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SEM Characterization of Green Synthesized Nanoparticles

Syeda Zehra Musvi[1], Swedha Hingnikar[2], Dipti Patil[3], Vaishnavi Karle[4], Dr. Sanjay Harke [5]

[1,2,3,4]UG Students, Institute of Biosciences and Technology, Mahatma Gandhi Mission University
[5]HOI, Institute of Biosciences and Technology, Mahatma Gandhi Mission University

Abstract

The present work covers the synthesis of six nanoparticles using a natural reducing agent obtained from tulsi *(Ocimum sanctum)* leaves. The method comprises boiling tulsi leaves in double distilled water and producing its juice which was used as the green reducing agent. The metal compounds included, gold chloride trihydrate, zinc acetate dihydrate, lithium chloride, silver nitrate, cadmium iodide, and graphene oxide that underwent reduction which was confirmed by color change. The synthesized nanoparticles were analyzed and proven to be successful in formation as it was characterized by scanning electron microscopy (SEM). This green, tulsi leaves-based route demonstrates a feasible pathway of sustainable nanoparticle synthesis which is promising for many fields of applications.

Keywords: Green nanoparticles, Gold, Zinc, Lithium, Silver, Cadmium, Graphene

1. Introduction

Green nanotechnology includes the synthesis of nanoparticles using ecofriendly methods like those of plant extracts or biological ways. It presents greener and less harmful approaches for production of nanoparticles for different purposes in healthcare and agricultures (Alqarni et al., 2022). Green nanotechnology involves a variety of disciplines including drug development, electronics, energy, and pollution management. Green nanoparticles (GNPs) fabricated from microorganism and plant origins represent an ecological, economical, and non-toxic alternative for multiple scientific and technological applications (Sh. Al-Obaidy et al., 2023). In green nanotechnology, biological synthesis of nanoparticles, especially metals like silver, gold, iron, selenium, and copper, is carried out using safe and environmentally friendly processes (Kamran et al., 2023). These nanoparticle play a vital role in improving various biomedical and environmental applications, such as the innovative plant-based synthesis method and the advanced methods of characterization that widen their scope of application (Vijayaram et al., 2024). The production of nanoparticles by plant extracts, bacteria, and other microorganisms is not only environmentally friendly but also provides warrants for usage in medical, agricultural, and environmental rehabilitation applications(Alqarni et al., 2022). Overall, green nanotechnology is undoubtedly the key to solving global problems such as climate change, pollution, and sustainable development (Verma et al., 2019) .

The gold nanoparticles obtained from plan extracts show promising therapeutic effects in nanomedicine due to their specific characteristics, which include their size, shape as well as their surface features, allowing for use in a broad range of biomedical applications (Koliyote & Shaji, 2023). The gold nanoparticles obtained from plants can be of a great use in the nanomedicine drug delivery system as they are found to be stable and effective in combination with anti-HIV and anticancer drugs (Priya & Iyer, 2022). Nanoparticles of plant origin (PDNP) are suggested for drug transportation in the direction of injured areas, such as inflammation and different types of cancer, and they are able to stimulate the growth of stem cells and reduce colitis injury, as well as activate intrinsic and external apoptosis pathways (Sarvarian et al., 2022).

Sustainable production of the zinc acetate dihydrate nanoparticles with plant extracts opens up many possibilities. The nanoparticles are widely characterized by their high purity, stability, and nanoscale size (KeskiN & Açikel, 2023). Furthermore, zinc oxide nanoparticles manufactured through green techniques have shown having strong antibacterial effects, which makes them able to fight different pathogens like those that were being studied by Dash and Ghosh in their study (Dash et al., 2023). Additionally, these nanoparticles have the capacity to act as antioxidants and antibacterials which provides them the opportunities to be suitable for nanomedicine especially in combating drug-resistant bacteria or reactive oxygen species.(Mushtaq et al., 2023). As a whole, the green synthesis of zinc acetate dihydrate nanoparticles by using plant extracts is a green and eco- friendly technique that holds an enormous biomedical potential (Wu et al., 2023).

