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Study the Effect of Using Carbon Nanoparticles Synthesized by Second Harmonic (Nd: Yag 532 nm) Laser Ablation on Microbial Fuel Cell Performance

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Pulsed laser ablation in liquid (PLAL) is one of the main techniques for synthesizing nanoparticle materials. The carbon target was dissolved in ultrapure water (UPW) and exposed to a Q-switched Nd: YAG laser (1064 nm) with a 6 ns pulse duration to produce carbon nanoparticles. In this sequence, the Nd: YAG laser beam was focused on the carbon surface. In the investigation of nanoparticles prepared by laser irradiation, the effect of different incident laser pulse energies (500, 1000 mJ) on particle sizes (52.09, 26.49 nm) was observed by atomic force microscopy (AFM), pH test, and lightning energy conductivity (EC) test of nanosolution was used to characterize the nanoparticles. Particle size was generated using (1000 mJ) laser pulse energy. The performance of the H-shaped microbial fuel cell (MFC) was also tested, using nanocolloids in a salt bridge. This work shows that (Co) NPs synthesized with an energy of (1000 mJ) pulsed laser can act as salt bridge catalysts to improve MFC power output.

Keywords: Carbon nanoparticles, Pulsed laser ablation, Microbial fuel cell (MFC).

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INTRODUCTION

The use or application of the microbial fuel cell (MFC) is considered one of the modern and environmentally friendly technologies, where organic waste can be used to produce renewable energy. Electrical energy is obtained from chemical energy during this process by relying on microbes[1]. The microbial fuel cell generally consists of one or two chambers, and in the case of two chambers, each chamber is separated from the other by a membrane. Where the positive pole is located in the anode chamber and the negative pole is located in the cathode chamber. Where the proton can be transferred from the anode to the cathode and the two chambers are separated by using a salt bridge[2, 3].

The development of nanomaterials has been a major advance in the science and industry of materials fabrication, and it has the potential to improve people's quality of life[4–6]. A material's chemical and physical characteristics will change noticeably when compared to the microscopic and nanoscale regions. Significant variations from the bulk material they are composed of are provided by these qualities. Heterogeneous catalysis relies on the use of extremely small metal NPs that have a high surface-to-volume ratio and a "clean" surface, meaning that there are a lot of active sites that are exposed to reactants. Nanoparticles of metals and metal oxides can be easily manufactured using Pulsed Laser Ablation in Liquid Environments (PLAL)[7–10]. Laser ablation has a significant impact on the laser beam's properties, including pulse count, duration, wavelength, and energy[11–15]. According to the research, the ablation rate grows exponentially with the fluence of the nanoparticles when dealing with semiconductors, dielectrics, and single metals. Laser ablation refers to the process of removing material from a surface by irradiating it with a laser beam. Chemical analysis, micromachining, surface modification, chemical analysis, and the production of nanoparticles are just a few of the many uses for laser ablation. Because the process depends on the laser's settings in addition to the optical and thermal properties of the target[16–18]. Improving and regulating the laser-induced removal of materials calls for investigation into the effects of parameters and energy transmission to the substance of interest[19].

In addition to having a high heat conductivity, the nanoparticles that are synthesized in base fluids, or nanofluids, have benefits that include enhancing heat transfer, shrinking systems, and more. Materials containing carbon nanoparticles are used because of their low density, huge surface area, and greater heat conductivity (k) in all axial directions[20–22]. Utilizing microorganisms as catalysts for the oxidation and subsequent synthesis of organic and inorganic substances, microbial fuel cells (MFCs) are a technological advancement. Through the action of a resistor or a load, electrons generated by these substrates are transferred to the anode, the negative terminal, and then travel to the cathode, the positive terminal[23–25]. These electrons travel via an external connection to the cathode. Whereby protons were combined with a chemical catalyst[26]. Nanoparticle generation at 1064 nm was attempted in this study using an ND: YAG laser pulse with pulse energy that varied according to the size of the excised carbon particles. The performance of the microbial fuel cell is then improved by using the produced nanoparticles.

The main aim of this work is to enhance the performance of the Microbial Fuel Cell by using the carbon in the salt bridge for three different microbial cells. The one is created without additives to form the salt bridge, while the second and third cells contain additives of nanomaterials (carbon) added to the salt bridge but in different sizes. The target (carbon exists in distilled water) was bombarded using Laser Ablation and different power values (500 mJ and 1000 mJ).

