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Carbon Conversion Using High Voltage Plasma Method Based on Mangrove Wood Charcoal

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***Abstract*--This study investigates the conversion of mangrove wood charcoal into graphene using high voltage plasma technology through arc discharge. The experiment involves heating carbon with high voltage plasma generated from rod and plate electrodes. The variables examined are the electrode distance and carbon treatment time. The results demonstrate the successful conversion of mangrove wood charcoal into graphene. The generated plasma is influenced by the electrode distance, with a 1 cm gap producing stronger bluish-orange plasma. Varying the treatment time also affects the graphene yield, with a 3-minute treatment generating more graphene compared to 2 minutes, and 2 minutes yielding more graphene than 1 minute. XRD analysis reveals characteristic peak shifts indicative of graphene presence. SEM analysis confirms the graphene structure with porous features and sub-micrometer sizes. SEM images and diameter data further validate the successful conversion of carbon into graphene. These findings provide a foundation for the development of high voltage plasma-based production of graphene from mangrove wood charcoal. The utilization of a 10kV Neon Power Supply transformer enables the generation of high voltage plasma for the carbon-to-graphene conversion process. The electrode distance in the transformer plays a crucial role, as greater distances result in higher voltages, while shorter distances lead to lower voltages. This research significantly contributes to expanding the knowledge and application of graphene in various scientific and engineering fields. Moreover, the understanding of how electrode distance affects the generated voltage using a Neon Power Supply transformer is an important finding for optimizing the performance of this type of transformer.**

Keywords--Electrode Distance, Graphene, High Voltage Plasma, Mangrove Wood Charcoal

I. INTRODUCTION

Wood is a material consisting of cellulose, lignin, hemicellulose, and extractive substances, each of which has a function in plants, including cellulose providing strength to cell walls, lignin supporting cellulose fibers and providing a hydrophobic effect and resisting pathogen attack. In contrast, extractive substances can provide the physical defense of wood [1]. Every chemical component contained in wood influences supporting wood plants and the resulting wood products. The composition of wood charcoal according to the standard requirements of SNI with values for moisture, ash, volatile matter, and bound carbon respectively ranges from 0.01−0.69%; 0.59−5.40; 13.95−26.15%; and 73.05−84% [2]. Charcoal is the result of the carbonization of carbon-containing materials due to decomposition by heat. Carbonization decomposes materials using direct or indirect heat in a furnace or retorts with limited air. The chemical composition of wood charcoal consists of carbon, hydrogen, oxygen, and others. These three chemical elements greatly determine the quality of wood charcoal as a fuel or absorbent material. Another factor that affects the quality of wood charcoal is authoring [3].

Carbon is a material that has various advantages in terms of physical and chemical properties, so many researchers are currently developing it. The advantages possessed by carbon make it a material with broad applications. The performance of this carbon is affected by its morphology (such as colloidal carbon, nanotubes, fullerenes, graphite, graphene, colloidal sphere, nanofiber, porous carbon, nanowire, and activated carbon) due to the method and conditions of synthesis [4]. Previously, research has been carried out on Few-Layer Wrinkled Graphene (FLwG) using a High-Voltage Plasma Method. This study uses raw materials from shell charcoal. Characterizing this main ingredient using Raman spectroscopy, transmission electron microscopy (TEM), and X-Ray diffraction (XRD) methods. Molecular vibrations are excited using a 488 nm wavelength. TEM investigations were carried out on a JEOL JEM 1400 instrument at an accelerating

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voltage of 120 kV. Next, XRD was equipped with CuKα radiation at 0.154 nm and operating with a step size of 0.01° [5].

In the Flash Joule Heating (FJH) process, amorphous conductive carbon powder is lightly compressed between two electrodes in a quartz or ceramic tube. The system can be at atmospheric pressure or under a light vacuum (~10 mm Hg) to facilitate gas release. The electrodes can be copper, graphite, or other conductive refractory materials and can be loosely fitted into a quartz tube to allow gas discharge at the FJH. The high-voltage electrical discharge from the capacitor bank brings the carbon source to temperatures higher than 3,000 K in less than 100 ms, effectively converting the amorphous carbon into turbostratic FG. High-quality graphene can be quickly identified by Raman spectroscopy. The FG of carbon black (CB-FG) has intense 2D peaks. The intensity of the 2D band relative to the G band (I2D/G) is greater than 10 in many locations. The very low intensity of the D band indicates a low concentration of defects from this FG product, which contributes to the amplification of the 2D band. Thus, the unusually high I2D/G = 17 of CB-FG is the highest value reported so far for all forms of graphene and may result from the extreme temperatures achieved in the flash process, which expels non-elemental carbon gas from the system. In addition, the two peaks, TS1 and TS2, at ~1.886 cm−1 and ~2.031 cm−1, respectively, confirm the turbostratic nature of the FG. The FG X-ray diffraction (XRD) pattern shows a well-defined peak (002), indicating successful graphitization of amorphous carbon. The (002) FG peak occurs at a diffraction angle of 2θ = 26.1° [6].