Lithium chloride green nanoparticles have a wide range of uses as demonstrated by scientific research. These nanoparticles have been already applied for controlled release of drugs like chlorpheniramine maleate, which means that they can be used as a component of nanocarrier systems for drug delivery (Kashale et al., 2016). Moreover, green nanoparticles containing lithium have shown promising results in various electronic applications such as Li-ion batteries. In particular, lithium anodes have been used as part of the anodes for these batteries with the ability to facilitate reversible Li-insertion and high cyclability (Pande et al., 2020). In addition, the analysis on encapsulation of semiconductor nanocrystals in a salt matrix which involved lithium chloride for stable and efficient conversion of light in light-emitting diode backlighting was been done and it showed that these materials can be used in the enhancement of display technologies (Pardakhty et al., 2021). Generally, lithium chloride green nano particles have proven to be versatile in application as drug delivery agents, energy storage devices, and electronic display apparatus (Kashale et al., 2016).

Silver nanoparticles are known as a great therapeutic tool, especially as a good and effective alternative to antibacterial agents of less safety. They have varied biological activities such as antimicrobial, anti-neoplastic, antioxidant, and antidiabetic activities, hence, being of value in the health sector as well as in the medicine industry (S. Marathe et al., 2023; Sakilam & Reddy, 2023). The silver nanoparticles are synthesized using the physical, chemical and biological methods. Although all these methods have their advantages, the biological method is the most environmentally friendly and has lower toxicity level (Tyagi et al., 2023). This nanoparticles are size-tunable, their absorption spectrum can be modified, therefore the multiplexing of optical properties for point-of-care diagnostics (Zeng et al., 2023). Besides that, silver nanoparticles have been successfully implemented in a range of antibacterial composite films with impressive mechanical properties and high antibacterial activity against pathogens such as E. coli and S. aureus (S. Shaheen, 2023). Silver nanoparticles have a crucial function in the combat of different microorganisms that cause disease, and henceforth, they are an important factor in the therapeutic applications.(Tyagi et al., 2023).

Cadmium sulfide nanoparticles (CdS NPs) prepared through the sustainable methods have caught the attention of researchers because of their wide range of uses in several applications. These nanoparticles are commonly made usin biogenic synthesis, which has the ability to control the size distribution by the avoiding of stabilizing agents(Ghasempour et al., 2023). CdS NPs have shown the antibacterial property with stronger activity versus Gram-positive bacteria like Staphylococcus (Regmi et al., 2023). The important structural features of CdS NPs, such as their size and coating composition, have a vital effect on their medical applications in the field, including anticancer and bioimaging activities(Hamid Rather et al., 2022). Eco-friendly synthesis techniques which have been extracted from environmental factors such as bacteria, fungi, algae and plants have gained significance because they are environmentally sound and the products can be easily reproduced during nanoparticle formation (Abbas & Yaaqoub, 2022). These green CdS NPs have the potential to be used in biosensors, bioimaging, and drug delivery technologies, which confirms the mention of green nanotechnology in biomedical field as a great opportunity (Al-Hammadi et al., 2023).

Graphene oxide nanoparticles (GO) have a wide variety of applications in different fields. They can be utilized in agriculture as part of "nano agriculture" to enhance plant growth without harming the environment (Jino Affrald, 2023; Mirza et al., 2022). Additionally,, the carbon-based nanoparticles such as the GO have some unique characteristics that have attracted application in the large-scale production, particularly in the biomedical field because of their eco-friendly nature and low toxicity(Norman et al., 2022). Graphene nanoparticles (GNPs) are more active and stable electrochemically than their counterparts of graphene and graphene oxide. This makes GNPs suitable for biosensing platforms as they are pre-cited with the property of enhanced electrochemical activity(Milosavljevic et al., 2022). Furthermore, the synthesis of graphene oxide based magnesium oxide nanocomposites using environment friendly method possess antimicrobial and anticancer properties, which may develop new areas in the healthcare. (Fathy & Mahfouz, 2021).

