Journal of Medicinal and Nanomaterials Chemistry 4 (2020) 291-299

SPC

Journal of Medicinal and Nanomaterials Chemistry

Journal homepage: https://jmnc.samipubco.com/

Review Article

# Plant mediated green synthesis of lanthanum oxide ($La_2O_3$) nanoparticles: A review

Harshal Dabhane[a,b], Suresh Ghotekar[c], Pawan Tambade[a,*], Vijay Medhane[b]

[a] *Department of Chemistry, G.M.D Arts, B.W Commerce and Science College, Sinnar, 422 103, Savitribai Phule Pune University, Maharashtra, India*

[b] *Department of Chemistry, K.R.T. Arts, B.H. Commerce and A.M. Science College, Nashik, Savitribai Phule Pune University, Maharashtra, India*

[c] *Department of Chemistry, Sanjivani Arts, Commerce and Science College, Kopargaon 423 603, Savitribai Phule Pune University, Maharashtra, India*

**ARTICLE INFORMATION**

Received: 5 May 2020
Received in revised: 15 June 2020
Accepted: 19 June 2020
Available online: 23 July 2020

DOI: 10.48309/JMNC.2020.4.3

**KEYWORDS**

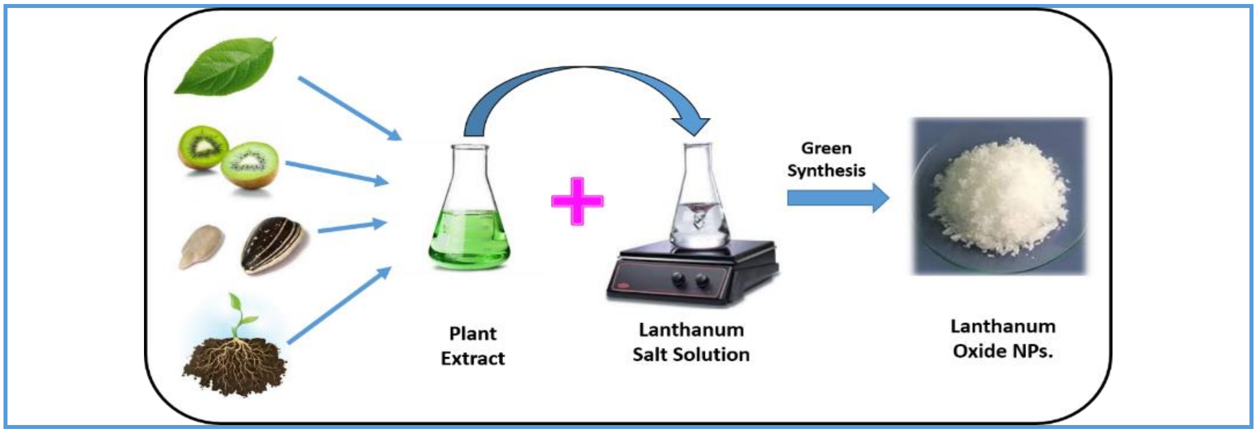
Green Synthesis
Plant extract
Nanotechnology
$La_2O_3$ NPs

**ABSTRACT**

Nanotechnology facilitates numerous magnificent applications due to the desired shapes and size of the nanoparticles (NPs). However, restricted study of synthesis and characterization of rare earth metal make them more fascinating to choose for further research, lanthanum oxide nanoparticles ($La_2O_3$ NPs) is an excellent choice for research due to their fabulous applications in electronics, sensors, insulators, antimicrobial agents, biomedicines, and biocatalyst. Due to countless importance of $La_2O_3$ NPs, in literature its synthesis is described by several chemical, physical methods, and there are quite a few reports exploring plants as catalyst to achieve synthesis goals. In a green synthesis of $La_2O_3$ NPs using plants, the plant extract is used as a surfactant that encompasses the biomolecule leds the bio-reduction of lanthanum salt into the $La_2O_3$ NPs. This review enlightens the synthesis, characterization, and applications of the $La_2O_3$ NPs obtained using various plant extracts.

Corresponding author, email: pawan.tambade@gmail.com (P. Tambade).
Tel.: +918275182035.

