Biological Synthesis of Nanoparticles from Plants

Approaches in Metal nanoparticles synthesis

Non-Biological

Top to Bottom

Mechanical/Ball milling, Diffusion flame

Thermal/ Laser ablation, Microwave, Ultra films, Lithography.

Bottom to Top

Chemical/electrochemical: Precipitation, Vapor deposition.

Atomic/molecular condensation, sol-gel process, Spray pyrolysis.

Biological (Green) synthesis:

Microscopic: Bacteria, Actinomycetes, Fungi

Macroscopic: Algae, Seaweeds, Plant Extracts (Leaves, Bark, Stem, Shoots, Seeds, Latex, Secondary metabolites, Roots, Twigs, peel, fruit, seedlings, essential oils, Tissue cultures, Gum)

Nanomaterials fabrication methods can be classified according to whether their assembly followed either:

i) Bottom-up approach, where smaller components of atomic or molecular dimensions self-assemble together, according to a natural physical principle or an externally applied driving force, to give rise to larger and more organized systems;

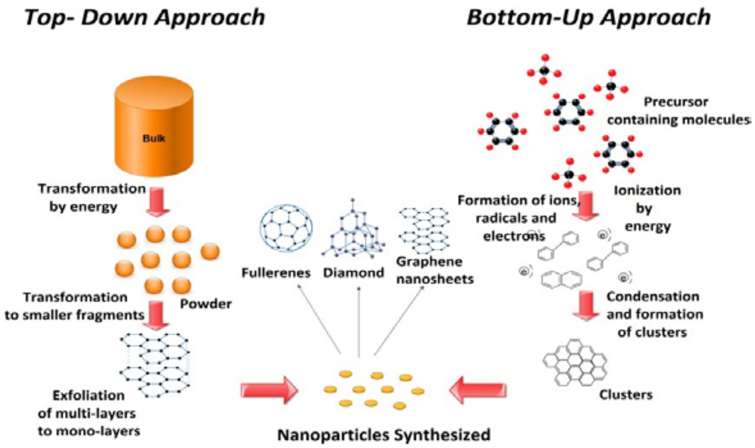
Self-assembly

Self-assembly is the 'fabrication tool' of nature: all natural materials, organic and inorganic, are produced through a self-assembly route to create complex structures with nanoscale precision.

Examples are the formation of the DNA double helix or the formation of the membrane cell from phospholipids.

In self-assembly, sub-units spontaneously organize and aggregate into stable, well-defined structures through **non-covalent interaction.**

ii) the top-down approach, a process that starts from a large piece and subsequently uses finer and finer tools for creating correspondingly smaller structures.



PHYSICAL AND CHEMICAL METHODS

Various physical and chemical processes have been exploited in the synthesis of several organic metal nanoparticles.

-The high energy requirement in physical methods of nanoparticle synthesis.

-the waste disposal problems in chemical synthesis,

-so both methods are costly.

-and generate toxic by product are major demerits of the conventional nanoparticle synthesis.

Biosynthesis of nanoparticles

Accordingly, there is a necessary need to extend for environmentally benign procedures for synthesis of nanoparticles.

A promising move towards to reach this objective is to develop the array of biological resources in nature.

Such drawbacks demand the development of clean, biocompatible, nonhazardous, inexpensive, energy-efficient, and eco-friendly methods for nanoparticles synthesis.

Phytonanotechnology

Phytonanotechnology has provided new avenues for the synthesis of nanoparticles and is an ecofriendly, simple, rapid, stable, and cost-effective method.

Phytonanotechnology has advantages, including: biocompatibility, Scalability, and the medical applicability of synthesizing nanoparticles using the universal solvent, water, as a reducing medium.

Mechanism of Biosynthesis

The exact mechanism and the components responsible for plant-mediated synthetic nanoparticles remain to be elucidated.

It has been proposed that proteins, amino acids, organic acid, vitamins, as well as secondary metabolites, such as flavonoids, alkaloids, polyphenols, terpenoids, heterocyclic compounds, and polysaccharides,

have significant roles in metal salt reduction and, furthermore, act as capping and stabilizing agents for synthesized nanoparticles.

Researcher showed the synthesis and stabilization of silver and gold nanoparticles by biomolecule attachment in Murraya koenigii leaf extract.

Reports also suggest that different mechanisms for synthesizing nanoparticles exist in different plant species.

For instance, specific components, such as emodin, a purgative resin with quinone compounds that is present in xerophytes plants (plants adapted to survive in deserts or environments with little water) are responsible for silver nanoparticle synthesis;

cyperoquinone, dietchequinone, and remirin in mesophytic plants (terrestrial plants adapted to neither a particularly dry nor particularly wet environment) are useful for metal nanoparticle synthesis.

Eugenol, the main terpenoid of Cinnamomum zeylanisum, was found to have a principal role in the synthesis of gold and silver nanoparticles.