The use of Tulsi (Ocimum tenuiflorum) for green nanoparticle synthesis has many advantages. Research reveals that the extraction of Tulsi leaves has been effectively used in the production of different nanoparticles, demonstrating its broad-range in nanoparticle production(Elsamra et al., 2023; Jivan Munja Dhotare et al., 2023). production (Elsamra et al., 2023; Jivan Munja Dhotare et al., 2023). These nanoparticles have become the key in the development of novel devices due to their impressive properties such as antibacterial activity, efficient electrochemical performance, high adsorption capacity for heavy metals, and even potential anticancer effects (Olawale et al., 2022). Moreover, this green synthesis approach, through Tulsi extract, is economical, ecologically friendly, and non-toxic compared to the hazardous chemicals traditionally employed in chemical synthesis, which reflects the principles of green chemistry and provides a safer choice. Hence, the Tulsi's application in nanoparticle synthesis not only can be proved to be effective but also environmentally friendly and sustainable in the application of nanotechnology (Vijayaram et al., 2024).

2. Methodology

2.1 Materials:

Gold chloride trihydrate, Zinc acetate dihydrate, Lithium chloride, Silver nitrate, Cadmium iodide and Graphene oxide, tulsi leaves which were collected from a local garden.

2.2 Preparation of green reducing agents from tulsi leaves:

To prepare the green reducing agent about 15g of leaves of tulsi were collected from a local garden. To purify the leaves and remove unwanted impurities they were washed with double distilled water and then boiled at 95 °C in 150 mL of double distilled water for 30 min. The juice was obtained using Whatman Filter paper no.1. The extract was then collected and stored in refrigerator at − 4°C.

2.3 Preparation of different nanoparticles:

Gold chloride trihydrate, Zinc acetate dihydrate, Lithium chloride, Silver nitrate, Cadmium iodide and Graphene oxide was reduced by using the green reducing agent. In a 250 mL round bottom flask, 0.1g of gold chloride trihydrate, 0.4g Zinc oxide, 0.4g lithium oxide, 0.2g Silver nitrate, 0.4g Cadmium iodide and 0.4g Graphene oxide powder was taken with 120 mL of double distilled water in separate beakers.(20 ml for each nanoparticle). The solution prepared was then ultrasonicated for 30 mins. To all the mixtures, 20 mL (0.1 g mL 1) of the green tulsi extract was added. The samples were kept in hot air oven for 1.5 hours at 800C. The colour change in all samples indicated the formation of the nanoparticles as per Fig no.7. The obtained mixture was centrifuged for all samples at 10000 rpm for 10 min each in the small centrifuge. The obtained product was dried in hot air oven at 850C. When the powder form was formed, the samples were taken for characterization.

3. Results

3.1 Gold results

The SEM analysis was done of gold nanoparticles at varying magnification of 1, 2,5, and 10um and the electron were bombarded at 10, 15 and 20kV. The size observed were 125nm, 127nm, 129nm, 135nm, 140nm, 146nm, 152nm, 157nm and 163nm.

