RESEARCH PAPER

Improvement of Optical Properties of Selenium Nanoparticles and Applications as Anti-Bacterial

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ABSTRACT

When preparing nanoparticles, pulsed laser ablation in liquid (PLAL) is a technology that has numerous advantages over conventional approaches. Using a Nd:YAG laser with three pulse durations (30, 40, and 50) pulse at a wavelength of 1064 nanometers and an output energy of 240 millijoules, nanoparticles were created from a sample of pure selenium metal using the pulsed laser ablation method in ethanol. Through optical analysis, this study investigates the impact of changing the number of laser pulses on the properties of the resultant nanoparticles and their potential uses in biology There was an improvement in the optical characteristics Whereas transmittance and energy gap dropped as the number of laser pulses grew, absorbance and reflectance both rose simultaneously. Both Gram-positive and Gram-negative bacteria were significantly inhibited by the selenium nanostructures.

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INTRODUCTION

Nanotechnology is predicated on the expectation that it would ultimately enhance scientific understanding and technological proficiency across several domains. Interest in nanotechnology arises from the expectation that it would lead to substantial advancements in scientific understanding and technological proficiency across various fields. Nanotechnology enables the creation of nanoparticles with meticulously specified shapes, sizes, characteristics, and applications [1]. Nanomaterials, such as nanoparticles, nanotubes, nanowires, and thin films, are characterized as minuscule aggregates of atoms measuring less than 100 nm in dimension. The significance of nanoparticles arises from their distinct physical, chemical, and biological properties relative to bulk materials, attributable to their elevated surface-to-volume ratio [2]. These exceptional attributes are crucial. The macroscopic condition of a material can lead to significant alterations in its physical and chemical properties at the nanoscale. Nanoparticles represent a remarkable technological development, always evolving due to their diminutive size and capacity to deliver drugs accurately to targeted tissues for therapeutic purposes [3]. Their ability to disengage from cell walls and their unique characteristics compared to conventional materials account for this [4]. Pulsed laser ablation (PLAL) and biological methods, often termed "green synthesis," are the principal techniques employed for the fabrication of selenium nanoparticles (SeNPs). The former employs biological and chemical agents, including bacteria, fungus, and plants, to revert oxidized selenium to its elemental

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form [5,6]. Laser technology is a viable way for producing mineral emulsions and nanoparticles. The principal benefit for biological applications is the generation of nanoparticles with a surface devoid of residual reactant ions. Furthermore, the processing configuration is cost-effective [7]. PLAL is a contemporary and efficient technique for synthesizing diverse nanomaterials that has garnered attention from researchers. The liquid approach of pulsed laser ablation is significant as it may produce nanoparticles of diverse sizes and shapes applicable in various situations [8]. The pulsed laser ablation (PLAL) procedure utilizes a laser beam to physically fragment large materials into smaller components. Advanced nanoparticles generated by pulsed laser illumination efficiently eliminate substances from surfaces [9]. This method rapidly produces very stable nanoparticles and is considered a cost-effective substitute for environmentally harmful chemicals. Selenium (Se), a non-metallic element in the chalcogen group, is situated in the fourth period of the periodic table. Tellurium, sulfur, and oxygen are all constituents of the same group in the periodic table. It possesses 34 atomic mass units. This item possesses a mass of 78.963 Daltons. The electronic configuration for [Ar] $3d^{10}$ $4s^2$ $4p^4$ is [11]. The melting point is 217 degrees Celsius, as stated in [12]. Selenium demonstrates exceptional photoconductivity, semiconducting properties, and biological activity, both alone and inside nanomaterials [13]. Various applications can derive advantages from selenium nanoparticles, or SeNPs. The capacity of small selenium nanoparticles (SeNPs) to impede the proliferation of pathogenic bacteria and fungi is exceptional. Their diminutive size and extensive surface area enable selenium nanoparticles to attach to and dismantle bacterial cell walls [14].