**Graphical Abstract**




## Introduction

Nowadays, nanotechnology serves as a master key to solve numerous difficulties in diverse sectors. NPs obtained from specific metalwork have been used in electronics, agriculture, biomedicine, catalysis, food technology, and textile industry [1–30]. In electronics, NPs are used to make the memory-related device as a memory circuit, memory storage, photovoltaic cell, light-emitting device, nanocrystal phosphors, and battery relate devices [31]. Nanotechnology also strengthens the medical field through its biomedical applications, several uses as fluorescence biological labels, drug and gene delivery, bio-detection of pathogens, detection of protein, probing DNA structure, tissue engineering, tumor destruction *via* heating (Hyperthermia), separation and purification of biological molecule and cell, MRI contrast enhancement and phagokinetic studies [32].

In the case of agriculture, fabulous applications have been studied and utilized to develop as pesticides and fertilizer, nano-insecticidal, nano-fungicides, controlling plant viruses, and food packaging [33]. One of the prime concern today in front of scientific community while creating and executing new ventures is to keep environment safe and clean. With the help of nanotechnology we do bioremediation of diverse contaminants, water treatment, and production of clean energy, nanotechnology also used in automobile industries to make vehicle and their parts [34]. Synthesis of nanomaterial from transition and other elements are most often studied by researchers and numerous NPs were obtained from transition metal using various physical and chemical methods and their miraculous applications were studied near about in every filed. However, the rare earth metals have minimal attention to researchers toward itself even though they have decent applications. Lanthanum is the first rare earth metal that undergoes size reduction achieves to bestow lanthanum oxide NPs having the largest band gap, lowest lattice energy, and high dielectric constant, hence it can be used for future electronics material [35]. Due to these properties, it has been used in MOSFET, NVM, insulator, nano-volatile memories, and catalytic fields (Figure 1) [36]. It has also been used as a heterogeneous biocatalyst for biodiesel synthesis by transesterification of *Jatrophacurcus L.* oil [37, 38]. Photoluminescence and photocatalytic activity shown by $La_2O_3$ NPs and antimicrobial activities were tested against various pathogens using various methods [39–45].

Due to the high-quality applications of $La_2O_3$ NPs in electronics and other fields, it was synthesized using several chemical and physical methods (Table 1). The $La_2O_3$ NPs was reported using chemical bath deposition [46], co-precipitation method [41, 44, 47–49], hydration technique [50], hydrothermal reaction [51, 52], micro emulsion method [53], reflux method [54], sol-gel methods [55], solution combustion [36], solvo thermal method [56], sonochemical method [57], spray pyrolysis [58], and thermal decomposition method [59, 60]. The choice of methods of formation of NPs based on the advantages, the above-cited method was certain downsides such as time-consuming, costly, non-eco-friendly, and required high energy. To avoid such problems, the way of green synthesis were adopt as it is biocompatible, cheap, non-toxic, and not required high energy for synthesis. The fabrication of $La_2O_3$ NPs using plant extract is a good task. Moreover, it does not have any negative effect on nature. So it has been used as a good alternative to chemical and physical methods of synthesis.

This review aimed at designing and construction of $La_2O_3$ NPs using various plant extracts and discussion over their applications.