Further research was conducted by [7]. Resonance Inverter in which the ozone generator is regulated by the dielectric barrier discharge method. The power supply used is a non-sinusoidal inverter with a maximum voltage of 15 kV and a frequency of 25 kHz. This study will investigate plasma characteristics, current and voltage characteristics, Lissajous diagrams, and ozone concentrations generated from several models. In addition, this research aims to synthesize graphene from coconut shell-based charcoal using the high-voltage plasma method. Plasma is made by modifying the ozone generator circuit to produce plasma different from the previous ozone generator barrier release, so this method results in the production of FLwG.

A. *Raw Material*

The raw material for this work is charcoal, made from wood. This wood-based charcoal starts from collecting some dry wood as fuel to prepare it. Mangrove wood is one of the materials that can be used in the water purification process because mangrove wood can be used as activated charcoal. Activated charcoal is a carbon compound produced from materials containing carbon or charcoal treated to get a wider surface area. The surface area of activated charcoal ranges from 300-3500 m2/gram, and this is related to the internal pore structure, which causes activated charcoal to have properties as an adsorbent.

B. *Graphene*

According to research[8], graphene is a single layer of carbon packed in a hexagonal (honeycomb) lattice with a carbon-carbon spacing of 0.142 nm. It is the first two-dimensional crystalline material and represents a whole class of 2D materials, including, for example, Boron-Nitride (BN) and Molybdenum-disulfide (MoS_2) monolayers, both of which have been produced after 2004. [8]. The electronic structure of graphene is different from that of ordinary three-dimensional materials. Six double cones characterize the Fermi surface.

C. *High Voltage Plasma Circuits*

The raw material used in this work is charcoal made from coconut shells, through the process of burning coconut shells to become charcoal which is then crushed to become charcoal powder. Then immediately emphasized by plasma arc discharge without further treatment. Implementation of a resonant-inverter-generated high-voltage ozone generator with a push-pull configuration has been reported. The complete electronic circuit of a resonant inverter [5].

D. *Arc Discharge*

Research [9] regarding arc discharge of carbon electrodes in the presence of H reported the formation of multiwalled carbon nanotubes (MWNTs) in the central part of the cathode and a petal-like graphite sheet consisting of interlaced graphene sheets in the outer region surrounding the cathode. In the procedure used by the researchers, researchers only collect deposits that form on the inner walls of the reaction chamber, avoiding material around the cathode, as the latter tend to contain significant amounts of MWNT and other carbonaceous materials. This study describes an arc disengagement method to prepare graphene samples with 2-4 layers. More importantly, the researchers demonstrated that this method helps prepare boron- and nitrogen-doped graphene [9].

E. *Scanning Electron Microscopy*

Scanning Electron Microscopy (SEM) is a type of microscope that uses electrons instead of light to see objects at high resolution. SEM is also useful for knowing a solid object's microstructure (including porosity and crack shape).

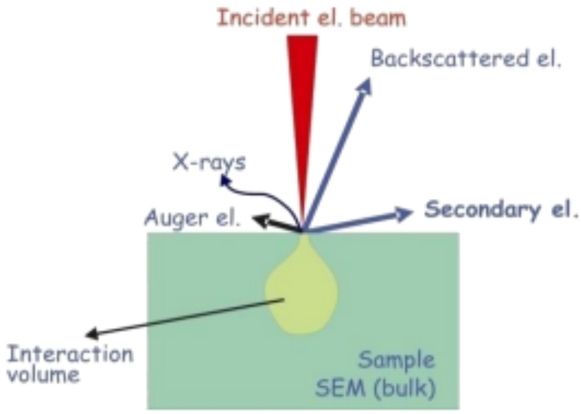

Fig. 1. Schematic of Scanning Electron Microscopy

F. *X-Ray Diffraction*

X-ray diffraction is one way to study the regularity of atoms or molecules in a specific structure. If the atomic or molecular structure is arranged regularly to form a lattice, then the electromagnetic radiation under certain experimental conditions will experience amplification. Knowledge of the experimental conditions can provide valuable information about the arrangement of atoms or molecules in a structure. XRD characterization aims to determine the crystal system. The X-ray diffraction method can explain lattice parameters, types of structures, different atom arrangements in crystals, crystal imperfections, orientation, grains, and grain size.