MATERIALS AND METHODS

Using a selenium metal block (bulk) sourced from India with a purity level of (99.5%), the nanoparticles were isolated. Its length was 1 cm and its diameter was 8 mm. The surface of the target was immersed in ethanol to eliminate impurities prior to extraction. At room temperature, precise synthesis of selenium nanoparticles (SeNPs) was achieved using the (PLAL) method. At the base of a glass beaker, submerged in 5 ml of ethanol, was placed a metal target. A liquid level of 6 mm was recorded above the sample, and the laser source was positioned 12 cm from the target at an angle of 5 cm relative to the user's orientation. While altering the number of laser pulses (30,40 and 50), the study kept the wavelength fixed at 1064 nanometers, the laser energy at 240 mJ, the repetition rate at 6 Hz, and the pulse duration at 9 ns. In order to create selenium nanoparticles, the process was repeated but with varied settings. Procedure for producing nanoparticles of colloidal

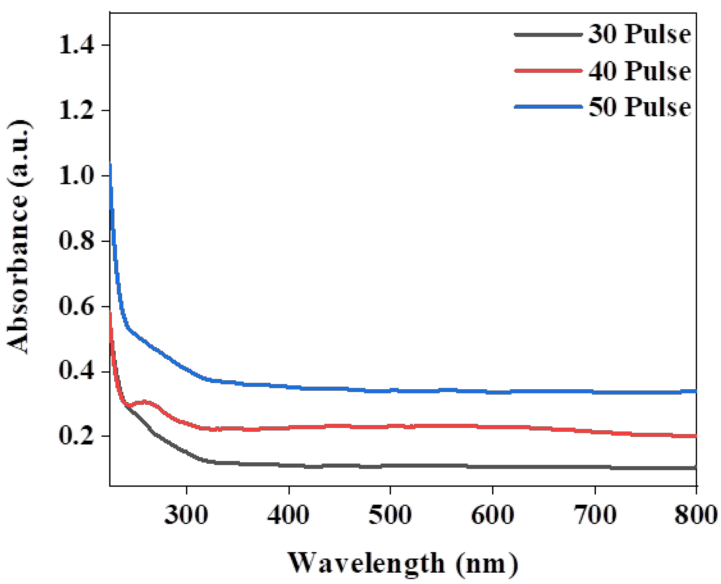

Fig. 1. Absorption spectra of selenium nanoparticles at different pulses.

selenium.

RESULTS AND DISCUSSION

Analyzing Opticals

Analysis of the absorption spectrum

For selenium nanoparticles produced using the laser ablation approach at different laser pulse counts, Fig. 1 shows the variation in the absorption spectra as a function of wavelength. The material can be used as a window in solar cell technology since its optimal absorption occurs at shorter wavelengths (the ultraviolet spectrum) and significantly decreases at longer wavelengths, leading to less absorption in the visible and

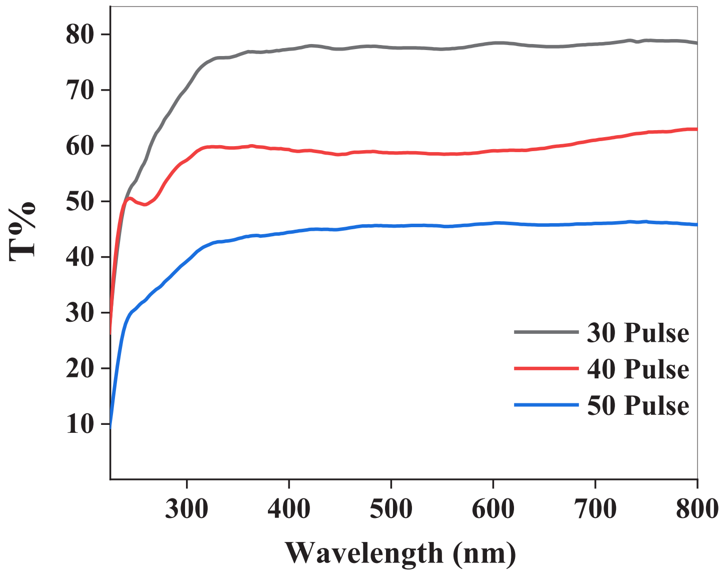

Fig. 2. Transmittance spectra of selenium nanoparticles at different pulses.