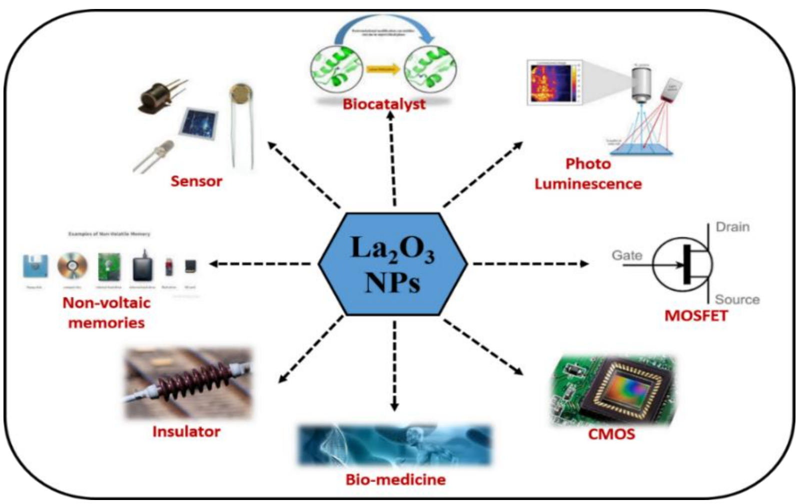



**Figure 1.** Applications of $La_2O_3$ NPs

**Table 1.** Different methods for the synthesis of $La_2O_3$ NPs

| Sr. No. | Name of the Synthetic Process | Reference |
|---|---|---|
| 1 | Chemical Bath Deposition | [46] |
| 2 | Co-precipitation Method | [47, 48, 49] |
| 3 | Hydration Technique | [50] |
| 4 | Hydrothermal reaction | [51, 52] |
| 5 | Microemulsion method | [53] |
| 6 | Reflux method | [54] |
| 7 | Sol-Gel Method | [55] |
| 8 | Solution combustion | [35, 36] |
| 9 | Solvothermal Method | [56] |
| 10 | Sono-chemical Method | [57] |
| 11 | Spray pyrolysis | [58] |
| 12 | Thermal decomposition | [59, 60] |

## Green synthesis of $La_2O_3$ NPs

Synthesis of NPs comes across several methods that categories into various types, the most common are chemical and physical methods, each method has some disadvantages. Henceforth, need to design such a protocols that minimizes the existing shortcomings. The green synthesis of NPs is the best option due to its fabulous advantages such as one-pot, non-toxic, bio-compatible, and required less energy [1, 4, 5]. The use of plant extracts in the synthesis of $La_2O_3$ NPs are eco-friendly, simple, rapid and proceed in one step, the biomolecule present in various part of the plant such as amino acid, proteins, tannins, enzymes, saponins, phenol, vitamins, sugar and flavonoids having medicinal importance and environmentally gracious (Figure 2). The biomolecule containing different functional groups activates in basic medium and attracted to positive metal ions to form interaction, during this process metal ion undergoes bio-reduction to yield $La_2O_3$ NPs. Few plants are reported to facilitate the synthesis of $La_2O_3$ NPs (Table 2). Various parts of plants such as fruit, flower, leaf, latex, seed, peel, and roots are used for the synthesis of $La_2O_3$ NPs. The $La_2O_3$ NPs are found to achieve in different morphologies, size and are showed various applications for diverse fields. The synthesized $La_2O_3$ NPs were analyzed using different techniques [62].

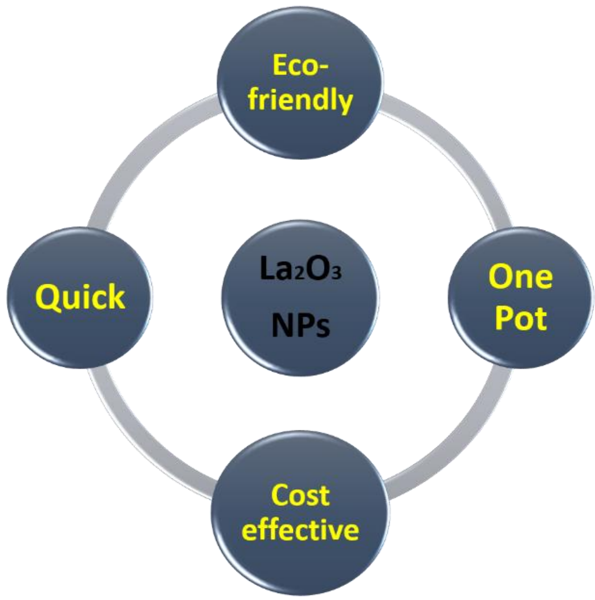



**Figure 2.** Advantages of green synthesis

**Table 2.** Green synthesis of $La_2O_3$ NPs using different plant sources with morphology and size

| Sr. No | Name of Plant | Part | Morphology | Size (nm) | Ref. |
|---|---|---|---|---|---|
| 1. | *Physalis angulata* | Leaves | Spherical | 25-50 | [61] |
| 2. | *Datura metel* | Leaves | Hexagonal | 200-500 | [62] |
| 3. | *Muntingia calabura* | Leaves | Spherical | 100 | [63] |
| 4. | *Andrographis paniculata* | Leaves | BBC | 43 | [64] |
| 5. | *Vigna radiata* | Seed | Round | -- | [65] |
| 6. | *Trigonella foenum-graecum* | Seed | Spherical | 100 | [66] |

