INVESTIGATION ON CORRELATION BETWEEN BIO-WASTE MATERIAL MORPHOLOGY AND ITS DIELECTRIC PROPERTIES

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BACHELOR OF ELECTRICAL ENGINEERING (ELECTRONICS) WITH HONOURS

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INVESTIGATION ON CORRELATION BETWEEN BIO-WASTE MATERIAL MORPHOLOGY AND ITS DIELECTRIC PROPERTIES

RUDRAA DEVI A/P GIAMASROW

Thesis submitted in fulfillment of the requirements
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ABSTRAK

Di Malaysia sebanyak 1.2 juta tan sisa bio yang berasaskan pertanian dilupuskan ke dalam tapak perlupusan sisa setiap tahun, dimana sis aini dikatakan 39% dari keseluruhan sisa yang dihasikan di negara kita. Ini merupakan salah satu punca terbesar kepada pencemaran di negara kita, seperti pencemaran air, pendemaran udara dan pemanasan global. Dengan pengfabrikasian dielektirk substrat mengunakan sisa bio berasaskan pertanian ini mempunyai potensi untuk menyumbang kepada pengurangan sisa di negara kita dan juga berpotensi untuk digunakan sebagai bahan alternatif kepada dielektrik substrat yang boleh digunakan dimana-mana perkakas elektrik, Papan Litar Bercetak (PCB) dan antenna. Kaji ini menekankan pembuatan baru daripada sisa bio berasaskan pertanian untuk mencipta dielektrik substrate. Daun nenas digunakan sebagai bahan asas didalam kajian ini kerana ia merupakan antara sisa yang terbanyak yang terhasil di negara Malaysia dan ia tidak pernah dikaji sebelum ini. Dielektrik substrat ini mempunyai sifat menyerap dan menyimpan gelombang elektomagnet. Sifat penyerap yang ada pada dielektrik substrat ini dikaji denagn memerhati struktur morfologi mengunakan TM3030 mikroskopi elektron penskanan (SEM). Untuk menyiasat kesesuian bahan asas ini sebagai penyerap gelombang electromagnet, unsur komposisi bahan tersebut disiasat menggunakan analisis EDX. Dari kaji ini didapati struktur morfologi bagi serat selulosa yang mentah dari daun nenas boleh dilihat dengan jelas, bagaimana pun struktur morfologi bagi serat selulose yang telah dijadikan serbuk tidak dapat dilihat dengan jelas. Bagi unsur komposisi didapati dielektrik substrat yang menpunyai nilai dielektrik memnpunyai peratus unsur karbon yang banyak dan peratus unsur oksigen yang rendah. Nilai dielektik tertinggi dalam kaji ini ialah 3.3103. Keputusan dari kaji ini didapati bahawa daun nenas mempunyai potensi untuk digunakkan sebagain pengganti dielektik substrat.

Kata kunci: sisa pertanian, nilai dielektrik, struktur morfologi, unsur komposisi

ABSTRACT

In Malaysia, 1.2 million tonnes of bio-waste agricultural base waste are disposed of into landfills annually, which is 39% of the total waste produced in our country. This is one of the biggest causes of pollution such as air pollution, water pollution, and global warming in our country. Fabricating of the bio-waste agricultural base dielectric substrate has the protentional to contribute to the reduction of waste in our country and is potentially useful as an alternative material as a dielectric substrate which can be used in any electrical appliances, Printed Circuit Board (PCBs), and antennas. This research highlights a newly developed dielectric material by using the bio-waste agricultural base dielectric substrate. Pineapple leaves are used as the raw material in this research because it is one of the abundantly available waste materials of Malaysia and has not been studied yet as it is required. The Dielectric substrate can absorb and store electromagnetic signals. The absorbent of the dielectric substrate is investigated by analyzing the morphology structure of the dielectric substrate using TM3030 Scanning Electron Microscopy (SEM). To investigate the suitability of this raw material as electromagnetic absorbing material, the element composition of the dielectric substrate is analyzed through EDX Analysis. From this research, the morphology structure of the raw cellulose fiber of the pineapple leaves can be seen meanwhile the powdered cellulose fiber can't be seen. In terms of element composition, the dielectric substrate with the highest dielectric value has a higher percentage of carbon element and a lower percentage of oxygen element. The highest dielectric value that was obtained through this research is 3.3103. The result of this research shows pineapple leave have more potentially useful as substitute materials for dielectric substrates.