SEM Images

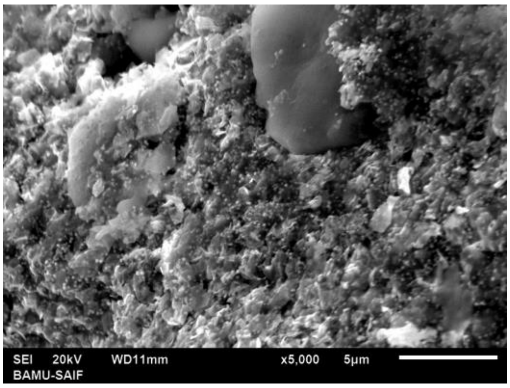

Figure 1

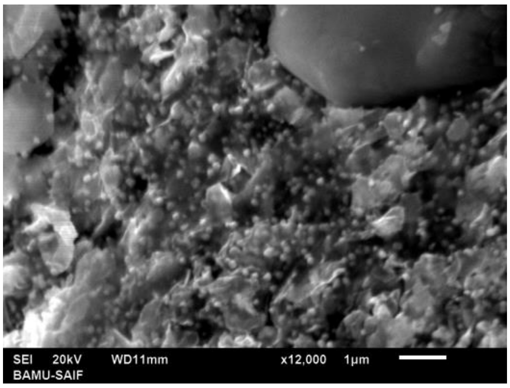

Figure 2

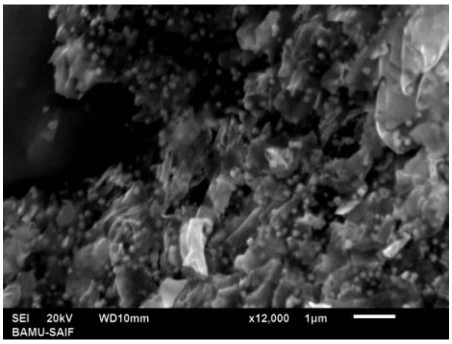

Figure 3

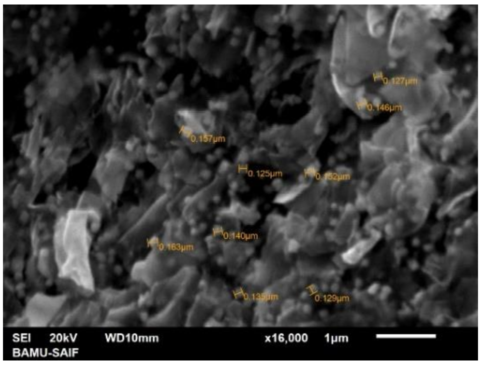

Figure 4

3.2 Zinc Results

The SEM analysis was done of Zinc nanoparticles at varying magnification of 2,5,10 and 20 um and the electron were bombarded at 20kV. The size observed were 212nm, 244nm, 265nm, 282nm, 296nm. SEM Images

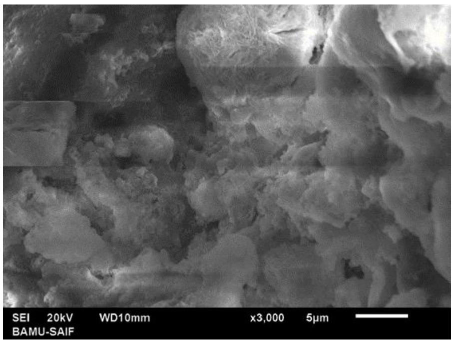

Figure 5

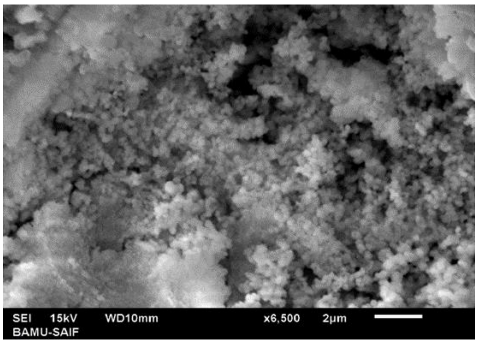

Figure 6

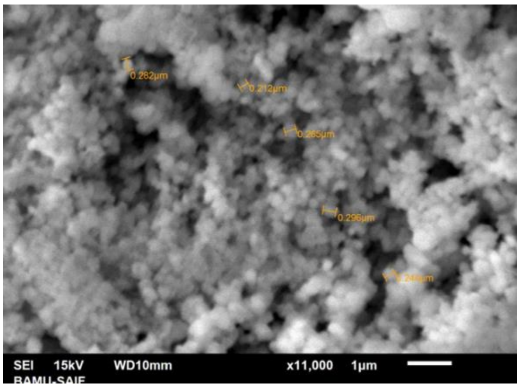

Figure 7

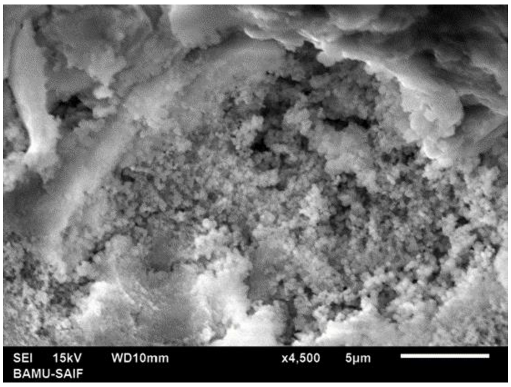

Figure 8

3.3 Lithium Results

The SEM analysis was done of Lithium nanoparticles at varying magnification of 2,5 and 10 um and the electron were bombarded at 20kV. The size observed were 5367nm, 6120nm, 7547nm, 8944nm, 9349nm.

