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A Survey of Current Research on the Green Synthesis of Silver Nanoparticles (AgNPs) and Their Antimicrobial Properties

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Abstract

The synthesis of nanoparticles using plants or their parts or powder or whole plant is knownas greensynthesis. In recent years, nanoparticles of noble metals such as gold, silver and palladium have drawn immense attention due to the wide range of new applications in various fields of industry. Particularly, silver nanoparticles have significant interest in medical applications such as very effective antibacterial agents without the toxic effects, and industry application such as inkjet inks containing well uniform dispersions of Nano-sized silverparticles that are useful for producing electronic circuits. It is important that the silver nanoparticles require not only the particles to be of Nano-size, but also synthesis of the nanoparticles to be produced easily and at low cost. Over the past few decades, many synthetic methods of silver nanoparticles have been studied. This paperaims to review different synthesis routes of silver nanoparticles and their applications. In particular, we mainly present several chemical approaches to preparing silver nanoparticles and their properties as well asapplications based on our recent studies. The focus is on effective and efficient synthesis ofpure colloidal silver nanoparticles with high electrical conductivity and their potential application. Nanotechnology is a revolutionary science that will have a large impact on human life. Nanoparticles are used for their countless applications in various areas such asenvironment, optical devices, mechanics, health care, biomedical, tissue engineering, gene and drug delivery, food industry, cosmetics etc. This review aims to present and to discuss recent publications related to antibacterial and antifungal activity using the different - different parts of plants like stem, roots, flowers, peel, bark, leaf, fruit, etc. and their silver nanoparticles in order to better understand the possible applications of these nanomaterial's in a safe manner.

Keyword: Sliver Nanoparticles; Green Synthesis; Antibacterial; Antifungal.

INTRODUCTION

Nanotechnology is an expanding field of science and technology dealing with the development of and designing of functional materials, devices, structures and systems at nanometer scale[1]. The concept of nanotechnology and nanomaterial's come from lecture by Nobel Laureate Richard Feynman in 1959 entitled "There's plenty of room

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at the bottom". Nanotechnology is interdisciplinary field of science which has been influencing all the fields of research involving Physics, Electronics, Materials Science, Chemistry, Environment, Biotechnology, Bioengineering, Pharmaceutical and Biomedical Science[2].

At Nano scale, nanomaterials have entirely different biological, chemical and physical properties as compared to their parent atoms, molecules and bulk materials. The characteristics properties of nanomaterial are due to small size and increased surface to volume ratio which influence the electrical, mechanical, chemical, physical and magnetic properties of the nanomaterial. By exploiting these novel properties, various nanostructures having different composition are produced such as thin films, nanospheres, nanorods, carbonnanotubes, dendrites, liposome, quantum dots polymeric micelles and nanoparticles (metallic and non- metallic) which are increasingly contributing to numerous innovative applications[3]. Nanomaterial have different size, geometry and surface chemistry by which it interacts with various targeting elements or ligands like peptides, proteins, nucleic acids and antibodies and exhibit huge applications in various fields.

Nanotechnology applied in field of medicine, provides great benefits for mankind and society, giving rise to 'Nanomedicine'. Nanomedicine is an interdisciplinary research area of biology, chemistry and medicine and it possibly alters the ways to treat diseases through novel and highly developed therapeutic and diagnosticmethods. It deals with design and development of various types of novel products[4]. Among all the nanomaterials, nanoparticles are considered as promising tools for biomedical applications in the disease diagnosis, treatment and prevention.

Nanoparticles

Nanoparticles, generally considered as particles with a size of up to 1-100 nm. Due to small size and high surface to volume ratio nanoparticles exhibit complete new or improved properties as compared to the bulk materials[5]. Nanoparticles have wide range of applications because of their unique optical, structural, electronic and catalytic properties in various fields such as biotechnology, bioengineering, catalysis, pharmaceutical, medical, drug delivery and photo-electrochemical. Nanoparticles offer unique approaches to control a wide variety of biological processes that occur at manometer level[6, 7].