.Keywords: agricultural wastes, dielectric value, morphology structure, element composition

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LIST OF SYMBOLS

ε	Dielectric properties
ε'	Dielectric constant
ε''	Dielectric loss factor

LIST OF ABBREVIATIONS

SEM	Scanning electron microscope
TFLA	Two Level Factor Analysis
OF	One factor at a time analysis
PL	Pineapple leave
PCB	Printed Circuit Board
DW	Distilled Water
CF	Cellulose Fiber

CHAPTER 1

INTRODUCTION

1.1 Project Background

There has been a lot of research about identifying bio-waste as a dielectric substrate for many years [1-9]. This bio-waste-based substrate has the protentional to contribute to the reduction of bio-waste in our country. There are a few types of bio-waste which are agricultural waste, green waste, and food waste. Agricultural waste is one of the major waste products in our country [3]. This waste is made up of organic compounds from living plants such as rice husk, mango tree leaves, and pineapple leaves [1-9].

Globally, 998 million tonnes of agricultural waste are produced per year and in Malaysia, 1.2 million tonnes of agricultural waste are disposed of into landfills annually [4], which is 39% of the total bio-waste produced by our country as shown in figure 1.1. This is one of the biggest causes of pollution in our country [4]. The usage of diverse raw materials will help to keep an ecological balance in nature.

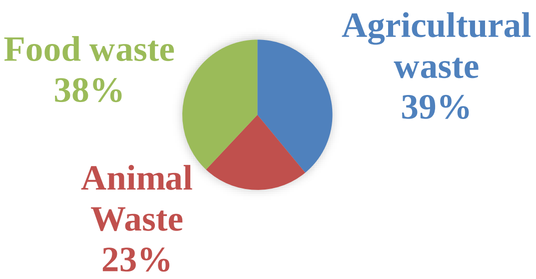

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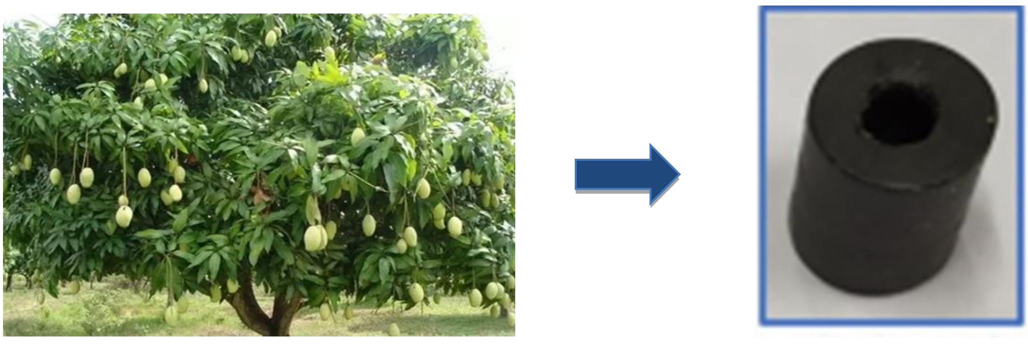
Figure 1.1 Dielectric substrate fabricated using Mango leaves

Agricultural wastes are non-product outputs of the production and processing of agricultural products that may contain material that can benefit man but whose economic values are less than the cost of collection, transportation, and processing for beneficial use. This factor makes the waste to be abandoned and this causes pollution such as air pollution, water pollution, and global warming around the county.

The most important property of bio-waste agricultural waste is its biodegradability and noncarcinogenic, with the advantage of being cost-effective. Above all agricultural waste is a renewable resource, thus providing a better solution of sustainable supply, like it has low density, least processing expenditure, no health hazards, and better mechanical and physical properties [11–16]. Reusing this huge and wide range availability of waste can reduce the pressure on forests and agriculture. This dielectric substrate is suitable for semiconductors, electric appliances, or dielectric substrates for antennas and Printed Circuit boards (PCBs).