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G. Power Dissipation and Electric Field Strength

The absorbed power is the power dissipated in a circuit. To determine the absorbed power, we can use the mathematical method. The equation can calculate the relationship between stress and charge during one shear cycle:

$$Pi = mSfC_0 \quad (1)$$

Pi: Power Dissipating (Watt), m: Transform Comparison (1: 1000), S: Area, f: Transform Frequency 21 kHz (21x103), C0: Capacitor 1μF (1x10-6)

$$S = \frac{\text{area chart weight * Square Area}}{\text{Square weight between the voltage point and the charge}} \quad (2)$$

There is an electric field in a high-voltage plasma discharge between the distance of the two electrodes. The resulting electric field is a non-uniform electric field because geometric differences between the electrodes generate a strong electric field around the tip of the electrode rod or graphite tip [10]. The magnitude of the electric field strength can be seen in the following equation:

$$E(x) = \frac{2V}{(r+2x-\frac{x^2}{d})\ln(1+\frac{2d}{r})} \quad (3)$$

V: The voltage is measured on the electrodes (V), r: The radius of the rod electrode tip (cm), d: Distance Between Electrodes (cm), x: The distance between the tip of the rod electrode and the surface of the sample (cm), E: Electric field strength kV/cm.

H. Electrical Energy Consumption

Electrical energy comes from an electric charge that creates an electric field used for everyday life and moving mechanical equipment to produce other forms of energy.

$$E = V*I*t*\cos\varphi \quad (4)$$

E: Electrical energy (Wh), V: Voltage (V), I: Current (A), T: Time (s)

II. METHODOLOGY

A. High Voltage Plasma Design

The high voltage plasma generator circuit with the arc discharge method is assembled using 220V AC voltage as the source voltage and connected to a neon power supply transformer as a voltage step up from 220V to 10kV. Then the anode on the transformer is connected to the rod electrode, and the cathode on the transformer is connected to the plate electrode or discharge electrode. Then the distance between the electrodes is adjusted, and a sample is given between the electrodes. In the process of testing high-voltage plasma, we can apply a sawyer tower circuit for plasma generation where in this method, there are additional components, namely capacitors, and ground. This circuit is assembled by connecting a 220V source voltage to a step-up transformer; the transformer anode is connected to the rod electrode, and the transformer cathode is connected in series with the plate electrodes and the capacitor, which then the other leg of the capacitor is connected to grounding. We can use high-voltage probes, current probes, and PC oscilloscopes to perform voltage, current, and capacitor measurements.

B. Calculation Process

We can produce a Lissajous diagram by comparing the data between the output voltage of the transformer and the load with the load; the first step is to compare 300 output voltage measurement data with the load, then we input the data in Excel and change it in the form of a scatter diagram so that a diagram will be produced its Lissajous. After the Lissajous diagram is generated, we print it using 80-gram paper with a height of 14,0716 cm and a width of 22,8346 cm. After that, the Lissajous diagram is cut, and then the weight is weighed using an analytical balance to determine the surface area of the Lissajous diagram.

Fig. 2. The Process of Weighing the Areas of the Lissajous

For the calculation of power factor, for a resistive load in an AC circuit, there is no phase difference between the voltage and the current; for an inductive load, the voltage phase is behind the current by Φ (lagging), and for capacitive loads, the voltage phase is in the front current of Φ (leading). The figure below shows the phasor diagram for an inductive load, where the current leaves the voltage at an angle of Φ. Thus, the current is divided into two parts: the current I cos Φ as a pure current and the current I sin Φ, also called a reactive current 90° perpendicular to the pure current. The diagram shows that the Φ angle determines the value of the power factor of a circuit with a reactive load. The smaller the angle Φ, the higher the power factor value.