Nanoparticles can be broadly classified into two groups: organic nanoparticles and inorganic nanoparticles. Organic nanoparticles are carbon nanoparticle and nanotubes (fullerenes), polymeric micelles, nanovesicles, liposomes, dendrimers, liposome and inorganic nanoparticles are noble nanoparticles (gold and silver), semiconductor nanoparticles (titanium oxide and zinc oxide), and magnetic nanoparticles (iron oxide). Organic nanoparticles have various applicationinfieldof biologysuchas genedelivery, drugdelivery[8]and waste removal[9]. Inorganic nanoparticles have special attention due totheir superior material properties with versatile functions and good biocompatibility. Various metals are used for the synthesis of nanoparticles for eg. Silver[10], gold, copper, zinc, iron, titanium, magnesium, aluminum, etc. Each metal has unique characteristic properties which are imparted in the nanoparticles synthesized from them. Metal nanoparticles have a high therapeutic potential for various biomedical applications such as biosensing[11], drug delivery[12], molecular diagnostic[13], cell labeling and imaging etc.

Application of metal nanoparticles

Nanotechnology is a revolutionary science that will have a large impact on human life. Nanoparticles are used for their countless applications in various areas such as environment, optical devices, mechanics, health care, biomedical, tissue engineering, gene and drug delivery, food industry, cosmetics etc.

Health/Medicine

Drug delivery: Nanoparticles are able to deliver controlled release of drugat specific tumor targets site and increasing the permeability and retention time at particular site without affecting the healthy tissues[14].

Drugs and therapy: Nanoparticles are used as drugs in the treatment of various diseases like infectious diseases, free radical related diseases, cancer, inflammation, etc. Due to small size and high surface volume ratio, they are used effectively in different therapy as compared to conventional approach.

In-vitro diagnostics: Nanoparticles can form conjugate with specific target molecules and detect tumors, antigen, antibodies, ligands, etc. They are used indifferent techniques like immunoassays, DNA diagnostics and cellular imaging[15].

Biosensing: Nanoparticles based biosensors have high sensitivity and increase the ability to

detect and measure novel bioanalytes. They are used in early-stage diagnosis of some diseases and threats[16].

Environment

Waste water treatment: Nanoparticles removes various toxic substrates from wastewater mainly due to their small size and high surface area, act as adsorbents. They have high absorption capacity particularly to the pollutants present in water at very low concentration[17].

Dye degradation: Nanoparticles are widely used for decolonization and degradation of textile dyes. They possess large surfacea reas which act as a substrate for the electron transfer reaction. Electrons attack the dissolved oxygen and create surface bound superoxide anions and hydroxyl ions which cause the dye degradation and mineralization[18].

Microorganisms monitoring and detection- Nanoparticles label with fluorescence dye and use in microfluidic device which rapidly detect the bacteria at the single cell level and virus present in aqueous environments[19].

Chemical degradation and source recovery- Some studies reported that nanoparticles act as an effective oxidant in the removal of environmental contaminants because they can easily diffuse or penetrate into contamination area where micro particlescannotreach[20]. Nanoparticlesare usedascatalysts for reductive dichlorination[21] and also used to immobilize microbial cells that can degrade or bio recover specific chemicals[22].

Electronic

Metal nanoparticles have high conductivity so they are used as metal paste for electrodes. Nanoparticles increase conductivity of electronic devices and reduce the utilization of power[23].

Food

Nanoparticles provide new methods to enhance the safety and the nutritional value of food. Nanoparticles as Nano sensors detect food pathogens and generation of gases due to food spoilage[24].

Cosmetics

Nanoparticles based different products like shampoos, soaps, sunscreens, powders, lotions and makeup kits have enhanced skin penetration and hydration, better stability and bioavailability[25].

Fabric and Textile

Nanoparticles provide specific properties to fabrics such as water resistance, odor and moisture elimination, increased strength and elasticity, microbial resistance[26].

Synthesis of metal nanoparticles

Metalnanoparticleswithdifferentsizesandshapes can be synthesized by various physicochemical methods. The methods used for synthesis of metal nanoparticles are numerous for e.g. Chemical methods, electrochemical techniques, radiolysis methods, photochemical method, microwave assisted reduction, reverse micelles process, solvothermal synthesis, ultrasonic irradiation, etc. However, these methods are expensive, produce toxic chemicals and it requires high temperature, pressure and energy for synthesis of nanoparticles. Therefore, there is a considerable interest in the development of environmentally benign procedure for nanoparticle synthesis which avoids the use of toxic chemicals and solvents. Biological synthesis of metal nanoparticles is considered as simple, quick, environmentally friendly, high yield, nontoxic and cost-effective[27].

Biological routes of nanoparticles synthesis consists of using various plant extracts, microorganisms like bacteria, fungi and algae and they have proved to be potential eco-friendly alternatives to chemical and physical methods. However, use of microorganisms for the synthesis of nanoparticles requires elaborate process of maintaining cell cultures, multiple purification steps and sterile conditions. On the other hand, plant mediated synthesis or green synthesis of metal nanoparticles has advantage as compared to other methods because of their easy availability, simple, non-toxic, one step and cost-free process[28].