SEM Images

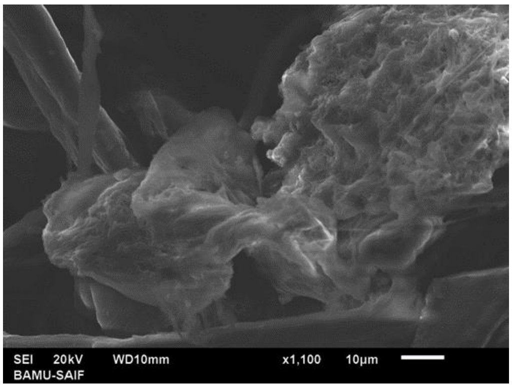

Figure 9

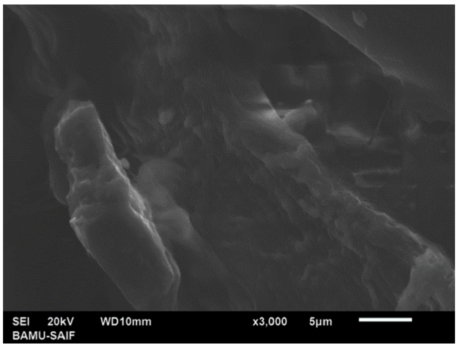

Figure 10

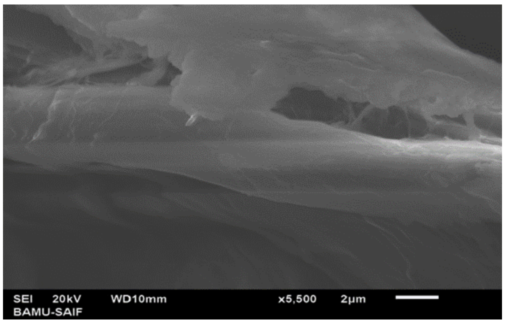

Figure 11

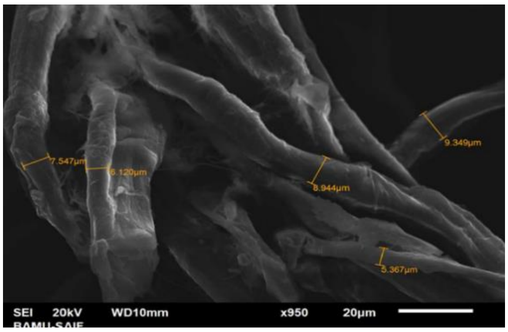

Figure 12

3.4 Silver Results

The SEM analysis was done of silver nanoparticles at varying magnification of 1, 2,5 and 10 um and the electron were bombarded at 15kV and 20 kV.