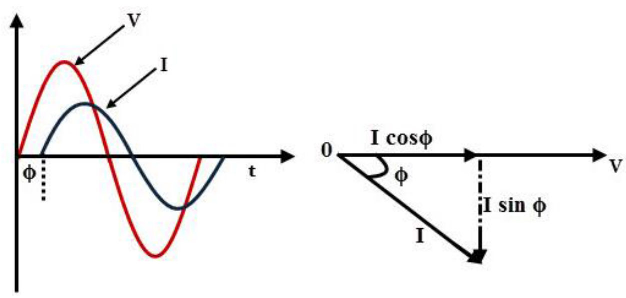

Fig. 3. How to Determine Power Factor Value

III. Result And Discussion

A. *High Voltage Plasma Circuit*

The image shows a high voltage plasma generator circuit comprising a 220V power source from the national grid (PLN), a 10kV Neon Power Supply transformer, rod and plate electrodes, a capacitor, and grounding. The assembly involves connecting the electrodes to the transformer's anode and cathode, creating a gap between them. The capacitor and grounding are then connected to the plate electrode junction. Finally, the transformer is linked to the PLN power source, stepping up the voltage to 10kV and generating high voltage plasma between the electrodes. This setup allows for various applications, including carbon-to-graphene conversion. Factors like electrode distance influence the characteristics of the plasma discharge. Safety precautions must be followed when working with high voltage equipment. The circuit provides a foundation for research and industrial applications, enabling advanced material synthesis and plasma physics studies.

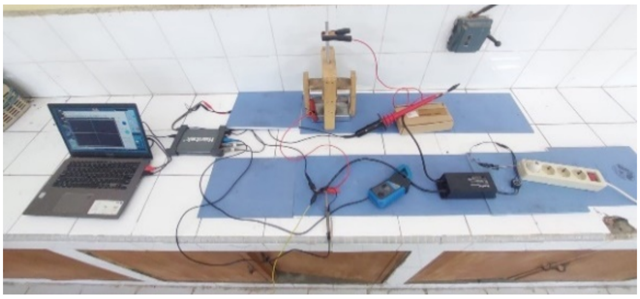

Fig. 4. High Voltage Plasma Circuit

B. *The Form of High Voltage Plasma and the Result of Plasma Discharge on Carbon*

Fig. 5. High Voltage Plasma

The Figure 5 is a form of high-voltage plasma discharge that has a visually orange color and emits a relatively strong sound.

Fig. 6. Results of Carbon Conversion After Exposed to High Voltage Plasma Discharge

C. *SEM Analysis*

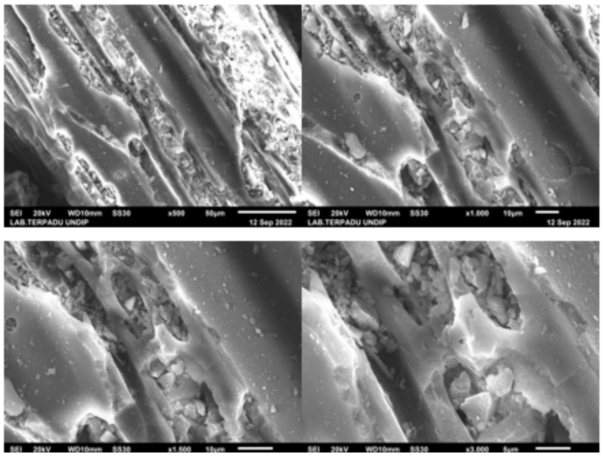

Fig. 7. SEM Analysis Results of Mangrove Wood Charcoal Exposed to High Voltage Plasma

In Figure 7 it can be seen that the carbon structure that has been exposed to high voltage plasma discharge will turn into porous and there are many micro-sized molecules and some are even nano-shaped or what is called graphene nanosheet. Figure 8 shows an x-ray diffraction pattern where it can be seen that the highest crystallization phase of mangrove charcoal occurs at an angle of 24.58°. In mangrove charcoal, it can be seen that the crystallization phase occurs at angles of 24.02°, 24.48°, 24.54°, 24.56°, and 24.58°. In untreated mangrove charcoal, it can be seen that the highest crystallization phase occurs at an angle of 24.7°. In the treated mangrove charcoal, it can be seen that the crystallization phase occurs at angles of 24.34°, 24.36°, 24.42°, 24.58, 24.7. on mangrove wood charcoal treated with the highest crystallization phase occurring at an angle of 20.9°. In the treated mangrove charcoal, it can be seen that the crystallization phase occurs at angles of 20.54°, 20.6°, 20.74°, 20.84°, and 20.9°. The occurrence of a shift in each peak, a sharp decrease in the effect of plasma discharge, and the narrowing of the peaks are characteristics of graphene.