Notably, decoct plants contain many secondary metabolites that may be suitable for nanoparticle synthesis

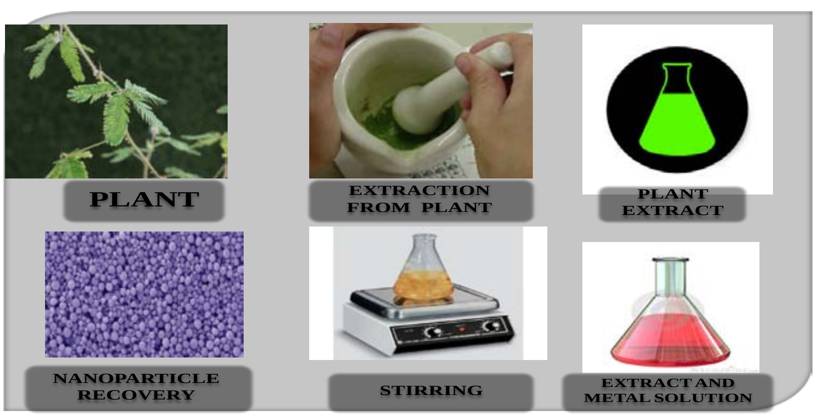
Recently, successfully synthesized gold and silver nano-particles using the leaf and root extract from the medicinal herb plant Panax ginseng suggested the use of medicinal plants as resources.

Additionally, various plant parts, including leaves, fruits, stems, roots, and their extracts, have been used for the synthesis of metal nanoparticles

Plant extracts

The reduction method using plant extracts is one step, low cost and eco-friendly, hence considered as the most preferred way for the synthesis of metal nanoparticles. Thus, this method may be included in the class of green technology.

Among various nanometals explored so far, nanoparticles of silver, gold, copper, zinc, palladium, titanium, nickel, indium etc. have been prepared by using a wide variety of plant extracts



Leaf extracts

The leaves of plants like *Mentha, Ocimum, and Eucalyptus were reported for the synthesis of* gold nanoparticles.

Ocimum leaf provided finer particles compared with other plant leaves used.

The polymorphic gold nanoparticles synthesis was reported from *Citrus limon, Murraya koenigii* Linn. leaves, and *Canna indica (red), Quisqualis indica pink flowers.*

The gold nanoparticles were polymorphic, stable, size 30–130 nm in non agglomerated form.

Seed extracts

The synthesis of silver nanoparticles through seeds of the plant *Elaeocarpus granitrus Roxb. (Rudraksha) was reported.*

The nanoparticles were involved for development of bionanocomposite with chitosan matrix and antimicrobial assay was done.

The synthesis of silver nanoparticles was reported using aqueous seed extract of *Jatropha curcas*.

The stable silver nanoparticles at different concentration of AgNO3 were spherical in shape with diameter ranging from 15 to 50 nm.

Essential oils

The synthesis of gold nanoparticles with essential oils extracted from the fresh leaves of *Anacardium occidentale was reported.*

The NPs synthesized at room temperature were hexagonal in shape while at higher temperature were a mixture of anisotropic particles.

Peel extract

The biosynthesis of silver nanoparticles (AgNPs) from *Citrus sinensis peel extract was* reported.

The synthesized AgNPs were an effective antibacterial agent against *Escherichia coli, Pseudomonas aeruginosa and Staphylococcus aureus.*

The aqueous extracts from the peels of Citrus fruits (orange, grapefruit, tangelo, lemon and lime) were used for the synthesis of AgNPs using microwave technology; the synthesis was successful for the orange peel extract.

Secondary metabolites

The plant broth of *Phyllanthus amarus* containing secondary metabolites was used for the formation of silver nanoparticles (AgNPs).

The coconut water was used for synthesis of gold nanoparticles through microwave irradiation.

The nanoparticles were tested for cytotoxicity on two human cancer cell lines, HeLa (human cervical cancer) and MCF-7 (human breast cancer). The nanoparticles found to be nontoxic.

Stem extracts

The stem extract of *Breynia rhamnoides* was used for synthesis of gold and silver nanoparticles was reported.

The nanoparticles showed antibacterial property against multi-drug resistant bacteria such as *Streptococcus pyogens, Pseudomonas aeruginosa, Escherichia coli, Bacillus subtilis* and *Staphylococcus aureus.*

Fruit extracts

Tribulus terrestris L. fruit bodies were used for synthesis of silver nanoparticles.

The nanoparticles were spherical shaped with 16-28 nm of size.

Latex extracts

The latex of *Jatropha curcas was used in* silver nanoparticles synthesis.

The particles radius was 10–20 nm and stabilized by the cyclic peptides.

The latex of *Euphorbia milii was used in* silver nanoparticles synthesis.

The silver nanoparticles sizes were of 10–50 nm .

Tissue culture extracts

The extracts from tissue culture-derived callus and leaf of the salt marsh plant (*Sesuvium portulacastrum L.) used in the synthesis of silver* nanoparticles.

The callus extract was able to produce antimicrobial silver nanoparticles than leaf extract.

The silver nanoparticles synthesized were spherical in shape with size 5 to 20 nm. The silver nanoparticles inhibited clinical test strains of bacteria and fungi.