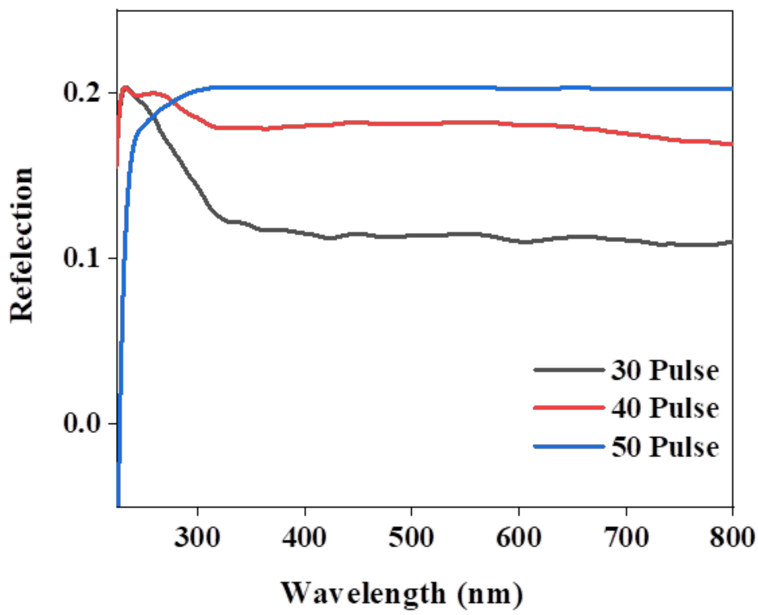

Fig. 3. The Reflectivity spectra of selenium nanoparticles at different pulses.

near-infrared areas. Due to the larger amount of material ablated, the absorption increases as the number of laser pulses increases in comparison to the minimal number of pulses [15].

Analysis of the Transmittance Spectrum

The transmittance spectra of selenium nanoparticles produced by laser ablation vary with wavelength, as seen in Fig. 2. This fluctuation corresponds to varying laser pulse counts. In the electromagnetic spectrum, transmittance, which rises with longer wavelengths in the ultraviolet region and sharply decreases with shorter wavelengths, shows an inverse relationship with absorption. The concentration of absorbed nanoparticles in the solution increases with the number of laser pulses, which lowers transmittance because the nanoparticles absorb more energy from incident electromagnetic radiation [16].

Analysis of the Reflectivity spectrum

The absorption and transmission spectra were combined with the formula (T+A+R=1) to calculate the reflectance spectrum. The reflectance spectra of selenium nanoparticles produced by laser ablation change with wavelength for different numbers of laser pulses Fig. 3. Because more particles are ablated, we observe that the reflectance peak increases as the number of laser pulses increases. Shorter wavelengths are demonstrated to have better reflectivity [17].

Analysis of the optical energy gap

The formula was used to determine the forbidden energy gap the relationship between photon energy and the change in $(\alpha h\nu)^2$ is depicted in Fig. 4 The energy gap decreases as the number of laser pulses increases. This decrease may be explained by more photons hitting the material as

