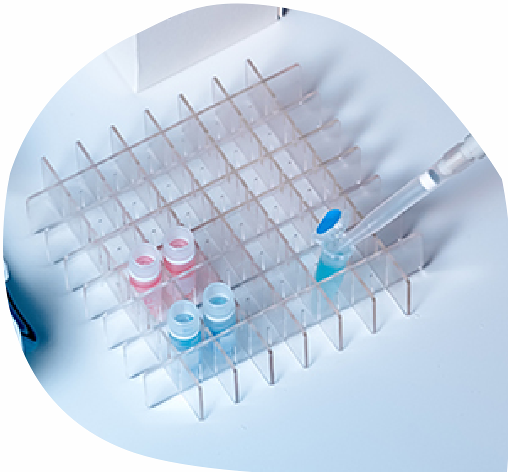

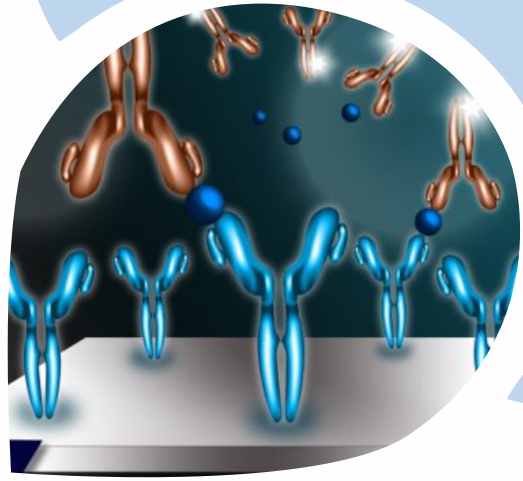

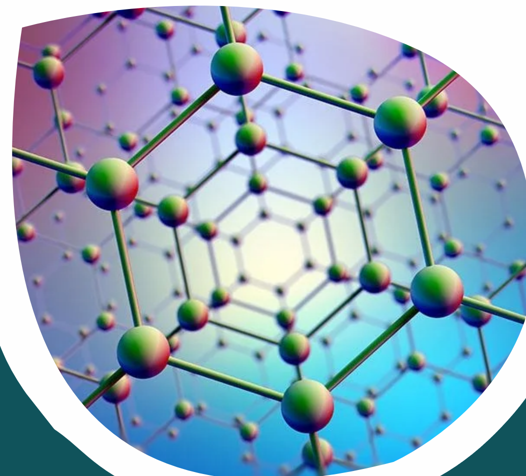

BIOLOGICAL METHODS OF NANOMATERIAL SYNTHESIS AND THEIR APPLICATIONS

DR. SULOCHANA MUNGA

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Edited by

DR. SULOCHANA MUNGA

Lecturer in Chemistry

S.Y.T.R Govt Degree College, Madakasira,

Sri Krishnadevaraya University, Ananthapur,

Andhra Pradesh, India.

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Chapter
7

Glimpses on Bioassisted Synthesis of Nanostructures

CHITRA. M[1], NEELAKANDESWARI. N[2], VASANTHAPRIYA. R[1] & UTHAYARANI. K[1]

[1] Department of Physics, Sri Ramakrishna Engineering College,
Coimbatore - 641 022, Tamilnadu, India.
[2]Department of Chemistry, Nallamuthu Gounder Mahalingam College,
Pollachi - 642 001, Tamilnadu, India.
*Corresponding Author: Neelakandeswari. N, Email: neelakandeswaringm@gmail.com

ABSTRACT
Bio-assisted synthesis of nanostructures has attracted the attention of scientific community due to its rapid, inexpensive and eco-friendly methods. In this present review article, nanostructures synthesised using biotemplates, phytochemicals and microbes have been explored as a tool to produce 3D hierarchical structures for technological advancements is studied in detail. These approaches aid in tailoring the multidimensional properties of nanomaterials by controlling the shape, size and morphology.

KEYWORDS: Nanostructures, Biotemplates, Phytochemicals, Microbes.

INTRODUCTION
At the outset of the development in nanotechnology, researchers mimic nature and pay attention in fabricating devices using novel bio-inspired structures. To encounter the bottlenecks in the conventional physical and chemical methods of preparing nanomaterials, research is explored on various environmentally reliable synthesis procedures [1]. In this present article, the role of biotemplates, phytochemicals and microbes in synthesising nanostructures have been discussed in detail. In the templated approach, the templates duplicate their morphological characteristics onto the synthesised material. The functionality of these biological species guides the assembly of the inorganic material during nucleation. Later, the template is removed upon calcination resulting in the required material with purity and hierarchical porous architecture [2]. In the phytochemical approach, the plants provide alcohols, phenols, proteins, alkaloids and so on which is eco-friendly and could be used for large scale production. In the microbial synthesis, they provide the key enzymes replacing the hazardous reducing and stabilising agents [3].