MATERIALS AND METHOD

Target Materials

Metallic plates Sigma Aldrich supplied one ounce of carbon (C), and carbon sheets were used as building blocks for oxide nanoparticles. A high level of purity (99.6–99.8%) is associated with C. The targets were divided into pieces of a certain size to fit the experimental setup before the experiment began.

Preparation Of Carbon Nanoparticles and Cell Design

Using the PLAL approach, a colloidal solution of carbon nanoparticles was created. The necessary carbon was exposed to varying energies (500, 1000) mJ/pulse Nd: YAG laser (1064 nm, 9 Hz, 6 ns) after being submerged in UPW (0.45 μS/cm). Utilizing a 1000 pulse per cycle, carbon nanoparticles were generated. A diagramm of the ablation setup can be seen in Fig. 1.

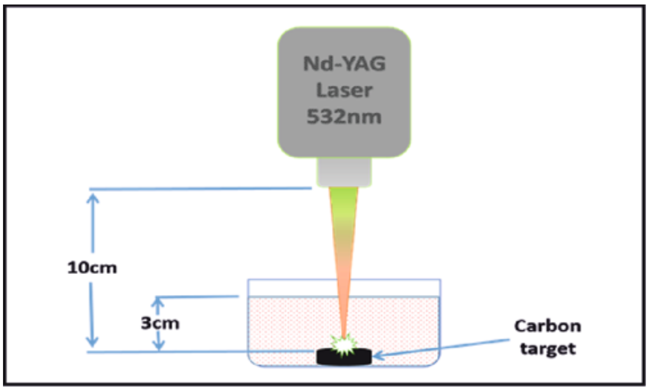

Figure 1. Figure out the altered PLAL system

The produced nanoparticles' surface shape, content, and inherent qualities were examined by many inspections. The pH meter, electrical conductivity (EC), and atomic force microscope (AFM) are these inspections. Dual-chambered MFC was designed and fabricated in the laboratory and consisted of two plastic bottles. The volume of the anode and cathode chambers was the same 500 mL, with a side opening connected by a horizontal salt bridge.

The separator used in all experiments was a salt bridge. The solidifying agent used was (Agar-Agar) from HiMedia. Agar was dissolved into (UPW) at a concentration of 10% g/L and put the mixture on the heater with continuous stirring with a magnetic bar. The mixture was poured into the plastic pipe while it was still warm and before it began to thicken. The mixture was allowed to cool and solidify. The salt bridge preparation was repeated but with the addition of a colloidal solution of carbon nanoparticles with different energies (500 and 1000) mJ. Each cell operated for 120 minutes and the voltage was recorded in each 10 minutes to obtain the performance curve. Figure 2 shows the details of the of the proposed process.