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D. X-Ray Diffraction Analysis

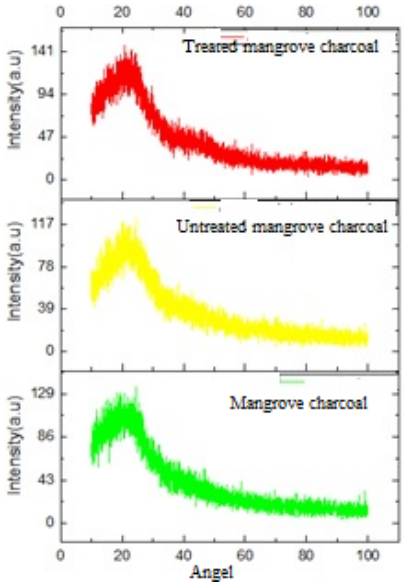

Fig.8. XRD Pattern of Mangrove Charcoal, Untreated Mangrove Charcoal, and Treated Mangrove Charcoal.

E. Measurement Result Data

TABLE I. Transformer Output Measurement

No	Voltage (V)	No	Voltage (V)
1	-2.7294	21	0.1255
2	-2.9176	22	0.3451
3	-3.1686	23	0.5333
4	-3.3569	24	0.7843
5	-3.5765	25	0.9725
6	-3.7647	26	1.2235
7	-4.0157	27	1.4118
8	-4.0471	28	1.6000
9	-4.0471	29	1.8510
10	-4.0471	30	2.0706
11	-4.0471	31	2.2588
12	-4.0471	32	2.5098
13	-4.0471	33	2.6980
14	-4.0471	34	2.8863
15	-4.0471	35	3.1059
16	-4.0471	36	3.2941
17	-4.0471	37	3.5137
18	-4.0471	38	3.7020
19	-4.0471	39	3.8588
20	-4.0471	40	3.9529

Table I is the data from the measurement results of the neon power supply transformer without load. In measuring the transformer voltage without load above, we can see that the output value of the transformer has positive and negative values, where the principle of high voltage plasma is almost the same as the principle of a short circuit; the farther the gap used to produce plasma, the greater the voltage needed to produce plasma, if If the measured voltage is negative, the plasma current is small, meaning that the resistance when the voltage is negative is higher than the voltage when the voltage is positive. From the measurement results above with variations in the distance of the electrodes, namely 1cm, 1.5cm, and 2cm, and the transformer without load, we can see that the farther the distance between the electrodes, the greater the voltage value required.

TABLE II. Voltage, Current, and Capacitor Voltage Measurement Data With 1cm Electrode Distance

No	Current (A)	Voltage (kV)	Voltage Capasitor (V)
1	-0.1882	1.6314	1.6314
2	-0.1882	1.6627	1.5059
3	0	1.7569	1,5059
4	0.0627	1.7882	1.4431
5	0.0627	1.8510	1.4431
6	0.1255	1.8824	1.4431
7	0.2510	1.9137	1.3804
8	0.2510	1.9451	1.3804
9	0.2510	2.0078	1.2549
10	0.3137	2.0078	1.2549
11	0.3765	1.9451	1.2549
12	0.3765	1.9451	1.1922
13	0.3765	1.9451	1.1922
14	0.4392	1.9451	1.1294
15	0.5647	1.9451	1.1294
16	0.5647	1.9451	1.0667
17	0.6275	1.9451	1.1294
18	0.6275	1.9451	1.0667
19	0.4431	2.0706	0.5020
20	0.3765	1.0667	1.7569

TABLE III. Voltage, Current, and Capacitor Voltage Measurement Data With 1.5cm Electrode Distance