Synthesis of nano particles using plants or green synthesis

Utilization ofplants has been anovel, alternative and promising approach for synthesis of metal nanoparticles. The synthesis of nanoparticles using plants or their parts or powder or whole plant is known as green synthesis. Metal nanoparticles can be synthesized by using various parts of plant extracts like leaf, flower, bark, fruit, stem, seed, peel etc.

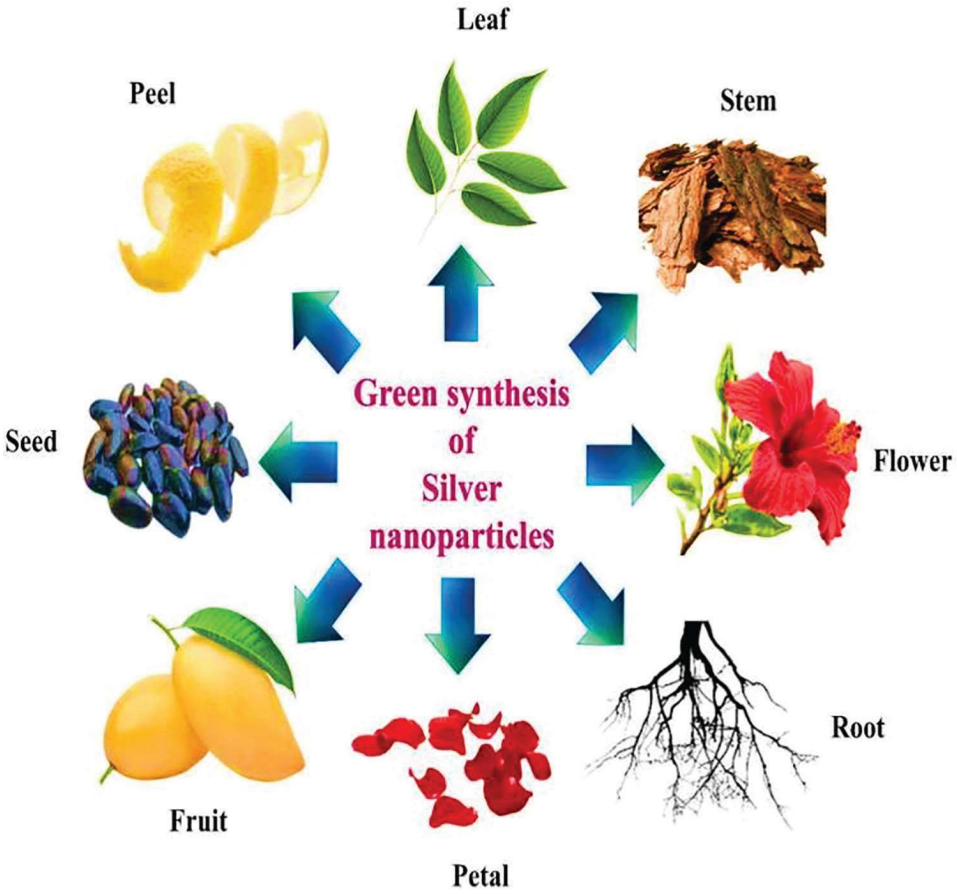

Fig. 1: Various plant parts used for the green synthesis of metal nanoparticles

Advantage of green synthesis of metal nanoparticles

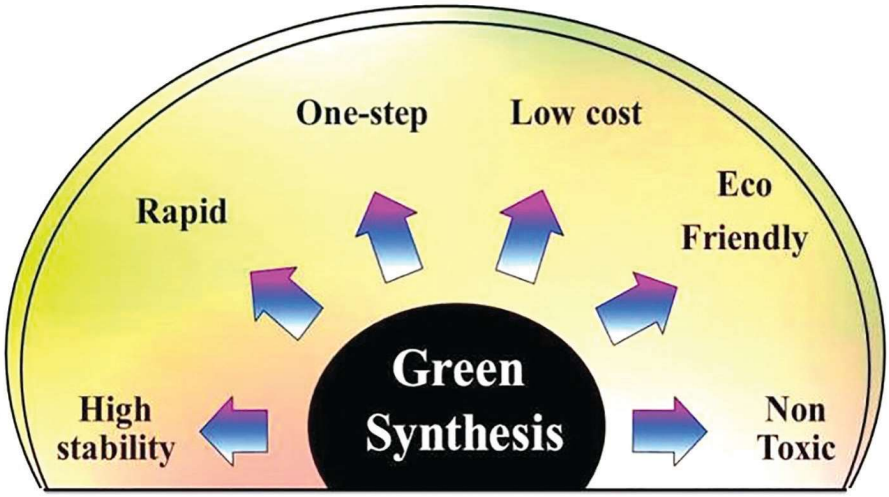

Fig. 2: Benefits of Green Synthesis

Synthesis of silver nanoparticles

Silver nanoparticles (AgNPs) can be synthesized by physical, chemical and biological methods. Some of the physical methods that are used for the synthesis of AgNPs are thermal decomposition, ceramic heater, arc discharge, direct metal sputtering in liquid medium, etc.; some of the chemical methods used for synthesis of silver nanoparticles are polyol process, polyol process plus modified precursor injection, oleylamine-liquid paraffin, etc. The physical and chemical

methods are numerous in number, however, many of these methods are expensive, make use of toxic substances, time consuming and hence are not much favored method so fsynthesis. An alternative, feasible method to synthesize silver nanoparticles is to employ biological methods i.e. use of plants and microorganisms[29].

Synthesis of AgNPs using microorganisms is more time consuming, requires maintenance of aseptic condition and it is expensive for large scale or industrial production. On the other hand, synthesis of AgNPs using plant extracts, is easy, simple, economic, eco-friendly, no requirement of high pressure, energy, temperature or toxic chemicals, can easily scale up for large scale synthesis. Therefore, it appears that the use of medicinal plant extracts is best for the synthesis of AgNPs.

Green synthesis of silver nanoparticles

Green synthesis of silver nanoparticles is apparently the best approach and method for synthesizing silver nanoparticles. Further, plant is a 'bio factory' of different phytochemicals such as phenols, terpenoids, flavones, ketones, aldehydes, amides, carboxylic acids, glycosides, saponins, alkaloids etc. which are responsible for the reduction of silver nitrate into silver nanoparticles; they infect act as reducing, capping and stabilizing agents. However, their action depends on the part and the plant extract used. Hence, it was thought of interest to synthesize metal nanoparticles using plant extracts and evaluate their biological activity. The aim of the present study was green synthesis of metal nanoparticles using selected plant extract and evaluate various biological activities.

