by alfalfa plants, and then the metal atoms were absorbed into the

plant, where growth of nanoparticles took place. Another dimension was added to the 'green chemistry' approach for pure metal synthesis with the use of plant broths [5]. Shankar et al. used lemongrass and geranium plant extracts to induce the formation of gold nanoparticles or structures when reacted with aqueous chloroauric acid [5]. Here we demonstrate uptake of high amounts of gold(III) ions by a leguminous shrub, *Sesbania drummondii*, with subsequent reduction of Au(III) ions to Au(0) inside plant cells or tissues. What makes our report different from other studies is the intracellular formation and growth of spherical gold nanoparticles (6–20 nm) and their *in situ* catalytic function. The nanoparticle-bearing biomatrix of *Sesbania* has the ability to reduce a hazardous and toxic pollutant, aqueous 4-nitrophenol.

The optoelectronic and physicochemical properties of nanoscale materials are a strong function of particle size. Nanoparticle shape also contributes significantly to modulating their electronic properties [5]. Therefore, producing biologically-inspired nanostructures of a desirable size and morphology is critical to their commercial applicability. The shape and size of biogenic nanoparticles depends on the biological species involved, for example, geranium leaf broth reacted with aqueous chloroaurate ions induced a variety of gold nanoparticle shapes that included rods, flat sheets and triangles, while its endophytic fungus (*Colletotrichum* sp.) produced essentially spherical nanoparticles under the same conditions [5]. Yet another plant, lemongrass (leaf broth) induced the formation of a high percentage of single-crystalline gold nanotriangles under similar conditions. Even the parts of a plant species affect the nature of nanoparticle synthesis. The root broth prepared from geranium exhibited a propensity towards forming flat nanostructures in comparison with the spherical nanoparticles that formed with geranium stem broth [5].

The unusual physicochemical and optoelectronic properties of nanoscale materials have made nanotechnology one of the exciting areas of contemporary research. Chemical and physical methods have been widely used to synthesize nanoparticles of varying shapes and sizes [6]. However due to the simple recognition that environmentally friendly products and processes are economical in the long term, scientists have increasingly been trying to marry 'green chemistry' with nanotechnology. Yeast, fungi, bacteria and plant extracts have been so far used for the synthesis and assembly of metal and semiconductor nanostructures. Both unicellular and multicellular organisms are known to produce inorganic materials either intra- or extra-cellularly often of nanoscale dimensions and of exquisite morphology

and hierarchical assembly. Some well-known examples of bio-organisms synthesizing inorganic materials include magnetotactic bacteria (synthesizing magnetite nanoparticles), diatoms (synthesizing siliceous materials) and S-layer bacteria (producing gypsum and calcium carbonate layers). Even though many biotechnological applications such as remediation of toxic metals employ microorganisms such as bacteria and yeast, it is only relatively recently that material scientists have investigated microorganisms as eco-friendly nanofactories [7]. It was demonstrated that gold particles of nanoscale dimensions may be readily precipitated within bacterial cells by incubation of the cells with Au^{3+} ions. Joerger et al. [1] have shown that the bacteria *Pseudomonas stutzeri* isolated from silver mine, when placed in a concentrated aqueous solution of $AgNO_3$, resulted in the reduction of the Ag^+ ions and formation of silver nanoparticles of well-defined size and distinct morphology within the periplasmic space of the bacteria. Nano-crystals of gold, silver and their alloys have been synthesized by reaction of the corresponding metal ions within cells of lactic acid bacteria present in buttermilk [2]. More recent and detailed investigations into the use of microbes in the deliberate synthesis of nanoparticles of different chemical compositions include bacteria for CdS ZnS, Magnetite iron sulfide, yeast for PbS and CdS and algae for gold.