SEM Images

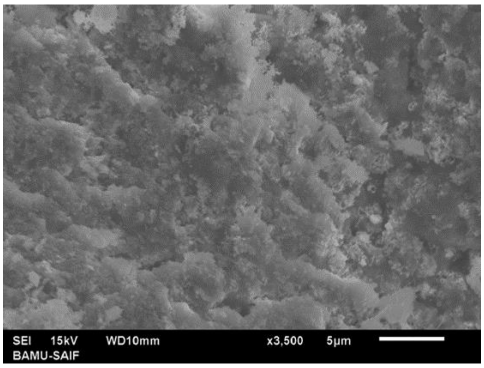

Figure 13

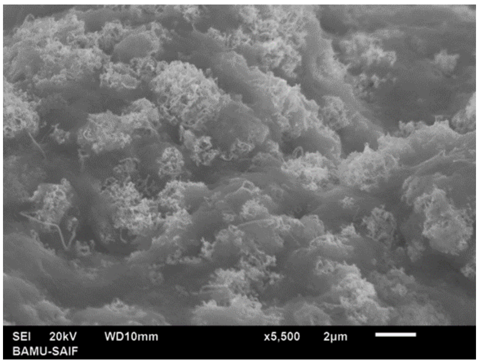

Figure 14

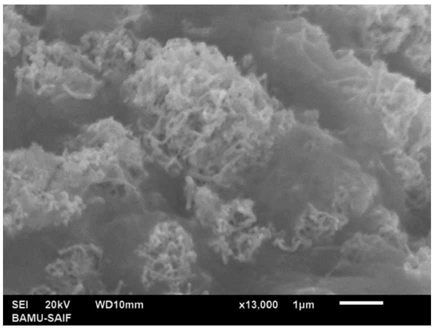

Figure 15

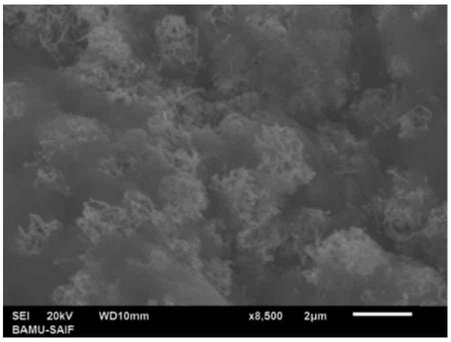

Figure 16

3.5 Cadmium Results

The SEM analysis was done of Cadmium nanoparticles at varying magnification of 1, 2,5 and 50 um and the electron were bombarded at 15kV. The size observed were 605nm, 901nm, 906nm, 941nm, 1151nm.

SEM Images

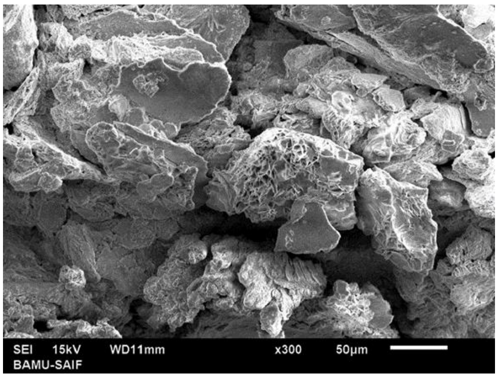

Figure 17

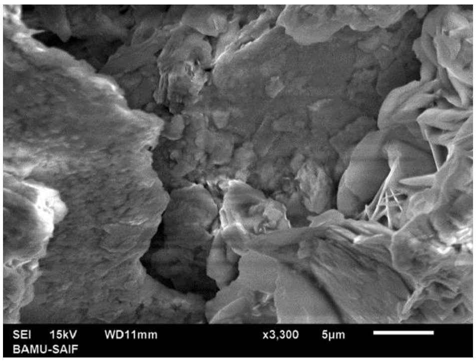

Figure 19

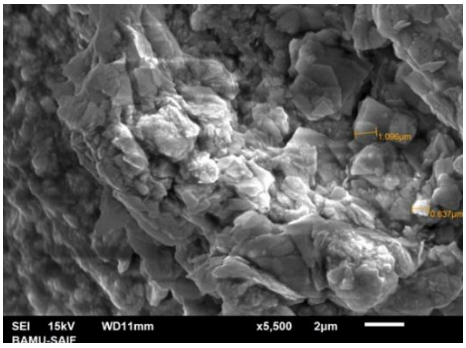

Figure 18

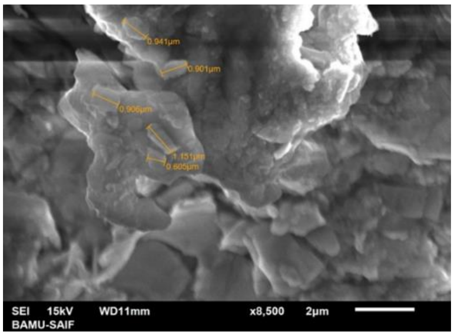

Figure 20

3.6 Graphene Results

The SEM analysis was done of Graphene nanoparticles at varying magnification of 2,5 and 10 um and the electron were bombarded at 20kV.