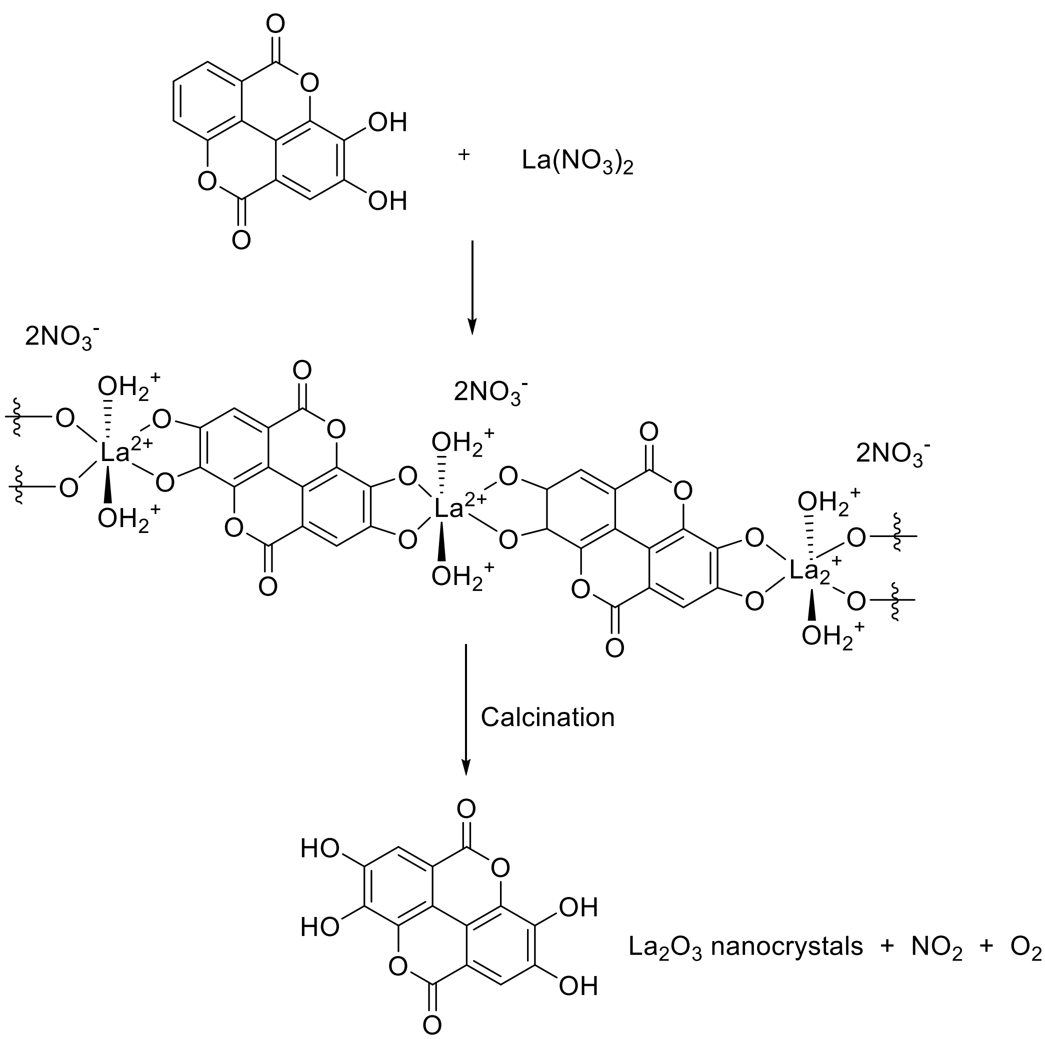
## General protocol explored for green synthesis of $La_2O_3$ NPs

The plant assisted green synthesis of NPs involves the use of phytochemicals present in different parts of the plant to yield the NPs of different size and morphology. Very few plants are explored for the synthesis of $La_2O_3$ NPs, as depicted in Table 2. The choice of the plant depends upon the phytochemicals present in it and their medicinal importance, after the selection of plant, the particular part was chosen (fruit, flower, leaf, peel, latex, and roots), wash number of times with distilled water and is crush or chop into small pieces and boil up to get the extract. The plant extract was filtered through filter paper and the lanthanum salt solution was added with continuous stirring at desired temperature, in order to maintain the basic pH a solution of base (NaOH) is added. In basic medium the acidic proton gets abstracted and phytochemicals are activated to reacts with lanthanum salt, after the bio-reduction it yields $La_2O_3$ NPs. The prepared NPs are separated by filtration and wash with distilled water, dried and calcined, characterized and finally employed for desired applications [61].