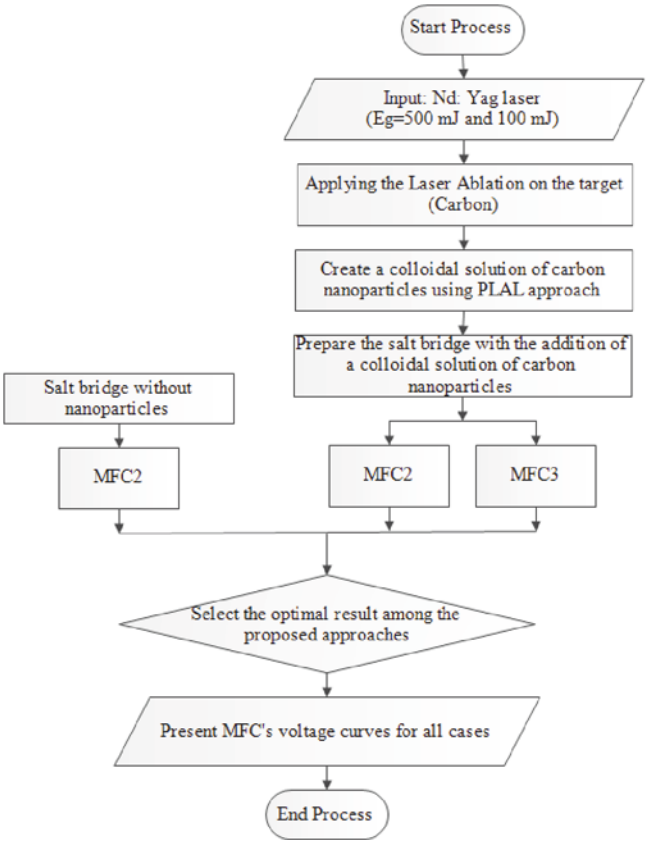

Figure 2. The flowchart of the proposed approach

RESULTS AND DISCUSSIONS

Scanning Electron Microscopy (SEM) analysis

Figure 3 displays the micrograph pictures of the morphological investigations conducted on carbon nanoparticles using scanning electron microscopy (SEM), along with the results obtained for carbon NPs generated using a 500 mJ laser pulse. Nanoparticles, which are nearly spherical in shape, develop singly and form a small number of agglomerates on the surface. SEM images for Co nanoparticles done with laser pulse energy of 1000 mJ are shown in Figure 4, the nanoparticles have an almost spongy shape over the surface.

Atomic force microscopy (AFM) analysis

The produced carbon nanoparticles have been deposited onto a glass substrate to form a thin layer. An AFM measurement was performed to assess the roughness and surface morphology. Figure 5 shows the carbon nanoparticles that were created using a laser pulse

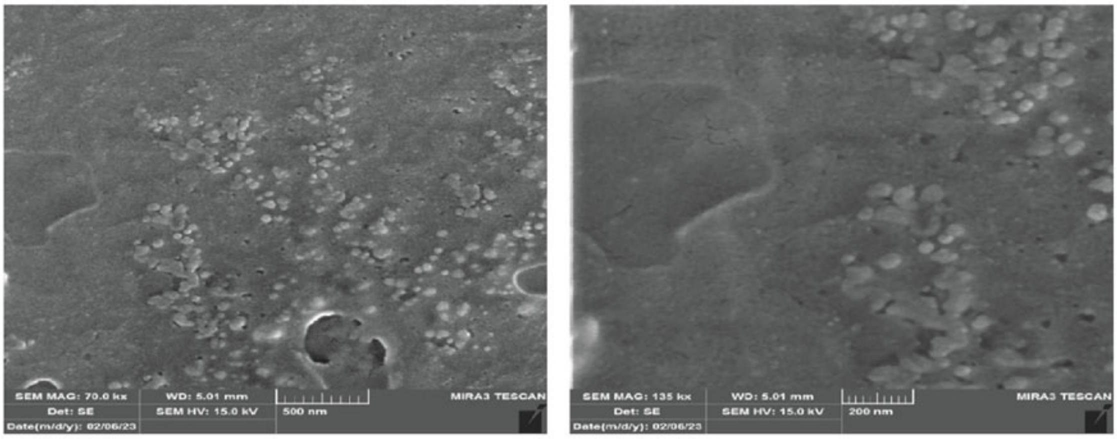

Figure 3. Photos were taken by scanning electron microscopy of carbon nanoparticles that had been generated with a 500 mJ laser pulse

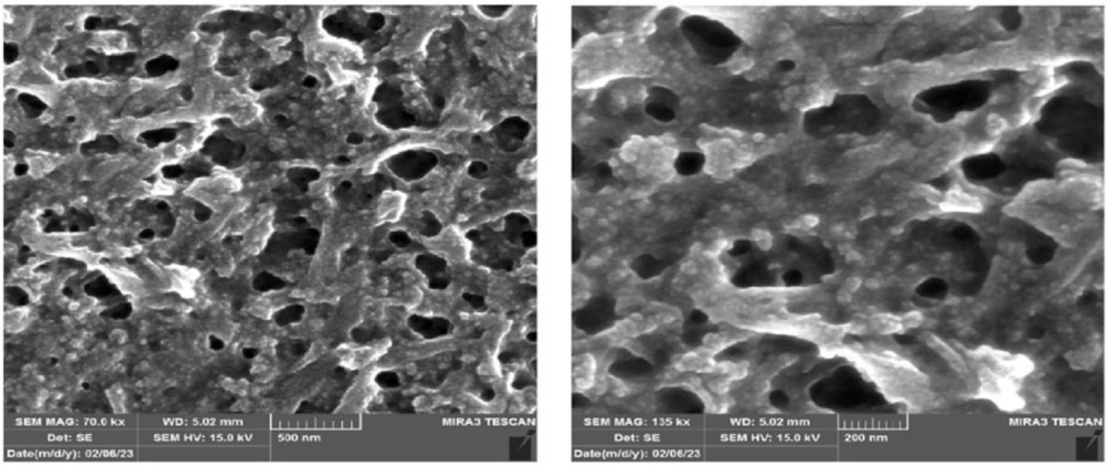

Figure 4. SEM pictures of the silver nanoparticles that were created using a 1000 mJ laser pulse