IMPORTANCE OF NANOSTRUCTURES

The growth of nanotechnology has revolutionised in the field of optoelectronics, catalysis, water treatment, sensors, supercapacitors, drug delivery, energy harvesting, energy storage areas, bioremediation, food conservation, pharmaceuticals and biological tagging [4]. Nanostructures owing to their reduction in size, diverse morphologies and larger surface area exhibit unique properties that significantly differ from their coarse-grained materials. These include increased strength, hardness, enhanced diffusivity, improved ductility, toughness, increased specific heat, higher thermal expansion coefficient, lower thermal conductivity, increased oscillator strength, blue shifted absorption, increased luminescence and superior soft magnetic properties in comparison to conventional bulk materials [5, 6]. These properties of nanostructures are size dependent in nanometer range due larger surface area and quantum confinement effect [5 -7]. Nowadays, it is challenging to synthesize pure nanosized particles of different morphology.

SIGNIFICANCE OF BIOSYNTHESIS APPROACH

Nowadays in the era of nanotechnology, engineered nanostructures with different architecture have been synthesised via various top down and bottom up approaches [8]. These approaches involve the usage of toxic chemicals, high energy consumption, requires high temperature, high cost and not eco-friendly, expels solid or liquid wastes which requires proper disposal treatments. To address these issues in various conventional approaches, emphasis is made on to investigate the synthesis of nanostructures using biotemplates, green approach and microbes {Fig. 1].

Synthesis using biotemplates is a cost effective alternative for the synthesis of size or shape controlled patterned nanostructures. The use of templates with micro or nano sized known patterns is a low cost, easy and versatile method to fabricate nanomaterials with defined structures [9 - 11]. The material is made to deposit onto such templates and grown to form respective nanomaterials having the shape of the template. Once the material is grown over the template, the templates are removed by suitable methods to produce free standing nanostructures. Integrating biosystems into the nanotechnology has been taken up as a novel task by many researchers nowadays. Scientists put forth their efforts in synthesising these nanostructures using agricultural wastes which were used as reducing and capping agents which has been alternative to the use of hazardous and toxic chemicals [12 - 14].

In addition, researchers also work on synthesis of nanomaterial using green chemistry. This green synthesis is a multidisciplinary and rapidly developing field which promotes safe and eco-friendly research culture, prevents the formation of by-products, reduces the energy demand, utilizes renewable and natural resources (Biosynthesis of Nanomaterials using Algae).

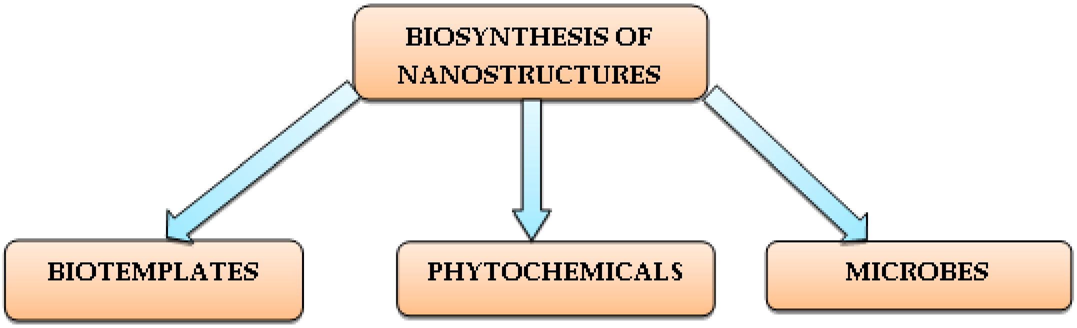

Fig. 1: Approaches for Biosynthesis of Nanostructures

ROLE OF BIOTEMPLATES

Biotemplates have now become a new source of inspiration for synthesising large surface area nanostructures which impart enhanced performance while fabricating devices. The well-defined chemical and structural heterogeneity of the biotemplates in the current scenario can be exploited for their precise and multifaceted control over shape, size, and crystal orientation, and morphology, chemo-selectivity, binding agents, inorganic localization and higher-order assembly. Reports available on templates such as cotton, wood, sorghum straw, onion, egg shell membrane, grape fruit, pineapple, cucumber etc., [Table 1] reveal that the morphology imparted on the nanostructures while synthesising promotes greater catalytic reactivity and larger specific surface area. The formation of natural hierarchical nanostructures by adding new functionalities in the form of templates promotes better structural and device performance. Few to say, cotton which has cellulose structure provides twisted ribbon like morphology results in the formation of LaFeO3 hollow fibers with enhanced gas sensing performance [Peng et al (2010)]. Yuan Chun et al (2008) replicated the cotton morphology in the resulting of high selectivity in the catalytic decomposition of alcohols using MgO. Works on sorghum straw results in the formation of honeycomb and biomorphic porous $LaFeO_3$. The better performance of these mentioned nanostructures were attributed to their porous structure, large surface area, numerous surface active sites and presence of more oxygen defects [13 - 16]. Also from the table it is observed that ZnO which is a multifunctional material synthesised via palm olein, rice, butterfly wings, tomato, orange juice, silk and so on results in diverse morphologies. Thus, various inorganic materials prepared via different biotemplates resulted in portable devices with flexiblity and excellent sustainability.