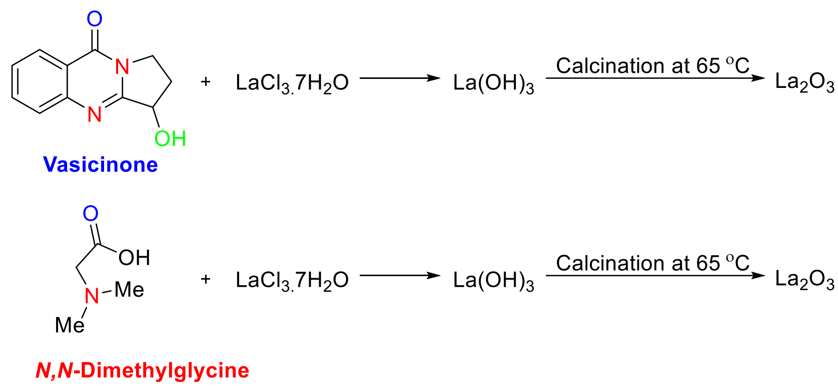
**Mechanism of green synthesis of $La_2O_3$ NPs**

In the plant-mediated synthesis of $La_2O_3$ NPs, the phytochemical reacts with lanthanum salt and carry out the reduction in to the nano level. R. Uma Maheswari and co-workers reported the synthesis of $La_2O_3$ NPs using organic *Datura metel* leaf extract and explain the mechanism for the formation of $La_2O_3$ NPs [62] (Scheme 1).

Muthulakshmi *et al.* reported [BIMB $PF_6$] ionic liquid driven synthesis of $La_2O_3$ nanoparticles using *andrographi spaniculata* leaves extract. The authors suggested possible reaction mechanism for the synthesis of nanoparticles, as depicted in Scheme 2 [64]. As it was reported, vasicinone (a quinazoline alkaloid) and or *N*,*N*-dimethylglycine reacted with $LaCl_3{\cdot}7H_2O$ to form corresponding hydroxides which on calcination provide $La_2O_3$ NPs.




**Scheme 1.** Mechanism of formatioof Lanthanum Oxide nanocrystals [52]




**Scheme 2.** Synthesis mechanism of $La_2O_3$ NPs by vasicinone and *N*, *N*-dimethylglycine [54]

### Characterization of $La_2O_3$ NPs

The physicochemical properties of NPs are depending up on their morphology and size, and the size and morphology can be controlled and manipulated by the way of synthesis. There are many spectroscopic and electronic microscopic techniques are available for characterization of NPs which gives us the relevant information about synthesized NPs. The synthesized $La_2O_3$ NPs were characterized using various analytical tools viz. UV-Visible (UV-Vis), Fourier transform infrared spectroscopy (FT-IR), photoluminescence (PL), Brunauer-Emmett-Teller (BET), zeta potential (ZP), scanning electronic microscopy (SEM), transmission electronic microscopy (TEM), thermogravimetric analysis (TGA), powder X-ray diffraction (XRD), dynamic light scattering (DLS), energy-dispersive X-ray spectroscopy (EDS), and atomic force microscopy (AFM) (Figure 3). The Size and morphology of NPs analyzed by UV-Vis, IR, XRD, SEM, and TEM techniques whereas the thermal stability is identified by TGA method, the surface and porosity are determined by BET methods.

### Applications of $La_2O_3$ NPs

The synthesized $La_2O_3$ NPs has been widely utilized in electronics especially in the construction of MOSFET and NVM devices, and in biomedicine and as a biocatalyst. Manoj Kumar and co-workers [63] reported the biosynthesis of $La_2O_3$ NPs using *Mutingia calabura* leaf extract, the nanoparticles were tested for antibacterial activity, bacterial toxicity, antioxidant activity, blood compatibility, and dye degradation efficiency. Antimicrobial and antioxidant activity was analyzed using the well diffusion method. Also, the photocatalytic dye degradation was tested on Coomasie brilliant blue dye, and the results were analyzed using the FT-IR techniques.

Ionic liquid mediated morphologically improved lanthanum oxide nanoparticles are synthesized using *Andrographi spaniculata* leaves extract by Muthulakshmi and co-workers. The IL assisted $La_2O_3$ NPs were characterized using various tools like powder XRD, FT-IR, UV-visible spectroscopy, SEM EDX, TEM, and XPS analysis. The synthesized materials exhibited applications as antibacterial and anti-inflammatory agents. The antibacterial performance of $La_2O_3$ NPs tested for *E. coli* and *S. aureus* [64].