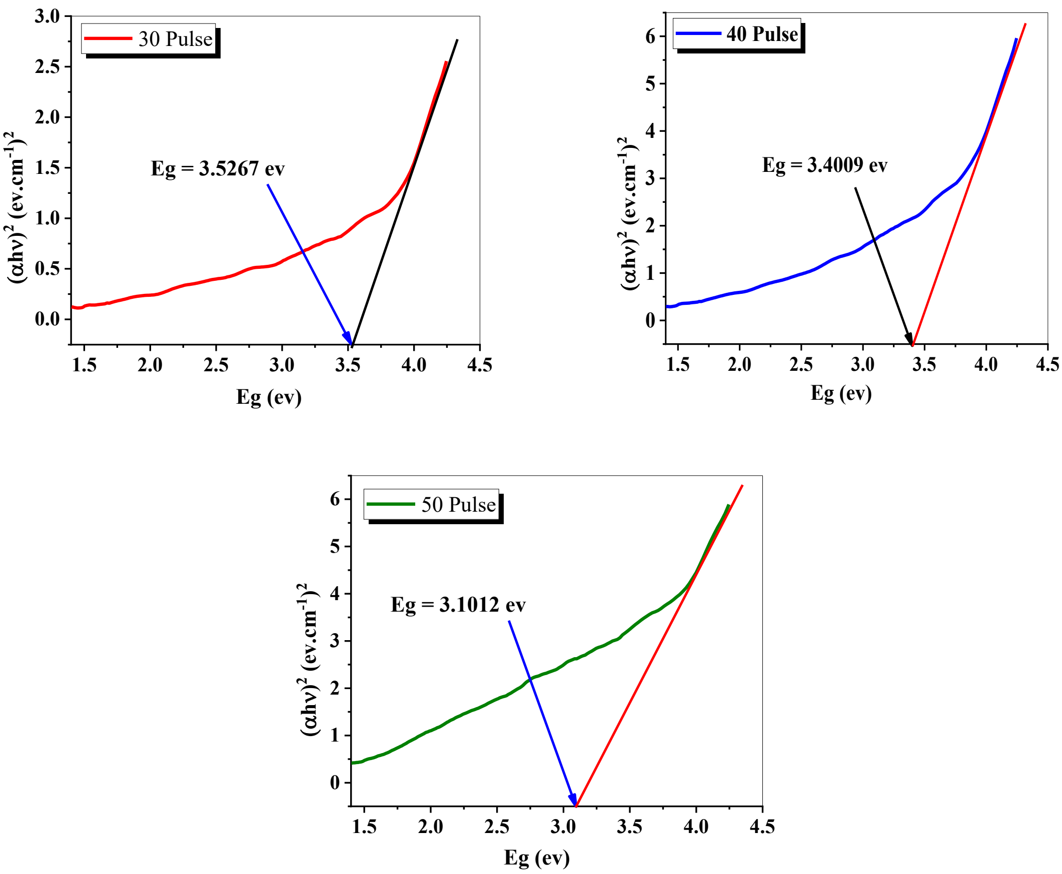

Fig. 4. Energy gap of selenium nanoparticles at different pulses.

a result of more laser pulses. As the concentration of electrons and holes increases due to the material absorbing more light, the energy gap gets smaller. Another reason for the shrinking of the energy gap is the reorganization of the atomic distribution of the material [18].

An examination of the antimicrobial properties of selenium nanoparticles (SeNPS)

The tiny size and high surface-to-volume ratio of metal nanoparticles enable them to interact tightly with microbial membranes, which has a major impact on bacterial inhibition, in addition to releasing metal ions into solutions [19]. By measuring the widths of the inhibition zones in the culture medium, the effectiveness of selenium (Se) colloidal solutions made by the Pulsed Laser Ablation in Liquid (PLAL) method in preventing the growth of particular bacterial species was assessed. Tests were conducted on the solutions at (30,40 and 50) pulse counts. The secondary selenium nanoparticles synthesized at (30,40 and 50) pulses, respectively, demonstrated high efficacy against the Gram-positive bacterium Staphylococcus auras and the Gram-negative bacterium Escherichia coli. Figs. 5 and 6 demonstrate that increased inhibition is correlated with increased laser pulses. Table 1 displays the bacterial inhibition diameters. Gram-negative bacteria have a special part of their cell walls called LPS. When a negatively charged area is formed, nanoparticles are drawn to it. However, only found in the cell walls of Gram-positive bacteria, teichoic acid disperses nanoparticles along the molecular phosphate chain, limiting their accumulation. All particles, except for large ones, cannot penetrate Gram-negative bacteria due to a