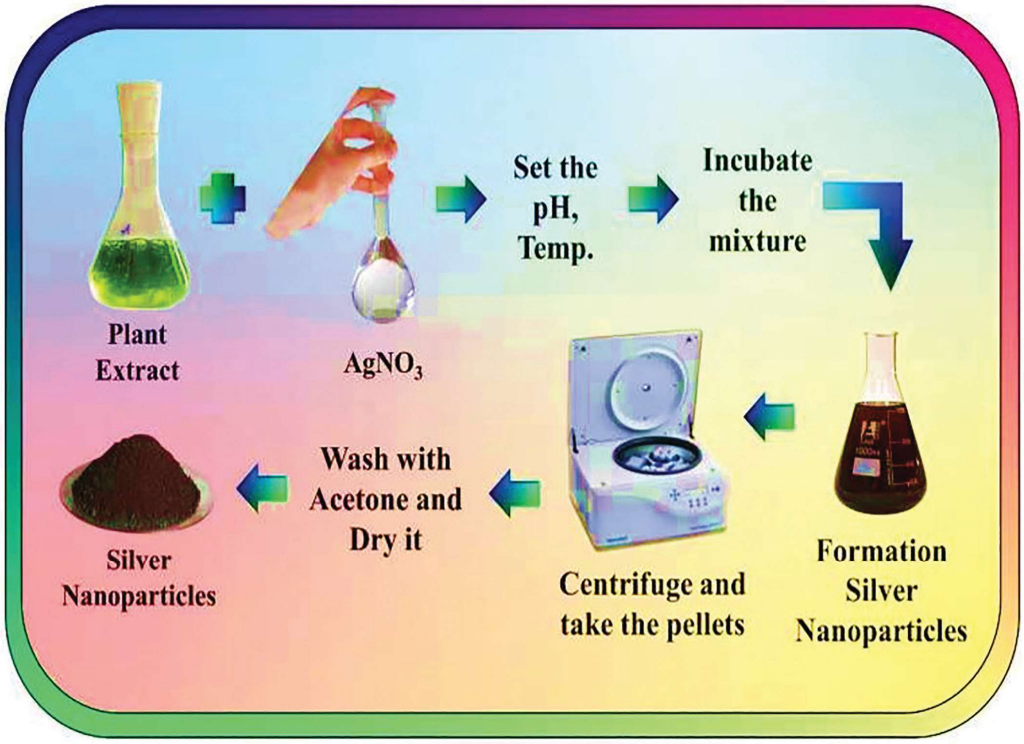

Fig. 3: General procedure for the synthesis of silver nanoparticles

CONCLUSION

The current Research mainly focused on biosynthesis of AgNPs using different parts of plants like leaf, Stem, bark, seed, flower, peel, root, petals, rhizome, fruits, tuber, etc. Different techniques were used to get different analysis in terms of particles size, morphological characters and confirm formation of silver nanoparticles**.** Silver nanoparticles showed significant antibacterial and antifungal activity against various microbial pathogens. Thus, AgNPs might be a good alternative to develop as antibacterial agent against the multidrug-resistant strains of bacteria. The applications of AgNPs may lead to valuable findings in various fields such as medical devices and antimicrobial systems. AgNPs are

used as an antimicrobial agent, electrochemical sensors, Biosensors, in medicine, health care, agriculture and biotechnology. They have great bactericidal potential against both gram positive and gram-negative pathogens. A large Number of nanoparticles are being explored in many areas of industry technology, biotechnology and agriculture. It is known that various forms of silver from laundry, paints, clothes etc. and bio-solids reach the sewage and sludge. The use of AgNPs reduces the Necessary doses of the antibiotic and the nanoparticle required to achieve an effective Antibacterial activity against various bacteria, thus decreasing the side effects. Most Importantly different plant source can be utilized to synthesize silver nanoparticles. These are used as good reducing agents and no harmful chemicals were used. AgNPs are entirely Free from chemical and environmentally eco-friendly these develops method are more Economical and cost effective and also enhance the antibacterial activity. Overall, biosynthesized silver nanoparticles show excellent properties against the Different varied bacteria. The specificity of antibacterial is a highly desired property during. The treatment of bacterial infections without affecting the natural existing flora. So, it can be concluded that silver nanoparticles have exceptional antimicrobial properties and further can be incorporated in dental materials or can be used to coat suture materials to improve their properties.