Abraham *et al.* [65] reported the biosynthesis of $La_2O_3$ NPs using green gram seed (*Vigna radiata*). The as synthesized material was analyzed using the FT-IR and SEM analysis. The obtained material was tested against the clinical pathogens such as *Pseudomonas aeruginosa, Serratia marcescens, Escherichia coli, Shigella sp., Staphylococcus aureus, Proteus mirabilis, Enterobactersp, Salmonella sp.,* and *Klebsiella pneumonia.* The antioxidant as well cytotoxicity activity of $La_2O_3$ NPs also tested against the osteosarcoma cell lines. Abraham and co-workers [66] also explored *Trigonella foenum-graecum* seed extract for the synthesis of $La_2O_3$ NPs and characterized using the FT-IR and SEM analysis.

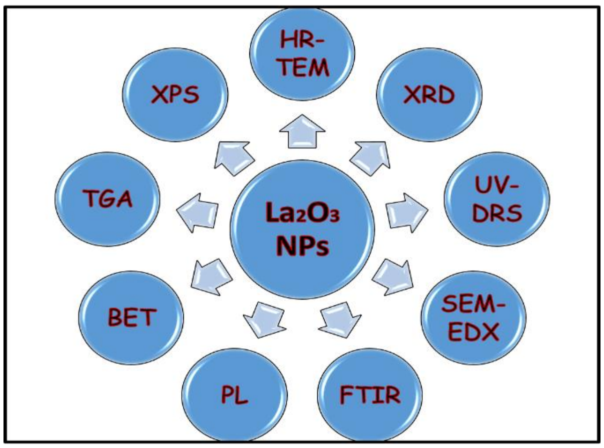



**Figure 3.** Various tools explored for characterization of $La_2O_3$ NPs

## Conclusions

$La_2O_3$ NPs are having tremendous potential to explore for various fields of science and technology. The synthesis of $La_2O_3$ NPs is reported using various known methods. The plant-assisted synthesis of NPs is relatively new and emerging areas in the field of nanotechnology, because plant materials can act as a stabilizing and reducing agents for synthesis of $La_2O_3$ NPs with desired shapes and size. However, plant mediated synthesis of the $La_2O_3$ NPs has paid very less attention by scientific community and thus there is wide scope for the $La_2O_3$ NPs synthesis using various plants. Therewithal, further research needs to highlight the lucid mechanism behind the synthesis of $La_2O_3$ NPs and improve their effective applications for diverse branches of nanotechnology.

## Disclosure Statement

No potential conflict of interest was reported by the authors.

## Orcid

*Suresh Ghotekar* 0000-0001-7679-8344

*Pawan Tambade* 0000-0002-9728-7591

## References

[1]. Basnet P., Chanu T.I., Samanta D., Chatterjee S. *Journal of Photochemistry and Photobiology B: Biology*, 2018, **183**:201

[2]. Ghosh C.R., Paria S. *Chemical Reviews*, 2011, **112**:2373

[3]. Daniel M.C., Astruc D. *Chemical Reviews*, 2004, **104**:293

[4]. Ghotekar S. *Asian J. Green Chem.*, 2019, **3**:187

[5]. Nikam A., Pagar T., Ghotekar S., Pagar K., Pansambal S. *Journal of Chemical Reviews*, 2019, **1**:154

[6]. Gawande M.B., Goswami A., Felpin F.X., Asefa T., Huang X., Silva R., Varma R.S. *Chemical Reviews*, 2016, **116**:3722

[7]. Frewer L.J., Gupta N., George S., Fischer A.R., Giles E.L., Coles D. *Trends in food science & technology*, 2014, **40**:211

[8]. Kamble D.R., Bangale S.V., Ghotekar S.K., Bamane S.R. *J. Nanostruct.*, 2018, **8**:144

[9]. Syedmoradi L., Daneshpour M., Alvandipour M., Gomez F.A., Hajghassem H., Omidfar K. *Biosensors and Bioelectronics*, 2017, **87**:373

[10]. Ghotekar S., Pansambal S., Pagar K., Pardeshi O., Oza R. *Nanochem. Res.*, 2018, **3**:189

[11]. Savale A., Ghotekar S., Pansambal S., Pardeshi O. *J. Bacteriol. Mycol. Open Access.*, 2017, **5**:00148