No	Current (A)	Voltage (kV)	Voltage Capasitor (V)
1	0.2196	1.8824	-0.1882
2	0.1569	1.8824	0
3	0.1569	1.8824	0
4	0.2196	1.8824	0.0627
5	0.1569	1.8824	0.1882
6	0.1882	2.0392	0.2510
7	0.1569	2.0392	0.3137
8	0.1569	1.8824	0.3765
9	0.1882	2.0392	0.3765
10	0.2196	2.0392	0.5020
11	0.1882	2.0392	0.5647
12	0.1882	2.0392	0.6275
13	0.2196	2.0392	0.6275
14	0.1882	2.0392	0.7529
15	0.1882	2.1961	0.7529
16	0.2196	2.0392	0.8157
17	0.2196	2.1961	0.8784
18	0.2196	2.1961	0.8784
19	0.2196	2.1961	0.9412
20	0.1882	2.1961	0.9412

TABLE IV. Voltage, Current, and Capacitor Voltage Measurement Data With 2cm Electrode Distance

No	Current (A)	Voltage (kV)	Voltage Capasitor (V)
1	0.1569	2.3529	0.3137
2	0.3137	2.6667	0.9412
3	0.3137	2.8235	0.9412
4	0.3137	2.8235	0.9412
5	0.3137	2.8235	0.9412
6	0.3137	2.8235	1.0980
7	0.3137	2.8235	1.0980
8	0.3137	2.8235	1.0980
9	0.3137	2.8235	1.0980
10	0.3137	2.8235	1.4118
11	0.3137	2.8235	1.4118
12	0.3137	2.8235	1.4118
13	0.3137	2.8235	1.4118
14	0.3137	2.9804	1.5686
15	0.3137	2.8235	1.5686
16	0.3137	2.8235	1.5686
17	0.3137	2.8235	1.5686
18	0.3137	2.8235	1.5686
19	0.3137	2.8235	1.7255
20	0.3137	2.8235	1.7255

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F. *Great Power Dissipation To Produce Graphene*

1) Electrode Distance1 cm

It is known that the area weight in the diagram is between 1kV voltage (1 kV = 1cm) and 1μC charge (1μC = 1 cm). To determine the area value, we can use equation (2). It is known that the area weight in the diagram is between 1kV voltage (1kV = 1cm) with a charge of 1μC (1μC = 1cm). To determine the area value, we can use equation (2):

$$S = \frac{1.022\text{gram} * (1\text{ cm} * 1\text{ cm})}{0.0388\text{gram}} = 26.34\text{ cm}^2$$

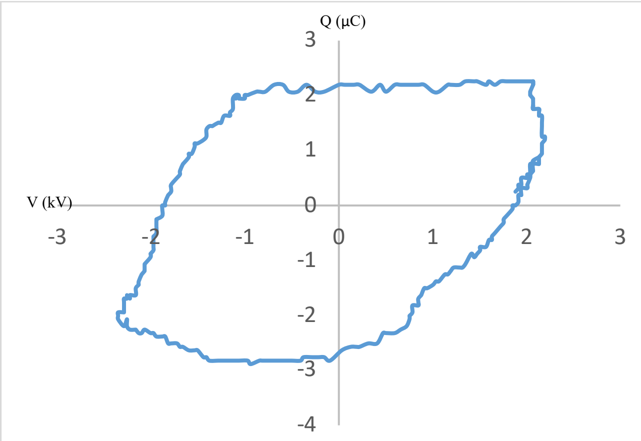

Fig.9. Lissajous Diagram with 1cm Electrode Spacing

It is known that the ratio of the transformer is 1:1000, the frequency is 21kHz, and the capacitor (C_0) = 1μf, with an electrode distance of 1cm; the amount of power used will be obtained using equation (1):

$$Pi = 1000 * 26.34 * 21 * 10^3 * 10^{-6}$$
$$Pi = 553.14\text{ Watt}$$

2) Electrode Distance 1.5cm

It is known that the area weight on the diagram is between 1kV voltage (1kV = 1cm) and 1μC charge (1μC = 1cm). To determine the area value, we can use equation (2):

$$S = \frac{0.9391\text{ gram} * (1\text{cm} * 1\text{cm})}{0.0592\text{ gram}} = 15.86\text{ cm}^2$$