REFERENCES

1. Mnyusiwalla, A., Daar, A.S., & Singer, P.A. (2003). 'Mind the gap': science and ethics in nanotechnology. *Nanotechnology*, *14*(3), R9.
2. Cutkosky, R.E. (1960). Singularities and discontinuities of Feynman amplitudes. *Journal of Mathematical Physics*, *1*(5), 429-433.
3. Cao, G. (2004). *Nanostructures &nanomaterials: synthesis, properties & applications*. Imperial college press.
4. Chun, Y.W., & Webster, T.J. (2009). The role of nanomedicine in growing tissues. *Annals of biomedical engineering*, *37*, 2034-2047.
5. Mohanraj, V.J., & Chen, Y. J. T. J. O. P. R. (2006). Nanoparticles-a review. *Tropical journal of pharmaceutical research*, *5*(1), 561-573.
6. West, J.L., & Halas, N.J. (2000). Applications of nanotechnology to biotechnology: Commentary. *Current opinion in Biotechnology*, *11*(2), 215-217.
7. Salata, O.V. (2004). Applications of nanoparticles in biology and medicine. *Journal of nanobiotechnology*, *2*, 1-6.
8. Kostarelos, K., Bianco, A., & Prato, M. A. U. R. I. Z. I. O. (2009). Promises, facts and challenges for carbon nanotubes in imaging and therapeutics. *Nature nanotechnology*, *4*(10), 627-633.
9. Talens-Alesson, F.I., Anthony, S., & Bryce, M. (2006). Removal of phenol by adsorptive micellar flocculation: Multi-stage separation and integration of wastes for pollution minimisation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *276*(1-3), 8-14.
10. Donga, S., & Chanda, S. (2021). Facile green synthesis of silver nanoparticles using Mangiferaindica seed aqueous extract and its antimicrobial, antioxidant and cytotoxic potential (3-in-1 system). *Artificial Cells, Nanomedicine, and Biotechnology*, *49*(1), 292-302.
11. Pareek, V., Bhargava, A., Gupta, R., Jain, N., &Panwar, J. (2017). Synthesis and applications of noble metal nanoparticles: a review. *Advanced Science, Engineering and Medicine*, *9*(7), 527-544.
12. Khan, B.A., Warner, P., & Wang, H. (2014). Antibacterial properties of hemp and other natural fibre plants: a review. *BioResources*, *9*(2), 3642-3659.
13. Seferos, D.S., Prigodich, A.E., Giljohann, D.A., Patel, P.C., &Mirkin, C. A. (2009). Polyvalent DNA nanoparticle conjugates stabilize nucleic acids. *Nano letters*, *9*(1), 308-311.
14. De Jong, W.H., &Borm, P.J. (2008). Drug delivery and nanoparticles: applications and hazards. *International journal of nanomedicine*, *3*(2), 133-149.
15. Azzazy, H.M., & Mansour, M.M. (2009). In vitro diagnostic prospects of nanoparticles. *ClinicaChimicaActa*, *403*(1-2), 1-8.
16. Doria, G., Conde, J., Veigas, B., Giestas, L., Almeida, C., Assunção, M., . . . &Baptista, P. V. (2012). Noble metal nanoparticles for biosensing applications. *Sensors*, *12*(2), 1657-1687.
17. Sadegh, H., Ali, G.A., Gupta, V.K., Makhlouf, A.S.H., Shahryari-Ghoshekandi, R., Nadagouda, M. N., . . . &Megiel, E. (2017). The role of nanomaterials as effective adsorbents and their applications in wastewater treatment. *Journal of Nanostructure in Chemistry*, *7*, 1-14.
18. Vidhu, V.K., & Philip, D. (2014). Catalytic degradation of organic dyes using biosynthesized silver nanoparticles. *Micron*, *56*, 54-62.
19. Zhao, X., Xiao, B., Fletcher, A.J., Thomas, K.M., Bradshaw, D., &Rosseinsky, M. J. (2004). Hysteretic adsorption and desorption of hydrogen by nanoporous metal-organic frameworks. *Science*, *306*(5698), 1012-1015.
20. Nurmi, J.T., Tratnyek, P.G., Sarathy, V., Baer, D. R., Amonette, J. E., Pecher, K., . . . &Driessen, M. D. (2005). Characterization and properties of metallic iron nanoparticles: spectroscopy, electrochemistry, and kinetics. *Environmental science & technology*, *39*(5), 1221-1230.
21. Windt, W.D., Aelterman, P., & Verstraete, W.

(2005). Bioreductive deposition of palladium (0) nanoparticles on Shewanellaoneidensis with catalytic activity towards reductive dechlorination of polychlorinated biphenyls. *Environmental Microbiology*, *7*(3), 314-325.

22. Shan, B., Cai, Y.Z., Sun, M., & Corke, H. (2005). Antioxidant capacity of 26 spice extracts and characterization of their phenolic constituents. *Journal of agricultural and food chemistry*, *53*(20), 7749-7759.
23. Chen, H.Y., Hou, J., Zhang, S., Liang, Y., Yang, G., Yang, Y., . . . & Li, G. (2009). Polymer solar cells with enhanced open-circuit voltage and efficiency. *Nature photonics*, *3*(11), 649-653.
24. Das, B., Prasad, K.E., Ramamurty, U., & Rao, C.N.R. (2009). Nano-indentation studies on polymer matrix composites reinforced by few-layer graphene. *Nanotechnology*, *20*(12), 125705.
25. Anis, G., Sabagh, A.E., Ghareb, A., & Rewainy, I.E.L. (2016). Evaluation of promising lines in rice (Oryza sativa L.) to agronomic and genetic performance under Egyptian conditions. *International Journal of Agronomy and Agricultural Research*, *8*(3), 52-57.
26. Tang, B., Wang, J., Xu, S., Afrin, T., Xu, W., Sun, L., & Wang, X. (2011). Application of anisotropic silver nanoparticles: Multifunctionalization of wool fabric. *Journal of colloid and interface science*, *356*(2), 513-518.
27. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green chemistry*, *13*(10), 2638-2650.
28. Moghaddam, E., Teoh, B.T., Sam, S.S., Lani, R., Hassandarvish, P., Chik, Z., . . . &Zandi, K. (2014). Baicalin, a metabolite of baicalein with antiviral activity against dengue virus. *Scientific reports*, *4*(1), 5452.
29. Chanda, S. (2013). Silver nanoparticles (medicinal plants mediated): A new generation of antimicrobials to combat microbial pathogens-a review. *Microbial pathogens and strategies for combating them: science, technology and education*, 1314-1323.