Method used	Name of the Material	Biotemplate/Plant Extract/Microbes	Morphology	Ref
Biotemplates	ZnO	rice	stars and flakes	[9]
	TiO_2	rice straw	nanoparticles	[10]
	ZnO	butterfly wings	nanoparticles	[11]
	Fe_2O_3	egg albumen	quantum dots	[12]
	$Li_4Ti_5O_{12}$-TiO_2	butterfly wings	3D nanostructures	[13]
	Au	egg shell membrane	nanoparticles	[14]
	ZnO	tomato extract	nanoparticles	[15]
	Ag	potato	nanoparticles	[16]

Table. 1: Review of Biotemplated Approaches

ROLE OF PHYTOCHEMICALS

Among the bottom up approaches towards the synthesis of nanoparticles, generally chemical reducing agents are employed. Harsh reaction conditions and expensive methodologies employed with the reducing chemicals limit their applicability in the voluminous production of nanoparticles. In this scenario, use of phytochemicals as reducing as well as capping agents in nanoparticle synthesis grasp the attention of researchers. Extracts from various parts of plants like leaves, flowers, barks, fruit, seeds, etc., are easily available and used as an alternate for the existing chemical routs. Phytochemicals present in these extracts like polyphenols, alkaloids, terpenoids, flavanoids etc., are responsible for the reduction of metal precursor to a nano structure [17 - 18]. In addition to the reduction, these phytochemicals can also provide extra stability to the nano structures via capping on the surface with biomolecules and thereby hinders self aggregation. There are varieties of plants and their extracts employed for the preparation of nanoparticles. Among the metal nanoparticles, silver nanoparticles are the most commonly fabricated nanoparticles using phytochemicals owing to the simple, cost effective and eco-friendly schemes adopted [19 - 20]. Different plant extracts like Diospyros salvatica, Aegal marmelos, Capsicum annum, Swertia paniculate, Allium sativum, Psidium guajava, Azadirachta indica, Rosmarinus officinalis, Aloe vera, Jatropha curcas, Cinnamon zeylancium, Euphorbia hirta, Acalypha indica, Tinospora cordifolia, Vitex Negundo, Catharanthus roseus, Ananas comosus, Malva parviflora [21] were used for the synthesis of Ag NPs. Not only metal nanopaarticles like Ag, Au and Pt, but also metal oxides like CuO, MgO, ZnO, Fe_2O_3 were also been synthesized using photochemical owing to their above mentioned advantages. However, the plant mediated synthesis indirectly induces the threat to the loss of some medicinal plants, it is very much important to use plant based or agro wastes instead of a medicinally important fresh plants.

ROLE OF MICROBES

The use of microbial cells for the synthesis of nanosized materials has recently emerged as a novel approach for the synthesis of metal nanoparticles. Although the efforts directed towards the biosynthesis of nanomaterials are recent, the interactions between microorganisms and metals have been well documented and the ability of microorganisms to extract and/or accumulate metals is employed in commercial biotechnological processes such as bioleaching and bioremediation [22].

Some microorganisms can survive and grow even at high metal ion concentration due to their resistance to the metal. The mechanisms involve: efflux systems, biosorption, bioaccumulation, extra-cellular complexation or precipitation of metals and lack of specific metal transport systems. A little is known about the resistance against the noble metals, although it has been stated that gold can serve as a slow action drug in rheumatology. Some metal nanoparticles (Ag) are highly toxic to most microbial cells can be used as a biocide or antimicrobial agent. These metal-microbe interactions have important role in several biotechnological applications including the field of bioremediation, biomineralisation, bioleaching and microbial corrosion. Microorganisms considered as potential biofactory for synthesis of metallic nanoparticles such as cadmium sulfide, gold and silver [23]. A variety of bacteria, yeast, fungi and also some plant extracts have the ability to produce various kinds of nanoparticles. In addition, controlled size and shape of the nanoparticles can be achieved by manipulating the parameters such as pH, temperature, substrate concentration and exposure time to substrate [24].

Reactivity of metals with various biological agents is not unique and hence the exact mechanism of microbial synthesis of nanoparticles is yet to be explored. Chemicals produced in intra and extra cellular microorganisms are different and hence the mechanism of nanoparticle production is also vary. In the case of extra cellular microorganisms, the electrostatic interaction between the metal ion and the cell wall facilitates the reduction of metal cations by the enzymes present in the cell wall and finally the nanoparticles will diffuse out through the cell wall. While, the mechanism of intra cellular synthesis is associated with the enzyme nitrate reductase, which reduces the metal ions and produces the nanoparticles [25].

CONCLUSION

This review article presents a glimpse on the bioassisted approaches with well-defined architectures favoring the synthesis of nanostructures in an eco-friendly and cost effective manner

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