Nanotechnology forms a bridge between a range of highly promising disciplines in science and technology. It involves the tailoring of materials at atomic level to attain unique properties, which can be suitably manipulated for the desired applications. There is an enormous interest in the synthesis of nanomaterials due to their unusual optical, chemical, photo electrochemical and electronic properties. Biological methods using bacteria, fungi, algae or other biological materials [5] for the synthesis of metal and semiconductor nanoparticles represent a relatively unexplored and underexploited alternative, but had led to little advances with respect to size and shape control. Understanding biochemical processes that lead to the formation of nanoscale inorganic materials is therefore potentially appealing as eco-friendly alternatives to chemical methods for nanoparticle synthesis. In the area of nanotechnology, the development of techniques for the controlled synthesis of metal nanoparticles of well-defined size, shape and composition is an important aspect but a big challenge. The secrets gleaned from nature have led to the development of biomimetic approaches to the growth of advanced nanomaterials. Even though many biotechnological applications such as remediation of toxic metals employ microorganisms, like bacteria, fungi and yeast it is only recently that material

scientists have proposed microorganisms as possible eco-friendly nanofactories, for synthesis of nanoparticles, such as CdS [3], gold and silver. Intracellular synthesis of nanoparticles has been carried out using *Verticillium* sp., *Klebsiella aerogenes*, *Desulfovibrio desulfuricans* and *Pseudomonas stutzeris*, where as extracellular synthesis has been less explored. Foregoing facts disclose that the biological synthesis of metal nanoparticles is an exciting possibility, relatively unexplored and under exploited.

Materials and Methods

Marine alga is to be collected from the source and to be brought to the laboratory cleaned thoroughly in fresh water followed by distilled water and then shade dried for 5 days. Dried thalli were to be ground to powder in a glass mortar. Materials to be used for the synthesis of gold nanoparticles is chloroauric acid (HAuCl_4^-). Formation of Au (0) was carried out by taking 100 mg of seaweed powder in a 500 mL Erlenmeyer flask with 100 mL of 10^{-3} M aqueous HAuCl_4^- solution. The 95% of the bioreduction of HAuCl_4^- ions occurred within 2 hr. under stirring condition.

The following methods and equipment are generally used to characterize gold nanoparticles using standard protocols (i) UV-Visible spectra- UV-1601 Shimadzu spectrophotometer (ii) Fourier transform infrared (FT-IR) spectrum- a Shimadzu FTIR spectrophotometer (FTIR 8400) (iii) SEM-JOEL JSM-6360A (iv) TEM-JEOL TEMSCAN2000EX, (v) X- Ray diffraction (XRD) analysis-D8 Rich Seifert P3000 instrument operating at a voltage of 40 kV and a current of 30 mA with Cu $K\alpha 1$ radiations.

Reduction of the aqueous chloroaurate ions during exposure to the biomass of alga *Kappaphycus alvarezii* may be easily followed by UV-Vis spectroscopy. It is well known that gold nanoparticles exhibit lovely pink-ruby red colors, these colors arise due to excitation of surface plasmon vibrations in the gold nanoparticles. FT-IR analysis is to be carried out to identify the route for the stabilization of the nanoparticles in solution and also to gather clues as to what the reducing agents might be. SEM images show gold nanoparticles over long reduction times. A few larger particles are formed by the aggregation of smaller particles. This suggests that it may be possible to control particle size by controlling certain parameters such as time, initial metal concentration and temperature. The final products of gold uptake by algal biomass are nanoparticles whose size can be controlled by modifying the variables in the process. These micrographs evidence the presence of gold nanoparticles on the synthesized cell surface. It is possible to see

spherical nanoparticles randomly dispersed on the surface of the cell wall. Actually, few clusters of Au particles are observed on preferential regions of their surfaces. These results could be attributed to the colloid protector efficiency. The result obtained from the TEM study gives a clear indication regarding the shape and size of the nanoparticles. Fig. 1 shows the studies conducted by authors for marine red algae using TEM.