The main function of the dielectric substrate is the ability to absorb and store electromagnetic signal. Fabricating dielectric substrate by using agricultural waste can be an alternative to the current dielectric substrate that was fabricated by using porcelain (ceramic), mica, glass, plastics, and the oxides of various. Some of the agricultural waste that has been used to fabricate dielectric substrate are mango tree leaves, coconut husk, eggshells, banana peels, sugarcane, pineapple leaves, etc. Figure 1.2 shows one example of a substrate that was fabricated by using agricultural waste. Figure 1.2 (b) shows the dielectric substrate which was fabricated by using the mango tree leaves shown in figure 1.2 (a).



(a) (b)

Figure 1.2 Picture of (a) Mango tree ; (b) dielectric substrate fabricated using mango tree leaves

The dielectric substrate is characterized by its dielectric properties. A good electromagnetic absorbing material absorbs the electromagnetic signal and converts this wave into heat. Dielectric properties or complex permittivity determine the ability of the material to absorb signals [7-9]. The dielectric properties (ε) can be represented by complex permittivity as shown in Equation 1: [1].

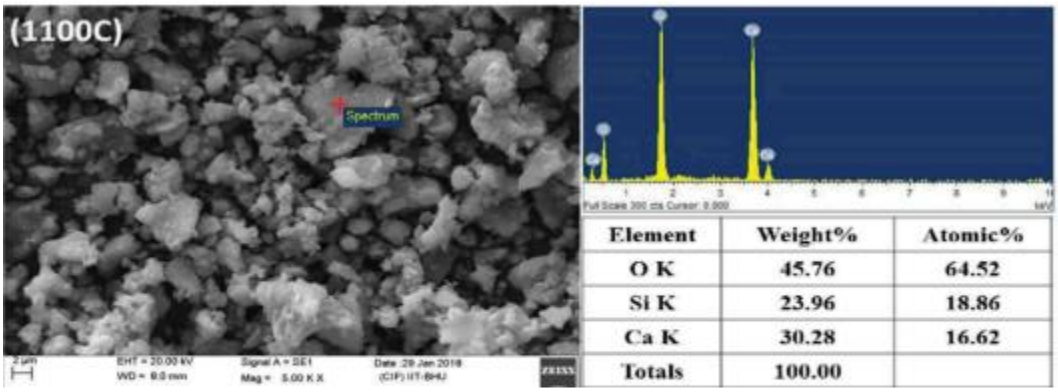
$$\varepsilon = \varepsilon' - j\varepsilon'' \tag{1}$$

Where ε is defined as dielectric properties, ε' is defined as dielectric constant and ε'' define as dielectric loss factor. The dielectric constant defines the ability of a material to store the electromagnetic signal while the dielectric loss factor defines the ability of a material to convert and dissipate the stored electromagnetic signal to heat [10]. The dielectric value of a substrate is measured by using a network analyzer.

As the dielectric substrate is most commonly known as an absorbing material, the absorbent of the dielectric substrate is determined by using the method of analyzing the morphology of the substrate using Scanning Electron Microscopy (SEM) which was suggested by a French chemist Antoine-Alexander- Brutus Bussyn [6]. By using SEM, the morphology structure and the element composition of the dielectric substrate can be analyzed.

SEM is a technique where only milligram quantities of material are used to determine the morphology structure of the material by observing the particle size, shape, and texture of the dielectric substrate. Other than that, the element composition of a dielectric substrate can be observed by using the same morphology structure from SEM by using the EDX analysis in software. The changes in the morphology structure can be correlated with the dielectric value of a dielectric substrate. Besides that, it is important to observe how the element composition in the substrate changes as the dielectric value changes. The main elements that can be observed in the dielectric substrate is carbon and oxygen element. Carbon plays the main role in a dielectric substrate as carbon is the main element that absorbs the electromagnetic signal

[7]. Figure 3 shows the morphology structure and the element composition of the dielectric substrate which was fabricated by using an eggshell [2].



Element	Weight%	Atomic%
O K	45.76	64.52
Si K	23.96	18.86
Ca K	30.28	16.62
Totals	100.00	

Figure 1.3 Morphology structure and element composition using SEM [2].