SEM Images

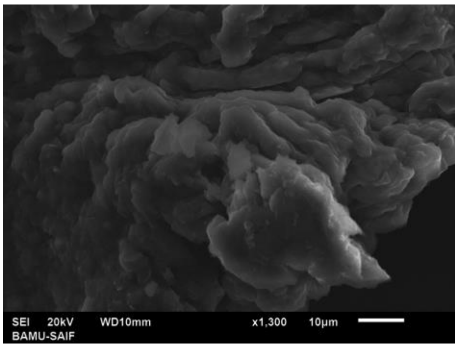

Figure 21

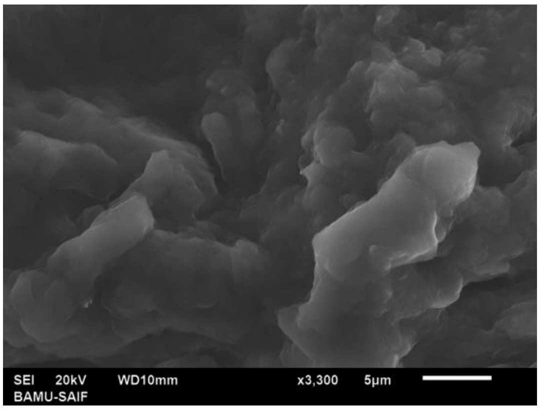

Figure 22

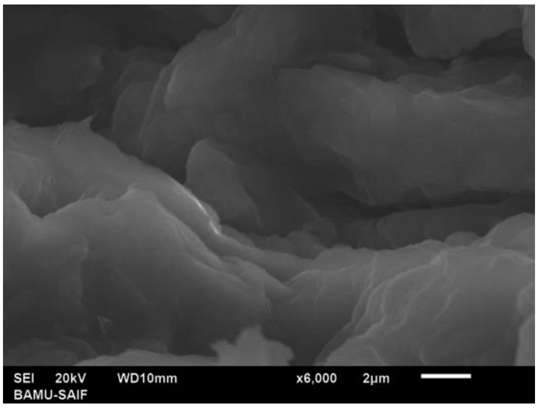

Figure 23

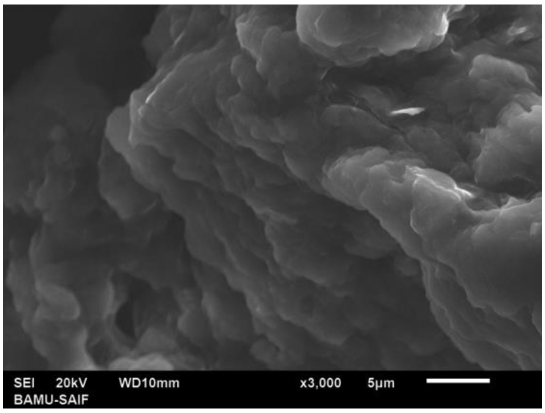

Figure 24

4. Discussion

The study utilized a Scanning Electron Microscope to observe nanoparticles of various materials. Gold, zinc, lithium, silver, cadmium, and graphene nanoparticles were examined under different electron bombardment energies and magnifications. Gold nanoparticles ranging from 125nm to 163nm were observed at 20 kV and 1 um magnification. Zinc nanoparticles ranging from 212nm to 296nm were observed at 15 kV and 1 um magnification. Lithium nanoparticles ranging from 5367nm to 9349nm were observed at 20 kV and 20 um magnification. Silver nanoparticles were observed without confirmed sizes, while cadmium nanoparticles ranging from 605nm to 1151nm were observed at 15 kV and 2 um magnification. Graphene nanoparticles were observed at various magnifications, with sizes inferred from literature comparisons. These findings provide valuable insights into the characteristics of these nanoparticles, facilitating further research in nanotechnology and related fields.

5. Conclusion

In summary, the synthesis of nanoparticles using Tulsi leaf extract offers a sustainable and efficient method with benefits such as rapid reaction times, stability, and cost-effectiveness. This eco-friendly approach, devoid of chemical involvement, holds promise for various industries. Through SEM observation, the nanoparticles' characteristics are evident, while further analysis using techniques like XRD, FTIR, UV-VIS spectroscopy, and nanoparticle size analysis can provide deeper insights. This research underscores the potential of botanical extracts in nanoparticle synthesis, driving forward greener and more accessible nanotechnology applications.

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