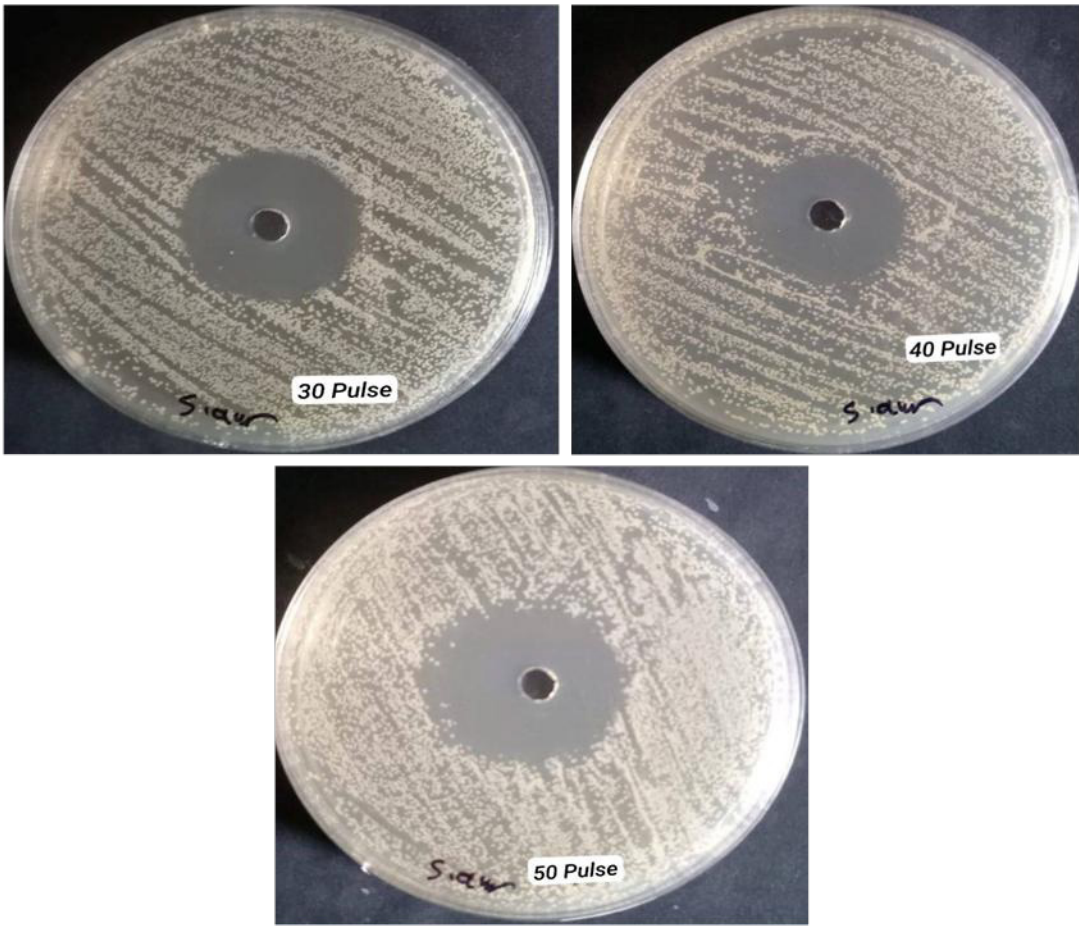

Fig. 5. Antibacterial activity against Staphylococcus auras from selenium nanoparticles at different pulses.

cell wall barrier made up of lipopolysaccharides, lipoproteins, and phospholipids. Nanoparticles are more effective against Gram-positive bacteria than Gram-negative ones, according to studies. However, the cell wall of Gram-positive bacteria is composed of teichoic acid and peptidoglycan.