1.2 Problem Statement

In many parts of developing countries, bio-wastes are indiscriminately dumped or burnt in public places, thereby resulting in the generation of air pollution, soil contamination, harmful gases, smoke, and dust, and the residue may be channeled into a water source thereby polluting the water and aquatic environment [10]. This waste can be reduced by reusing the waste to produce other useful things such as creating dielectric substrate.

Nowadays, many researchers are investigating the possible ways of fabricating dielectric substrates that can be used in Printed Circuit boards (PCBs) and antennas using bio-waste material. There are a few researchers that have found the possibility of using the waste as a dielectric substrate [4-8]. The newly developed dielectric material should be more than 2 in terms of its dielectric value to utilize in any electronic application [4-8]. To overcome this problem, the procedure for producing the dielectric substrate need to be formulated.

According to Risoluto, the performance of the dielectric substrate formulated from bio-waste materials is closely related to the morphological structures.[8] The techniques, parameters, or variables utilized during the preparation of the dielectric substrate might change the morphological structures as well as the dielectric value. The correlation between dielectric value and the morphology structure needs to be investigated.

1.3 Objective

By considering the problem as stated in the previous chapter, the main objectives are highlighted as below:

- Produce newly developed dielectric material by using bio-waste agricultural base
- Identify the contributing factor with combinations of components that increases the value of dielectric properties in term of dielectric value
- Investigate the correlation between the dielectric value of the substrate and the morphological structures and elemental composition of the material.

1.4 Scope

In this study, a new technique is proposed for fabricating a good performance bio-waste agricultural base dielectric substrate by combining the contributing factors.

The effect of combining the contributing factor in the morphological structure of the dielectric substrate would be investigated by using Scanning Electron Microscopy (SEM). The element composition using EDX analysis are also studied to investigate how the element composition effect the dielectric value of the dielectric substrate. The result obtains through EDX analysis and morphological structure are correlated with the dielectric value of the dielectric substrate.

1.5 Conclusion

There are five chapter in this thesis with the references attached at the end of the chapters. Chapter 1 briefly elaborated generally on bio-waste agricultural base material, morphological structure and element composition, problem statement, and objectives of study, and the scope of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Bio-waste as the base material in fabricating dielectric substrate

F.H.Wee et al in 2017 [34] used rice husk, rice straw, sugarcane bagasse and dried banana leave as base material to fabricate dielectric substrate. The investigation is done by using these four wastes with different percentage of filling. Figure 2.1 shows the dielectric substrate fabricated using rice husk, rice straw, sugarcane bagasse and dried banana leaves. Table 2.1 shows the dielectric value of each material used. Banana leave have the highest dielectric value compared with other material. With different percentage of filler used to fabricate the dielectric substrate the dielectric value of each material changes according to the percentage. By using higher percentage of filler, the dielectric value is increasing.

Table 2.1 Dielectric value of agricultural waste [34].

Sample	Filler		
	10%	20%	30%
Rice husk	2.496	2.5099	2.673
Rice straw	2.984	2.999	3.289
Sugarcane Bagasse	3.3100	3.736	3.422
Dried Banana leave	3.005	3.243	3.374

(a)

(b)

(c)

(d)

Figure 2.1 The dielectric substrate of (a) rice husk, (b) rice straw, (c) sugarcane bagasse and (d) dried banana leave.

S.k.Hossain et al in 2018 [33] used egg shell as the base material to fabricate dielectric substrate. The dielectric value of the substrate is investigated under different sintered temperature. Table 2.2 shows the dielectric value of the dielectric substrate with different sintered temperature. At 1100-degree Celsius the dielectric value is 4.62 meanwhile at 1200-degree Celsius is 6.02. The increment in the dielectric value is due to the presence of strong ionic bonds in the calcium silicate. The chemical reacts with the base material at the highest sintered temperature and cause the increment in the dielectric value.

Table 2.2 Dielectric value of the dielectric substrate [33].

