

PERFORMANCE ENHANCEMENT OF MICROBIAL FUEL CELLS USING CARBON NANOPARTICLES PRODUCED BY LASER ABLATION

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Pulse Laser Ablation in Liquid (PLAL) was used to prepare carbon nanoparticles by using a carbon target immersed in deionized water (DW). Then, the target was irradiated with the first harmonic of an Nd: YAG laser, which has a wavelength of 1064 nm and a 6 ns pulse duration, and then the laser beam was focused on the target surface. The composite particles were studied to explore the effect of laser pulse energy on the size. Varying incident intensi-

ties 500 mJ, 1000 mJ give particle sizes from 52.09 nm to 26.49 nm, respectively. An atomic force microscope (AFM), pH meter, and electrical conduction (EC) testing of nanoscale solutions were included in the nanoparticle characterisation, with special attention to (1000) mJ laser pulse power level producing the smallest particle size. The nano-colloidal salt bridge prepared using the nano-colloids was used for the H-shape microbial fuel cell (MFC), whose performance was then tested. This study indicates that the Co NPs prepared with a mean pulse laser energy of 1000 mJ should bridge an electrolyte, which is a catalyst for increased output MFCs.

Keywords: *MFC, nanoparticles carbon technique, Nd: YAG laser.*

1. INTRODUCTION

The material's properties (physical and chemical) differ greatly from nano to micro levels. Most of the properties change from the bulk material of which they are made. The surface-to-volume ratio is one of the characteristics of very small metallic NPs. Therefore, a high density of NPs to the reactants is essential for heterogeneous catalysis. Using techniques for preparation of metal oxide nanoparticles like pulsed laser ablation in liquid environments PLAL [1]–[5], and the physical appearance of the laser ray (sum of pulses properties such as energy, pulse duration, wavelength) are powerfully precious by laser ablation [6], [7]. Investigations show that the ablation rate grows logarithmically with the nano pulse flux of a single metal, semiconductor, and dielectric laser ablation that attracts material after the target irradiation through a laser ray. Many applications, such as nanoparticle morphology, surface engineering of materials, micro-fabrication, thin films, and a wide range of chemical tests, use laser ablation.

This process is dependent on the optical and thermal properties of the target, in addition to laser parameters [8]–[12], and

must have energy transferred to the material physics being affected by removal techniques that measure and control human comprehension towards better understanding how to improve outcomes for materials printed with a laser-induced technique [13]–[18]. In addition, using bacteria as redox catalysts for generating current, the flux ratios of chemical and inorganic substances are implemented by microbial fuel cells (MFCs). The electrons produced by these substrates will be transferred to the positive electrode (negative terminal). Then, they flow toward the negative electrode (positive terminal), which is linked to a conductive material that either contains a resistor or works under load [19]–[21]. These electrons flow to the cathode through an outer circuit. A chemical cathode is mixed with protons [22]. Further, the results agree with ref [23]–[28]. This paper, moreover, produced nanoparticles from nano carbon particles using Nd: YAG laser pulse wavelength 1064 nm, using varying pulse energy based on the size of the nano carbon particle. The prepared nanoparticles were used to improve the performance of the microbial fuel cell.

2. EXPERIMENTAL METHOD

2.1. Target Materials

A pure carbon sheet (99.6 to 99.8 %) from Sigma-Aldrich was used as a target to prepare the carbon nanocolloids. In the ini-

tial test, carbon targets were cut to dimensions of 1 cm² to supply the beaker in the experimental procedure.

2.2. Cell Design and Preparation of Carbon Nanoparticles

The PLAL technique produces the carbon nanoparticle suspension solution. The carbon target was immersed in deionized water (DW) and irradiated with different pulse Nd: YAG laser 1064 nm and 6ns, with

energies from 500 to 1000 mJ. The number of pulses is 1000 each time used to formulate carbon nanoparticles. The PLAL technique setup is exposed in Fig. 1.