energy of 500 mJ. Where Figure 6 illustrates an AFM micrograph of the prepared carbon NPs with (1000 mJ) laser pulse energy. A thin structure with tiny 52.09 nm particle sizes is visible in the 3D AFM image. The Root Mean Square (RMS) is a commonly utilized quantity in AFM analysis. According to the findings of this study, the (RMS) was 6.62 nm, and the surface roughness was defined by an average roughness of 5.11 nm and a peak--to-peak distance of 46.1 nm.

The three-dimensional atomic force microscope (AFM) image reveals a fine structure with a small particle size of 26.49 Nm. The root mean square (RMS) is a measure that is widely used in AFM analysis. A root mean square (RMS) value of 3.74 nanometers and an average rough-

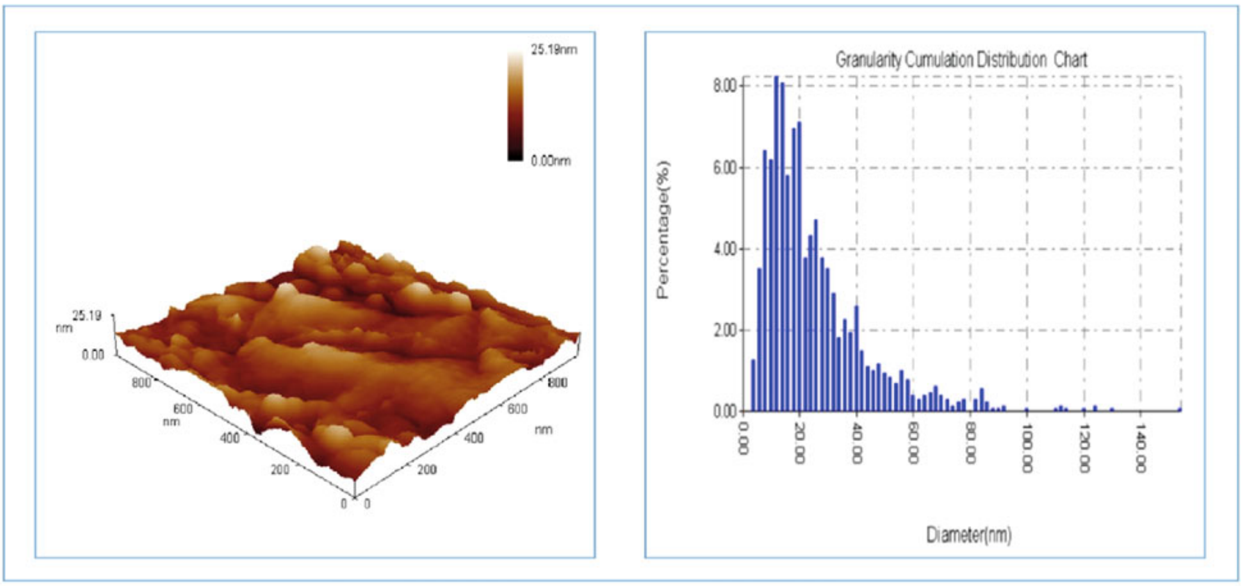

Figure 5. AFM image of the carbon nanoparticles that were created using a laser pulse energy of 500 mJ