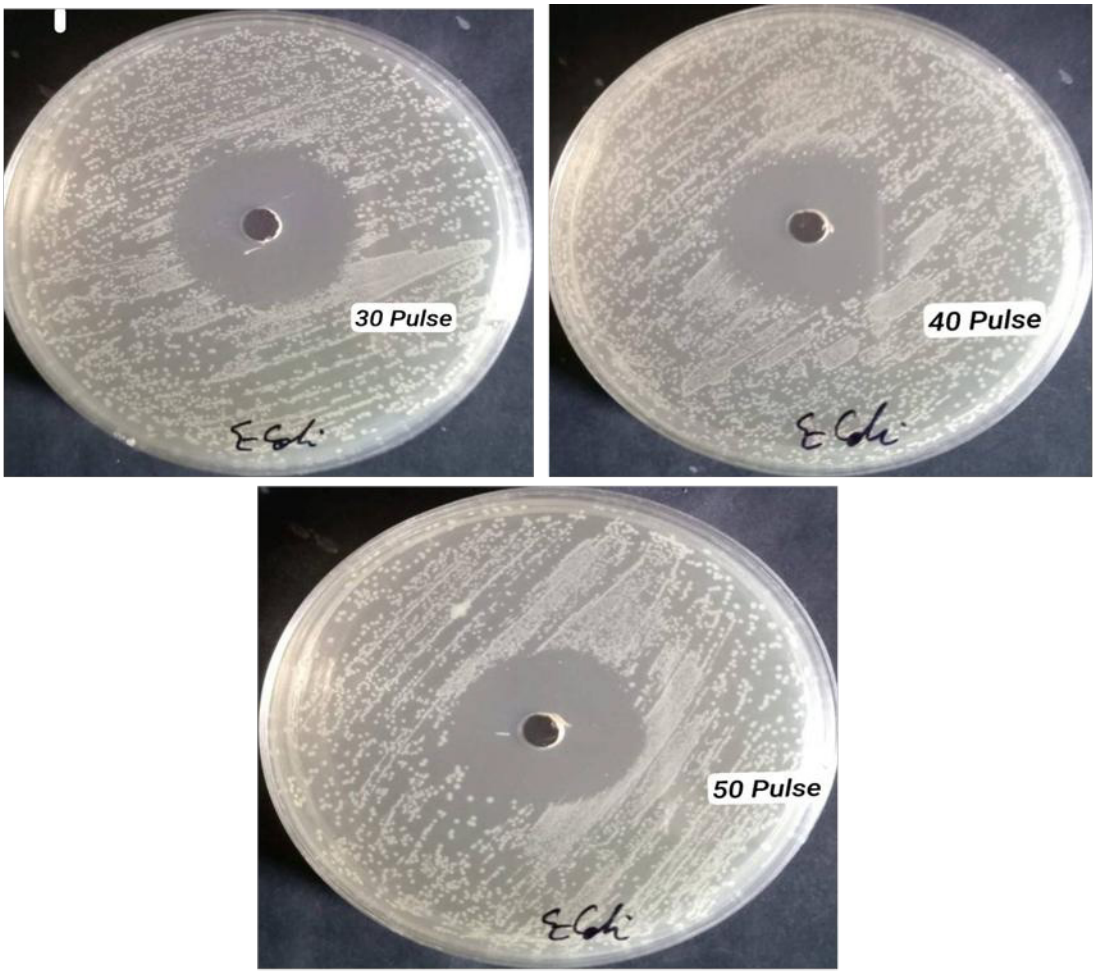

Fig. 6. Antibacterial activity against Escherichia coli from selenium nanoparticles at different pulses.

Table 1. displays the sizes at which bacteria are inhibited.

Pulse	inhibition zone diameter (mm) (S.aureus)	inhibition zone diameter (mm) (E. coli)
30	28	26
40	30	28
50	31	31

Invading particles can infiltrate cells and kill them because of these characteristics. Nanoparticles are more appealing to Gram-positive bacteria than to Gram-negative bacteria, which lack a strong negative charge on their cell walls [20].

CONCLUSION

The pulsed laser ablation method is a secure and efficient technique for producing nanoparticles, with their dimensions and characteristics contingent upon the number of laser pulses employed. The optical parameters, including absorbance, enhance, while transmittance and the optical band gap diminish. The synthesized selenium nanoparticles demonstrate significant germicidal activity, exhibiting greater effectiveness against Gram-positive bacteria compared to Gram-negative bacteria.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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