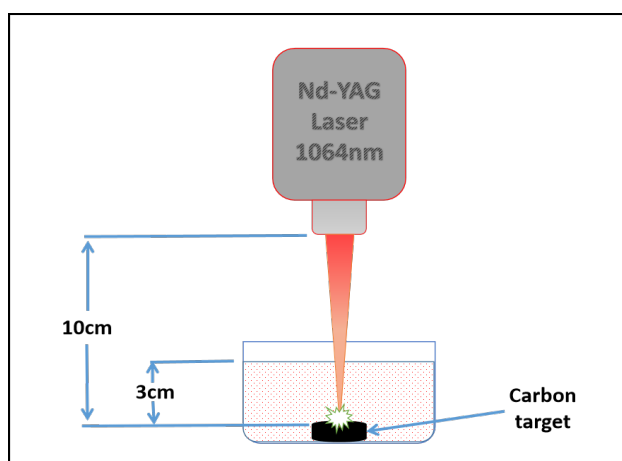


Fig. 1. PLAL technique set up.

Physical possessions of the chemical nanoparticles are analysed using the morphology and composition of the physical properties, surface morphology, and composition of nanoparticles using AFM, EC, and pH in an atomic force microscope. The microbial fuel cell (MFC) was also created in the laboratory; it was then called a twin-chamber battery, and so named because of the two plastic bottles used to fabricate it. Anode and cathode, respectively, occupied a volume of 500 mL. A two-sided open-

ing was created in the standard horizontal salt bridge in both chambers. In all trials, a salt bridge was used as the separator. Solids were made by dissolving agar-agar from Hi Media in ultrapure water (UPW) at 10 g/L. The solution was stirred continuously with a magnetic bar to dissolve it while being heated thoroughly. The mixture dropped into a plastic pipe while it was still slightly warm-before setting and while still fluidized. The operation of the cells was repeated, including using a colloidal carbon nanoparticle

solution. (Energy energies ranged from 500 mJ up to 1000 mJ.) Voltage data were taken

every 10 minutes for 120 minutes, thus generating a performance curve.

3. RESULTS AND DISCUSSION

3.1. Investigation of Atomic Strength Microscopy (AFM)

The prepared carbon NPs thin film surface, made of the morphology and roughness based on sedimentation on a glass

substrate, was evaluated by AFM measurement. The outcomes are shown in Figs. 2 and 3.

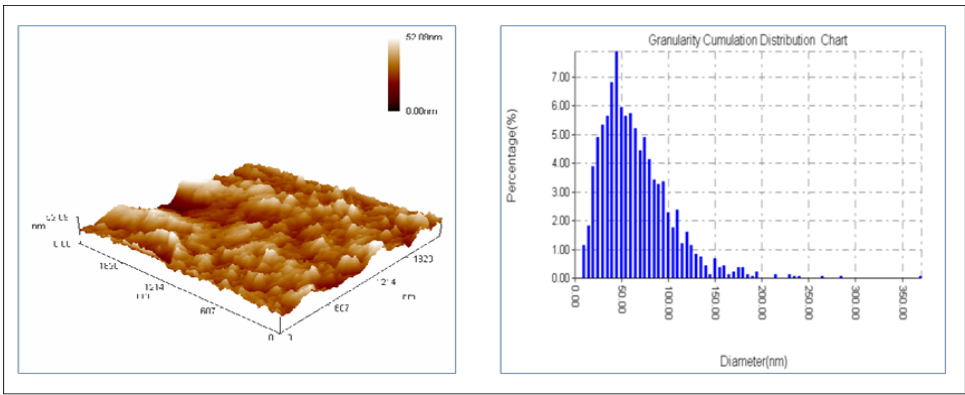


Fig. 2. AFM micrograph equipped with carbon NPs per 500 mJ laser pulse energy.

The root mean-square (RMS), a parameter common in wide application as AFM, in fact, is true with most measuring techniques around, ever being honored for it in

practice. Furthermore, a 3D AFM image betrays microstructure with a minimum particle size of 52.09 nm.

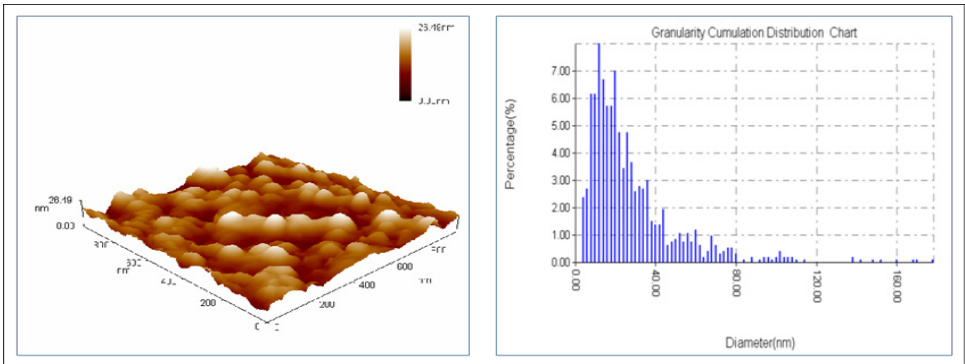


Fig. 3. AFM micrograph of enhanced carbon nanoparticles synthesized with 1000 mJ laser pulse energy.