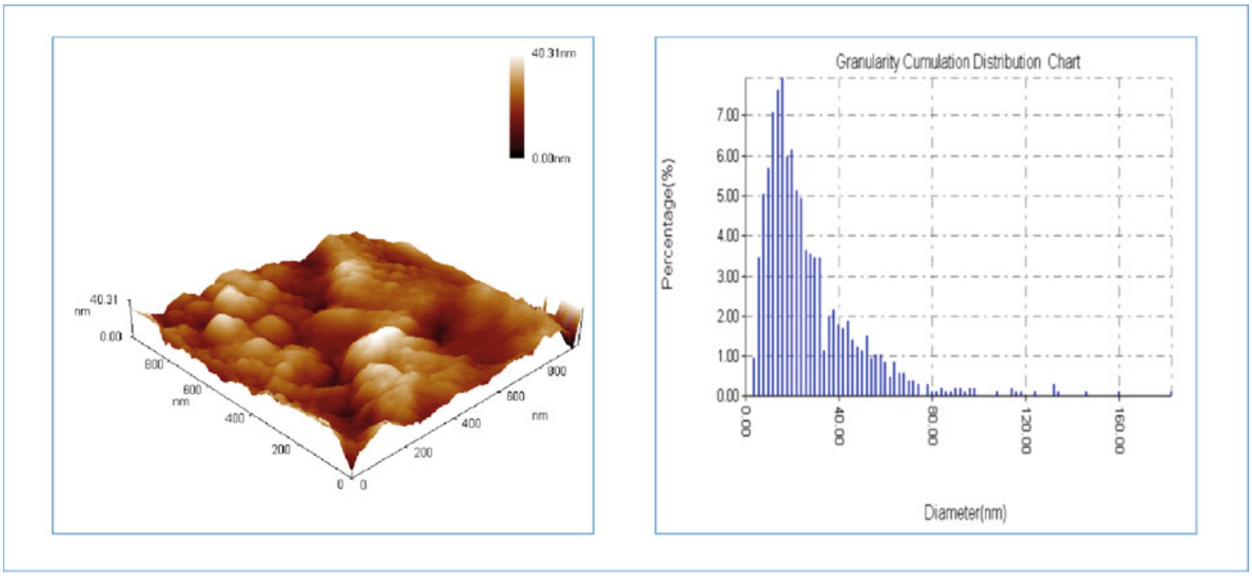

Figure 6. AFM micrograph of the prepared carbon NPs with (1000) mJ laser pulse energy

ness of 2.98 nanometers, together with a peak-to-peak difference of 23.7 nanometers, are the characteristics of the surface roughness for this study.

Measurements of pH and EC for nano-colloidal substances

Figure 7 illustrates the progression of the pH value of the samples that were generated as a function of the increasing laser pulse energy. In relation to the base fluid (water), the nano fluid's initial pH value was 8, and it eventually rose to a higher or even saturated pH of roughly 9.2. As laser pulse energy increases, so do pH value variations. The pH rose as a result of the pulsed laser energy escalation increasing the quantity of nanoparticles.

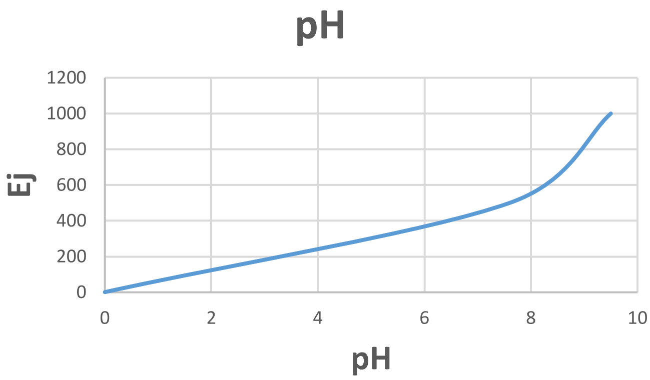

Figure 7. The nano solution's pH level in relation to the varying laser pulse energies

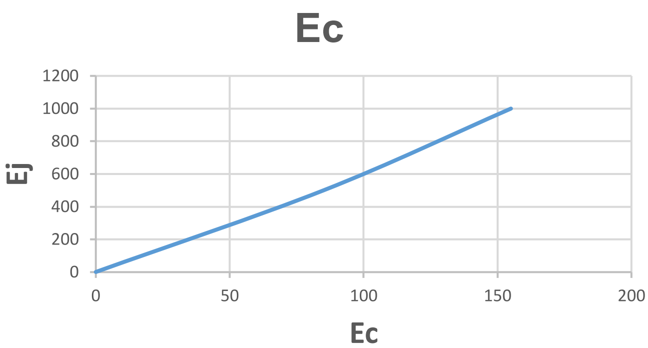

Figure 8. The nanosolution's electrical conductivity as a function of varying laser pulse energies

The change in electrical conductivity of the synthetic sample with increasing laser pulse energy is seen in Figure 8. An increase in the energy of the laser pulses caused the electrical conductivity value of the nanofluid to rise. The amount of nanoparticles grew as a result of the pulsed laser energy boost, increasing electrical conductivity.