It is known that the ratio of the transformer is 1:1000, the frequency is 21kHz, and the capacitor (C_0) = 1μf, with an electrode distance of 1.5cm; the amount of power used will be obtained using equation (1):

$$Pi = 1000 * 15{,}86 * 21 * 10^3 * 10^{-6} = 333.06\text{ Watt}$$

3) Electrode Distance 2cm

The area weight on the diagram is known to be between a voltage of 1kV (1kV = 1cm) and a charge of 0.5 μC (1 μC = 1 cm). To determine the value of the area, we can use equation (2):

$$S = \frac{0.9372\text{ gram} * (0.5\text{cm} * 1\text{cm})}{0.0516\text{ gram}} = 9.08\text{ cm}^2$$

It is known that the ratio of the transformer is 1000:1, the frequency is 21kHz, and the capacitor (C0) = 1μf, with an electrode distance of 2cm; the amount of power used will be obtained using equation (1):

$$Pi = 1000 * 9.08 * 21 * 10^{-6} = 190.68\text{ Watt}$$

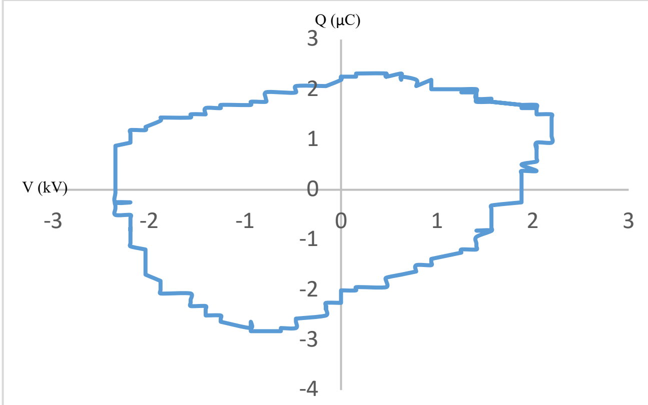

Fig. 10. Lissajous Diagram with 1cm Electrode Spacing

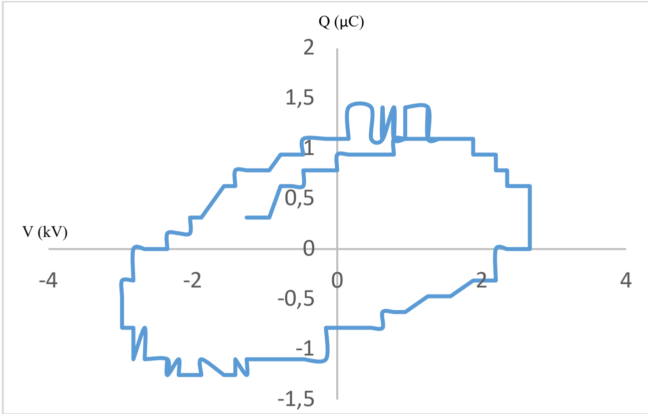

Fig. 11. Lissajous Diagram with 1cm Electrode Spacing

G. *Amount of Energy Used*

The amount of energy used to produce graphene made from mangrove wood charcoal using high-voltage plasma can be affected by the amount of energy used during the testing process. To determine the energy used, we can use equation 4 with variations in distance, namely 1 cm, 1.5 cm, and 2 cm, and the Time used is 1 minute, 2 minutes, and 3 minutes. Electrode distance of 1 cm with a voltage of 1.0667 kV, current of 0.3765 A with a time of 3 minutes, and φ = 22.5° then cosφ = 0.92388, using equation 4 then we get the amount of energy used is:

$$E = 1066.7 * 0.3765 * 0.05 * 0.92388 = 18.5521\text{ Wh}$$

The electrode distance is 1.5 cm with a voltage of 2.1961 kV, a current of 0.1882 A with a time of 3 minutes, and φ = 33.75° then cosφ = 0.83147, using equation (4) then we get the amount of energy used is:

$$E = 2196.1 * 0.1882 * 0.05 * 0.83147 = 17.1826\text{ Wh}$$

The electrode distance is 2cm with a voltage of 2.3529 kV, a current of 0.1569 A with a time of 30 minutes, and φ = 21.5° then cosφ = 0.930418, using equation (4) Then we get the amount of energy used:

$$E = 2352.9 * 0.1569 * 0.05 * 0.930418 = 17.1741\text{ Wh}$$

H. *Great Electric Field Strength*

In this stage, we will measure the magnitude of the electric field generated by the application of high-voltage