The RMS roughness measurement was 6.62 nm, the average was 5.11 nm, and the average peak-to-trough distance was 46.1 nm, extensively representing surface roughness characteristics. AFM (3D), stacking a higher-resolution image over a lower-

resolution one, indicates a fine structure with a particle size of 26.49 nm. The RMS roughness was determined to be 3.74 nm, the average was 2.98 nm, and the difference between peaks and troughs was 23.7 nm (see Fig. 2).

3.2. Nano-Colloidal of pH and EC Measurement

Figure 4 shows how pH changes and kinetic energy per laser pulse in samples produced depend on one another. Nanofluid: its initial pH is 8, a bit more than that of base fluids like water. It climbed to 9.2; later on, the greater the energy of the laser pulses, the greater the differences in pH values. As pulsed laser energy increases, more and more nanoparticles appear. This also

leads to an increase in particle size, which is associated with higher pH [29], [30]. The nanofluid exhibited improved electrical conductivity values with increased laser pulse energy, as measured using the EC meter. Increasing the power of the pulsed laser leads to a higher number of nanoparticles, which in turn enhances the electrical conductivity, as illustrated in Fig. 5.

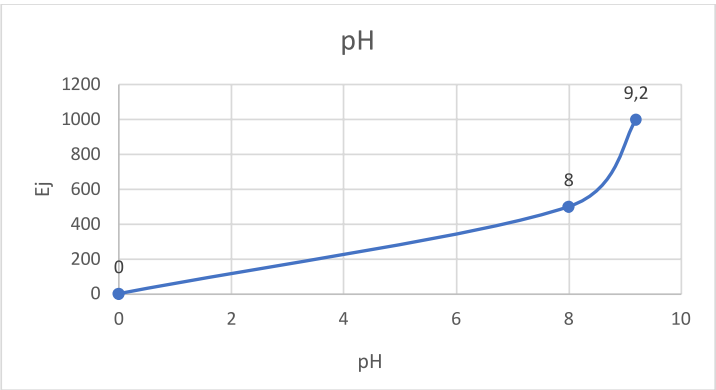


Fig. 4. pH value of the nano solution as a function of different energies of laser pulse.

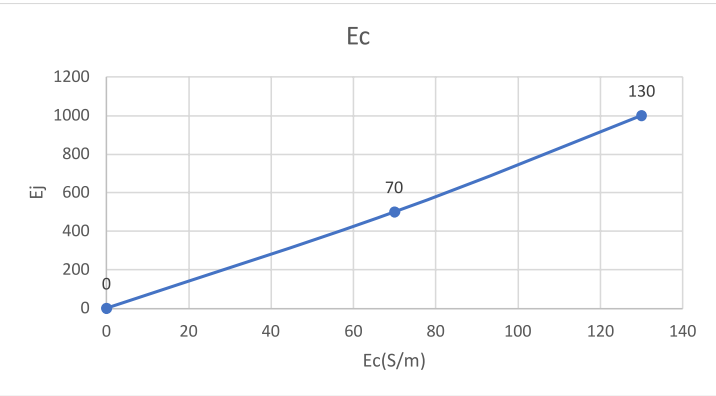


Fig. 5. A nano solution of electrical conductivity shows the function of different energy of laser pulses.

In addition, when the pulse number is constant, the wavelength and wave number of light vary according to the pulse' energy. Hence, it becomes essential to note this factor (termed the size tool) in the definition of

nanoparticle sizes here. Besides, Fig. 6 indicates that the particle size of the PLAL-created carbon was reduced as the laser pulse energy was raised for an optimum effect.