Figure 9 illustrates how the particle size of carbon nanoparticles produced by PLAL shrank in response to an increase in laser pulse energy. As a result, with constant pulse length, frequency, and wavelength, the sole factor influencing nanoparticle size–also referred to as the particle size production tool–is the variation in pulse energy.

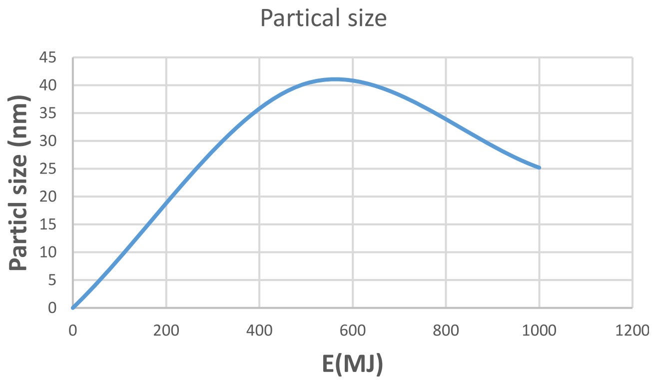

Figure 9. Size of particles in relation to varying laser pulse energies

THE MFC SALT BRIDGE

The salt bridge is the most influential factor in the performance of microbial fuel cells. It selectively transfers protons from the anode to the cathode while preventing the transfer of oxygen from the cathode to the anode on one side and preventing the transfer of substrate from the anode to the cathode on the other side. In most commercial microbial fuel cells, salt bridges are widely used. The current trend is to manufacture alternative salt bridges with nanoparticle-based materials, such as carbon, due to their wide applications in the energy production sector.

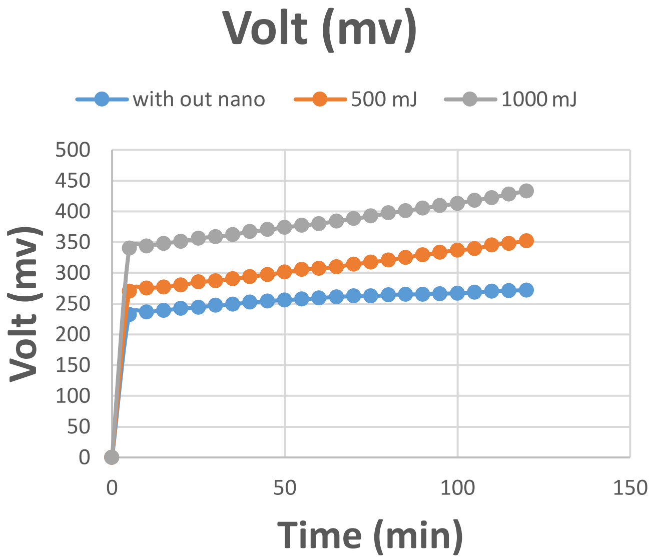

Figure 10. The salt bridge modified by a carbon nanoparticle with energies of 500 and 1000 mJ

The salt bridge in Figure 10 has been altered by a carbon nanoparticle with an energy of 500–1000 mJ. The behavior of the salt bridge was altered by 500 and 1000 mJ of carbon nanoparticles, which resulted in a voltage greater than that of the membrane without treatment. With the lowest carbon nanoparticle size, the MFC exhibits optimal salt bridge performance. For 500 and 1000 mJ, the voltage was (298 and 352) mv, respectively, whereas the voltage was 272 mv when the salt bridge was untreated.

CONCLUSIONS

Carbon nanoparticles were studied at a wavelength of 1064 nm with an exerted (1000) pulse of an Nd: YAG laser at different laser pulse energies to determine their size, electrical properties, and shape. A basic and flexible method to regulate the size dispersion and safety of colloidal carbon nanoparticles is the pulse energy, the conclusions are:

–The carbon NPs produced using the (PLAL) approach had different morphologies and particle sizes (52.09 and 26.49 nm) depending on the variation in laser pulse energy (500, 1000) mJ.

–The electrical conductivity of carbon nanocolloids increases with increasing laser pulse energy and decreases as nanoparticle size increases.

– The size appropriation and strength of carbon colloidal nanoparticles can be easily and adaptably controlled using pulse energy.

– The MFC's voltage curve indicated that the modified salt bridge, which is made of nanoparticles with a laser pulse energy of 1000 mJ and the smallest particle size and smoothest surface, performs best.

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