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plasma to convert mangrove wood charcoal into graphene. The objective of this phase is to understand and measure the strength of the electric field formed during the conversion process. By evaluating the variations in the distance between the rod electrode and the plate electrode, as well as the distance between the rod electrode and the carbon raw material (mangrove wood charcoal), we can determine the magnitude of the electric field generated. This information is crucial for understanding the influence of these parameters on the efficiency of converting mangrove wood charcoal into graphene using high-voltage plasma technology. By understanding the generated electric field strength, we can enhance our understanding of the conversion process and optimize the experimental conditions to achieve the desired outcomes. To measure the electric field strength with the distance between the electrodes, we can use equation (3), namely; an electrode distance of 1cm with a voltage of 2.0706kV, the radius of the rod electrode is 0.5 cm, the distance between the tip of the rod electrode and the sample is 0.5 cm, the distance between the electrodes is 1cm then:

$$E(0.5) = \frac{2(2.0706\text{kV})}{\left(0.5 + 2(0.5) - \frac{0.5^2}{1}\right)\ln\left(1 + \frac{2(1)}{0.5}\right)}$$
$$= 2.05846\ \text{kV/cm}$$

An electrode distance of 1.5cm with a voltage of 2.1961kV, the radius of the rod electrode is 0.5cm, the distance between the tip of the rod electrode and the sample is 0.5cm, the distance between the electrodes is 1.5cm then:

$$E(0.5) = \frac{2(2.1961\text{kV})}{\left(0.5 + 2(0,5) - \frac{0.5^2}{1.5}\right)\ln\left(1 + \frac{2(1.5)}{0.5}\right)}$$
$$= 1.69286\ \text{kV/cm}$$

An electrode distance of 2cm with a voltage of 2.3529kV, the radius of the rod electrode is 0.5cm, the distance between the tip of the rod electrode and the sample is 0.5cm, the distance between the electrodes is 2cm then :

$$E(0.5) = \frac{2(2.3529\text{kV})}{\left(0.5 + 2(0.5) - \frac{0.5^2}{2}\right)\ln\left(1 + \frac{2(2)}{0.5}\right)}$$
$$= 1.5576\ \text{kV/cm}$$

The distance between the electrodes proved to be a pivotal factor in shaping the electric field strength. Our meticulous observations unveiled the undeniable influence of electrode distance on the magnetic forces at play. As the gap widened between the electrodes, a gradual diminishment in the magnitude of the electric field ensued. The relationship between electrode distance and electric field strength became increasingly apparent, captivating our attention and urging us to unravel its intricacies. This captivating interplay between distance and electric field strength holds significant implications for the realm of plasma technology. It offers a pathway for fine-tuning and controlling the characteristics of the generated magnetic fields. The ability to manipulate and optimize the electric field strength by adjusting the electrode distance opens up new avenues for tailoring plasma-based processes and applications. Furthermore, this profound insight fosters a deeper understanding of the underlying mechanisms governing plasma-induced transformations. By comprehending the relationship between electrode distance and electric field strength, we can decipher the nuances that govern the behavior of plasma, unlocking a realm of possibilities for its utilization in various fields, from advanced material synthesis to energy conversion and beyond.

In essence, our findings emphasize the pivotal role of electrode distance in shaping the electric field strength and magnetic forces in high-voltage plasma systems. They underscore the need for meticulous control and precise manipulation of this parameter to harness the full potential of plasma technology and pave the way for groundbreaking advancements in scientific research and industrial applications.

IV. Conclusion

Charcoal made from mangrove wood can be converted into graphene. In carbon conversion, high-voltage plasma technology can be used with the arc discharge method by giving plasma discharge to the carbon sample. The distance between the rod electrode and the plate electrode and the distance between the electrode and the sample can affect the plasma produced, where at a distance of 1cm, the plasma produced is more robust. The color of the plasma is bluish-orange; when 1.5cm of plasma is produced, the color of the plasma is dark orange, and when 2 cm of plasma is produced, it is pale orange, and the sound is not too strong. Variations in carbon treatment time significantly affect the yield of converted carbon, where during 3 minutes treatment time, more graphene is produced than in 2 minutes, and 2 minutes produces more graphene than 1 minute. In the results of the XRD analysis, we can see that the three types of waves have differences, where there is a shift at each peak which is a characteristic of graphene material. The results of the SEM analysis were analyzed again using the ImageJ application to find out the structure's diameter; after measuring the diameter, it can be seen that the structure is under a micrometer in size which shows the characteristics of graphene.

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