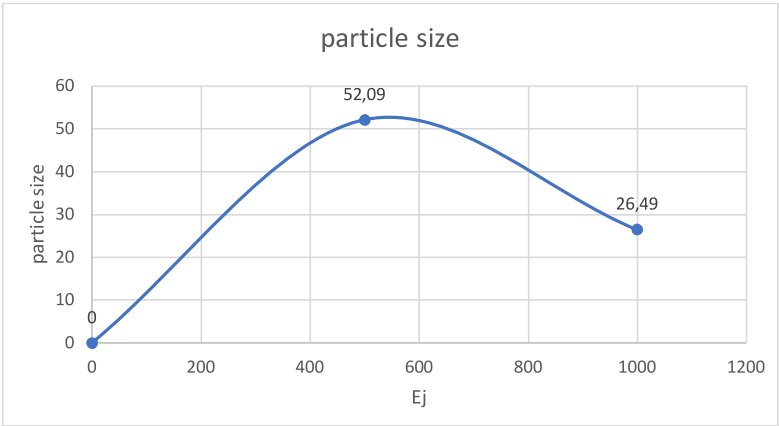


Fig. 6. Laser pulse energy as a function of a particle size changing.

The behavior of the salt bridge, modified with carbon nanoparticles at 500 and 1000 mJ, shows that the voltage is higher than that of the membrane without treat-

ment. Figure 7 illustrates the salt bridge modified with carbon nanoparticles at energy levels of 500 and 1000 mJ.

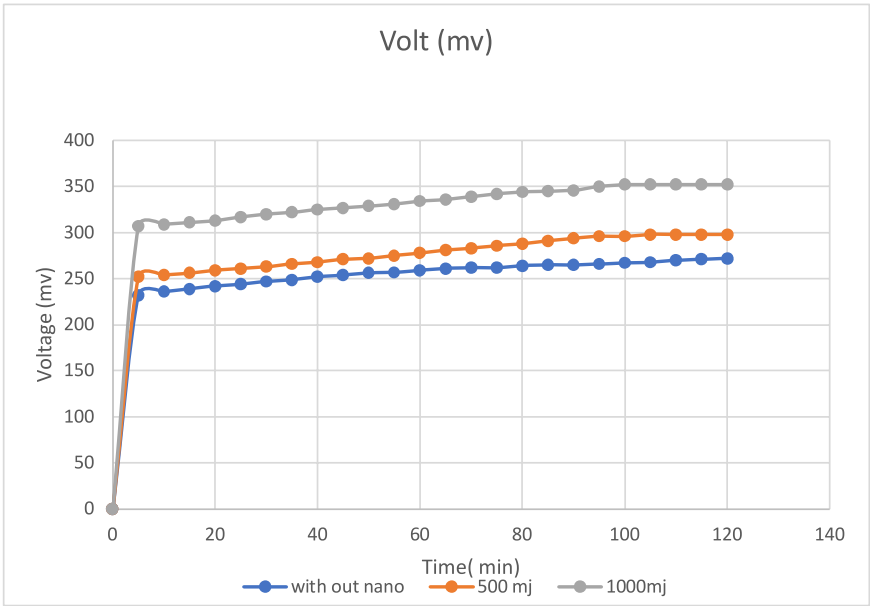


Fig. 7. Impact of carbon nanoparticles on salt bridge performance at energies of 500 mJ and 1000 mJ.

The best salt bridge performance of the MFC is with the smallest particle size of carbon nanotube. The voltage was 298 mv and 352 mv for 500 mJ and 1000 mJ,

respectively, whereas, when focusing on the salt bridge without treatment, the measured voltage value was 272 mv.

4. CONCLUSION

The study investigated carbon nanoparticles synthesized using varying Nd: YAG laser pulse energies, focusing on their size, electrical properties, and morphology. The pulse energy emerged as a critical and adaptable parameter for modulating colloidal carbon nanoparticle size distribution and stability. Notably, the variation in laser pulse energy (500 mJ and 1000 mJ) resulted in distinct particle sizes of 52.09 nm and 26.49 nm, respectively. The findings indicate that the smallest nanoparticles were produced at the higher pulse energy, which

also correlated with enhanced electrical conductivity. Furthermore, the analysis of the voltage curve from the MFC demonstrated that the optimal performance was achieved with the modified salt bridge incorporating nanoparticles synthesized at 1000 mJ. This configuration not only yielded the smallest particle size but also exhibited improved surface roughness, underscoring the significance of laser pulse energy in optimising the properties of carbon nanoparticles for enhanced MFC performance.

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