Sintered temperature (°C)	Dielectric value
1100	4.62
1200	6.02

2.2 Cellulose fiber extraction

Govardhan Goud et al in 2011 [9] has investigated the effect of using alkaline treated cellulose fiber and un-treated cellulose fiber with the dielectric value of the material. Roystonea regia, commonly known as the Cuban royal palm is used as the base material to fabricate the dielectric substrate [9]. The material is treated by using Natrium Hydroxide (NaOH). The suitable concentration to extract the lignin of the material is 5% [11]. Equation 2 is used to determine the mass of the NaOH and the distilled water that was used for the alkaline treatment. The dielectric value of alkaline treated cellulose fiber is lower than un-treated cellulose fiber. But alkali-treated fiber showed improvements in compressive strength and water resistance when compared with untreated fiber. Alkaline treated cellulose fiber is recommended to fabricate the dielectric substrate as the dielectric substrate must have water resistance characteristic so that it can be used in electrical appliance, PCBs and antennas [14].

$$5\% = \frac{\textit{Mass of NaOH}}{\textit{Mass of Distilled water}} \times \mathbf{100}\% \quad (2)$$

2.3 Scanning Electron Microscopy (SEM)

2.3.1 Structure and Working Principle of SEM

Scanning Electron Microscopy (SEM) has been an irreplaceable apparatus in inquire about since its innovation in 19626 and has altogether contributed towards science, medication and material sciences research [22]. SEM is used to observe the surface of the material with the magnification from 30 to 10,000. Figure 2.2 shows the components of SEM. The main component of SEM is electron gun, electromagnetic lenses, scan coil, electron detector, chamber, and computer screen. The electron gun is used to generate electron of high energy, electromagnetic lenses is used to column down the travelling electron, scan coil for deflection system, electron detector for backscattered the image, a chamber to hold the sample and lastly the computer system to view the scanned image of the sample. The working principle of SEM is the electron gun will produce an electron beam when tungsten wire is heated by current and accelerate by the anode. The beam travels in the vacuum column through electromagnetic field and lenses, which focus the beam down toward the sample. A mechanism of deflection coils enables to guide the beam so that it scans the surface of the sample in a raster pattern. The incident beam touches the surface of the sample and produce signal.

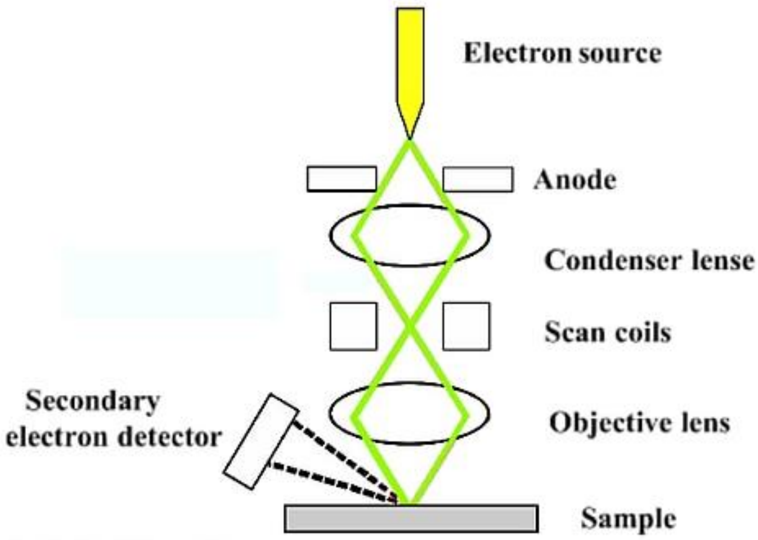
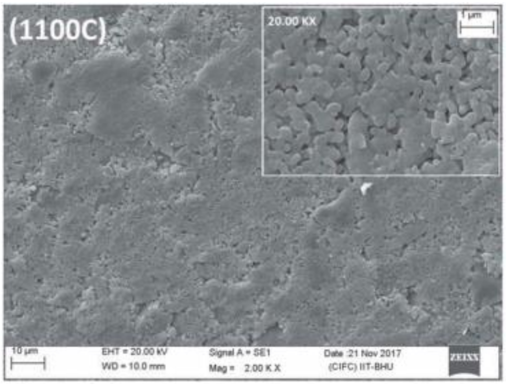