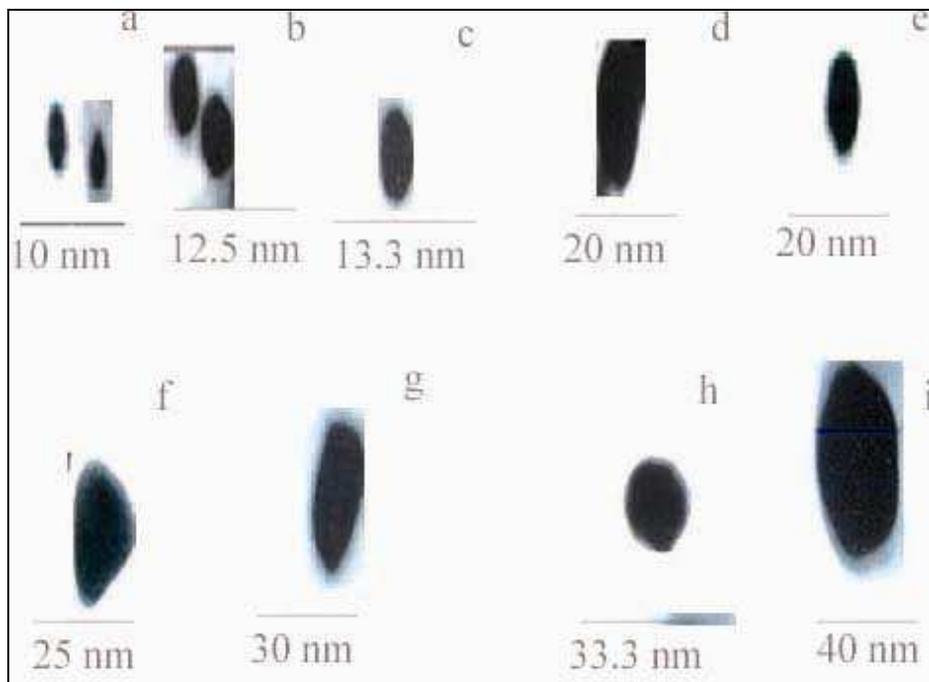


Fig. 1 TEM images of gold nanoparticles synthesized using *K. alvarezii*.

3. Conclusion

From this review, it is noted that the extracellular synthesis would make the process simpler and easier for downstream processing. Further, it can be noted that the results suggest that this methodology for gold nanoparticles synthesis using the algal biomass extracts is an attractive green process which is cost effective and environmentally benign, and is useful for achieving a high yield of gold nanoparticles. An immediate objective of further research is therefore to use the highly structured physical and biosynthetic activities of algal biomass to achieve controlled manipulation of the size and shape of the particles. Issues that need to be addressed include development of a fundamental understanding of the process mechanism on a cellular and molecular level, including isolation and identification of the compounds responsible for the reduction of gold ions.

References

1. Joerger R., Klaus T. and Granqvist C. G., 2000. Biologically produced silver-carbon composite materials for optically functional thin-film coatings. *Adv Mater.* 12, 407–409.
2. Nair B., Pradeep T., 2002. Coalescence of nanoclusters and formation of submicron crystallites assisted by *Lactobacillus* strains. *Crystal Growth Des.* 293–298.
3. Ahmad A., S., Senapati M. I., Khan R., Kumar M. and Sastry. 2003. Extracellular Biosynthesis of Monodisperse Gold Nanoparticles by a Novel Extremophilic Actinomycete *Thermomonospora* sp. *Langmuir* 19, 3550 -3553.
4. Gardea-Torresdey L., Gomez E., Peralta-Videa J. R., Parsons J. G., Troiani H. and Jose Yacaman M., 2003. Alfalfa spouts: a natural source for the synthesis of silver nanoparticles. *Langmuir* 19, 1357– 1361.
5. Shankar S. S., Ahmad A., Pasricha R. and Sastry M., 2003. Bioreduction of chloroaurate ions by geranium leaves and its endophytic fungus yields gold nanoparticles of different shapes. *J Mater Chem* 13, 1822–1826.
6. Sun Y. and Xia Y., 2002. Shape-Controlled Synthesis of Gold and Silver Nanoparticles. *Science* 298, 2176 – 2179.
7. Southam G. and Be veridge T. J., 1996. *Geochim. Cosmochim. Acta* 60, 4369.

Corresponding Author:

P. Rajasulochana*,

Email: prs_nellore@yahoo.com