[12]. Ghotekar S., Savale A., Pansambal S. *J. Water Environ. Nanotechnol.*, 2018, **3**:95
[13]. Pansambal S., Deshmukh K., Savale A., Ghotekar S., Pardeshi O., Jain G., Aher Y., Pore D. *J. Nanostruct.*, 2017, **7**:165
[14]. Bangale S., Ghotekar S. *Int. J. Nano Dimens.*, 2019, **10**:217
[15]. Pansambal S., Gavande S., Ghotekar S., Oza R., Deshmukh K. *Int. J. Sci. Res. in Sci. and Tech.*, 2017, **3**:1388
[16]. Pansambal S., Ghotekar S., Oza R., Deshmukh K. *Int. J. Sci. Res. Sci. Tech.*, 2019, **5**:122
[17]. Chaturvedi S., Dave P. *Chemical Methodologies*, 2019, **3**:115
[18]. Hameed A., Fatima G., Malik K., Muqadas A., Fazal-ur-Rehman M. *Journal of Medicinal and Chemical Sciences*, 2019, **2**:9
[19]. Fidelis G., Louis H., Tizhe T., Onoshe S. *Journal of Medicinal and Chemical Sciences*, 2019, **2**:59
[20]. Fani M., Ghandehari F., Rezaee M. *Journal of Medicinal and Chemical Sciences*, 2018, **1**:28
[21]. Gupta S., Lakshman M. *Journal of Medicinal and Chemical Sciences*, 2019, **2**:51
[22]. Sajjadifar S., Rezayati S., Arzehgar Z., Abbaspour S., Torabi Jafroudi M. *Journal of the Chinese Chemical Society*, 2018, **65**:960
[23]. Pagar T., Ghotekar S., Pagar K., Pansambal S., Oza, R. *Journal of Chemical Reviews*, 2019, **2**:260
[24]. Pagar K., Ghotekar S., Pagar T., Nikam A., Pansambal S., Oza R., Sanap, D., Dabhane, H. *Asian Journal of Nanosciences and Materials*, 2020, **3**:15
[25]. Ghotekar S., Pansambal S., Pawar S.P., Pagar T., Oza R., Bangale S. *SN Applied Sciences*, 2019, **1**:1342
[26]. Pansambal S., Ghotekar S., Shewale S., Deshmukh K., Barde N., Bardapurkar, P. *Journal of Water and Environmental Nanotechnology*, 2019, **4**:174
[27]. Ghotekar S. *Nanochemistry Research*, 2019, **4**:163
[28]. Korde P., Ghotekar S., Pagar T., Pansambal S., Oza R., Mane D. *Journal of Chemical Reviews*, 2020, **2**:157
[29]. Pagar T., Ghotekar S., Pansambal S., Oza R., Marasini, B.P. *Journal of Chemical Reviews*, 2020, **2**:201
[30]. Ghotekar S., Dabhane H., Pansambal S., Oza R., Tambade P., Medhane, V. *Advanced Journal of Chemistry-Section B*, 2020, **2**:102
[31]. Isao M. *Journal of Chemical Engineering of Japan*, 2005, **38**:535
[32]. Salata O.V. *Journal of Nanobiotechnology*, 2004, **2**:1
[33]. Ghidan A.Y., Al Antary T.M. *Intech Open*, 2019, p 1
[34]. Werner M., Kohly W., Simic M. *Nanotechnologies in Automobiles-Innovative potentials in Hesse for the Automotive Industries and its Subcontractors*, 2008, **3**, p 1
[35]. Pathan A.A., Desai K.R., Bhasin C.P. *Int. J. Nano. Chem.*, 2017, **3**:21
[36]. Pathan A.A., Desai K.R., Vajapara S., Bhasin C.P. *Advances in Nanoparticles*, 2018, **7**:28
[37]. Karthikeyan S., Prathima A. *Utilization, and Environmental Effects*, 2016, **38**:3174
[38]. Zhou Q., Zhang H., Chang F., Li H., Pan H., Xue W., Hu D.Y., Yang S. *Journal of Industrial and Engineering Chemistry*, 2015, **31**:385
[39]. Sisler J.D., Pirela S.V., Shaffer J., Mihalchik A.L., Chisholm W.P., Andrew M.E., Berry D.S., Castranova V., Demokritou P., Qian Y. *Tox. Sci.*, 2016, **150**:418
[40]. Balusamy B., Kandhasamy Y.G., Senthamizhan A., Chandrasekaran G., Subramanian M.S., Tirukalikundram K. *Journal of Rare Earths*, 2012, **30**:1298
[41]. Naderi E., Akbarzadeh T.N., Kondori T.,Tahkor A. *Eurasian Chem. Commun.*, 2020, **2**:265
[42]. Jing F.J., Huang N., Liu Y.W., Zhang W., Zhao X.B., Fu R.K .Y., Wang J.B., Shao Z.Y., Chen J.Y.,

Leng Y.X., Liu X.Y., Chu P.K. *Journal of Biomedical Materials Research Part A*, 2008, **87A**:1027
[43]. Liu J., Wang G., Lu L., Guo Y., Yang L. *RSC Adv*., 2017, **7**:40965
[44]. Subhan M.A., Abul Monsur M. Fahim, Saha P.C., Rahman M.M., Begum K., Azad A.K. *Nano-Structures & Nano-Objects*, 2017, **10**:30
[45]. Kunjie W., Yanping W.U., Hongxia L., Mingliang L., Deyi Z., Huixia F., Haiyan F. *Journal of Rare Earths*, 2013, **31**:709
[46]. Yadav A.A., Kumbhar V.S., Patil S.J., Chodankar N.R., Lokhande C.D. *Ceramics International*, 2016, **42**:2079
[47]. Ramjeyanthi N., Alagar M., Muthuraman D. *International Journal of Interdisciplinary Research and Innovations*, 2018, **6**:389
[48]. Zhang Q., JI Z., Zhou J., Zhao X., Lan X. *Materials Science Forum*, 2012, **724**:233
[49]. Wang G., Zhou Y., Evans D.G., Lin Y. *Ind. Eng. Chem. Res*., 2012, **51**:14692
[50]. Jiawen D., Yanli W.U., Weili S., Yongiu L. *Journal of Rare Earths*, 2006, **24**:440
[51]. Sheng J., Zhang S., Sa L.V., Sun W. *J Mater Sci*., 2007, **42**:9565
[52]. Wang Z., Wu W., Bian X., Xue S. *Advanced Materials Research*, 2015, **1081**:38
[53]. Tian Z., Huang W., Liang Y. *Ceramics International*, 2009, **35**:661
[54]. Karthikeyan S., Selvapandiyan M. *International Journal of Computer Science & Communication Networks*, 2019, **7**:70
[55]. Wang X., Wang M., Song H., Ding B. *Materials Letters*, 2006, **60**:2261
[56]. Tang B., Ge J., Wu C., Zhuo L., Niu J., Chen Z., Shi Z., Dong Y. *Nanotechnology*, 2004, **15**:1273
[57]. Salavati-Niasari M., Hosseinzadeh G., Davar F. *Journal of Alloys and Compounds*, 2011, **509**:134
[58]. Todorovsky D., Todorovska R., Petrova N., Uzunova-Bujnova M., Milanova M., Anastasova S., Kashchieva E., Groudeva-Zotova S. *Journal of the University of Chemical Technology and Metallurgy*, 2006, **41**:93
[59]. Pandas H.M., Fazli M. *Propellants Explos. Pyrotech*., 2018, **43**:1
[60]. Abboudi M., Messali M., Kadiri N., Ali A.B., Moran E. *Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry*, 2011, **41**:683
[61]. Sulaiman N., Yulizar Y., Apriandanu D.O.B. *AIP Conference Proceedings*, 2018, **2023**:020105
[62]. Maheswari R.U., Yuvakkumar R., Ravi G., Hong S.I. *Journal of Nanoscience and Nanotechnology*, 2019, **19**:4033
[63]. Manoj Kumar K.A., Hemananthan E., Renuka Devi P., Vignesh Kumar S., Hariharan R. *Materials Today Proceedings*, 2020, **21**:887
[64]. Muthulakshmi V., Balaji M., Sundrarajan M. *Journal of Rare Earths*, 2020, **38**:281
[65]. Chatterjee A., Archana L., Niroshinee V., Abraham J. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 2016, **7**:1461
[66]. Chakraborty P., Dam D., Abraham J. *J. Pharm. Sci. & Res*., 2016, **8**:1253

**How to cite this manuscript:** Harshal Dabhane, Suresh Ghotekar, Pawan Tambade*, Vijay Medhane. Plant mediated green synthesis of lanthanum oxide ($La_2O_3$) nanoparticles: A review. *Journal of Medicinal and Nanomaterials Chemistry*, 2(4) 2020, 291-299. DOI: 10.48309/JMNC.2020.4.3