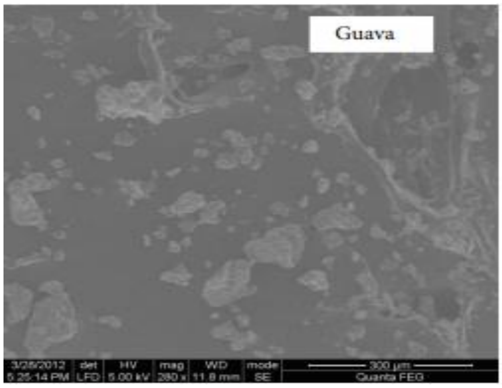
Figure 2.2 Components of SEM [24].

2.3.2 Morphology Structure by SEM

Morphology, in biology, is the study of the size, shape, and structure of animals, plants, and microorganisms and the relationships of their constituent parts. The term refers to the general aspects of the biological form and arrangement of the parts of a plant or an animal. C. S. Chadwick said that morphology is taken in its broadcast concept. It concerns the study of the form and structure of living organisms. It provides a basis for interpretation and understanding of other aspects of biology, such as physiology, heredity, ecology, taxonomy, evolution, and others. The development of the electron microscope and of methods for preparing ultrathin sections of tissues created an entirely new aspect of morphology—that involving the detailed structure of cells. Electron microscopy has gradually revealed the amazing complexity of the many structures of the cells of plants and animals. One of the major thrusts in contemporary morphology has been the elucidation of the molecular basis of cellular structure. Techniques such as electron microscopy have revealed the complex details of cell structure, provided a basis for relating structural details to the particular functions of the cell, and shown that certain cellular components occur in a variety of tissues.[1] The morphology structure affects the dielectric properties of a material for example sugarcane, rice husk, groundnut shell, oil palm shell, coconut shell, corncobs, durian shell, soybean oil cake [5-8]. Figure 2.3 shows the example of morphology structure of egg shell, guava, sapota, banana peels, mango tree and bamboo [8-15]. Some of the element that can be observed through the morphology structure are the size of particles, porosity, polarity and the roughness of the surface.



(a)



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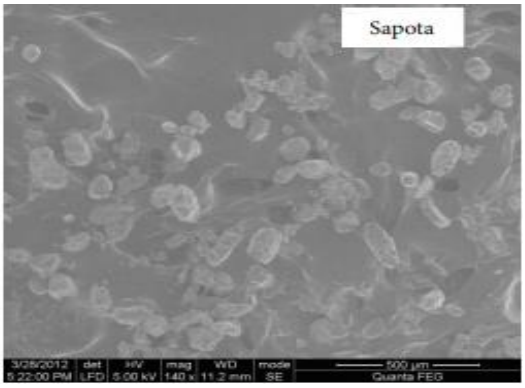

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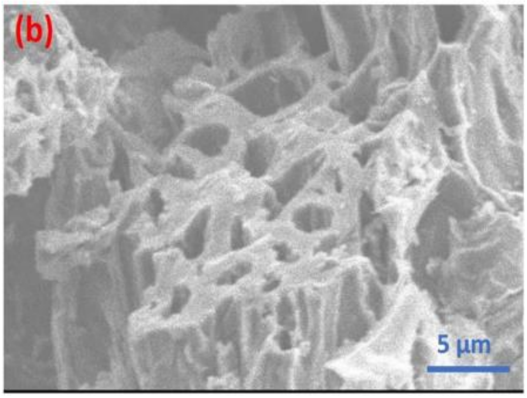

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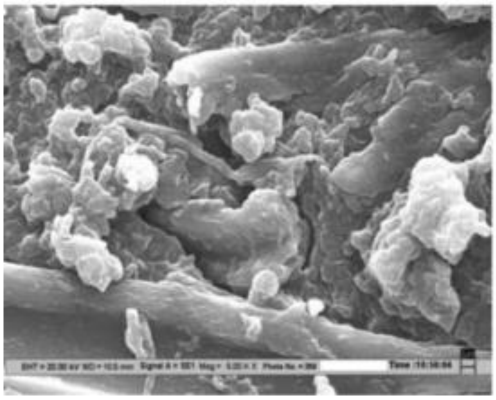
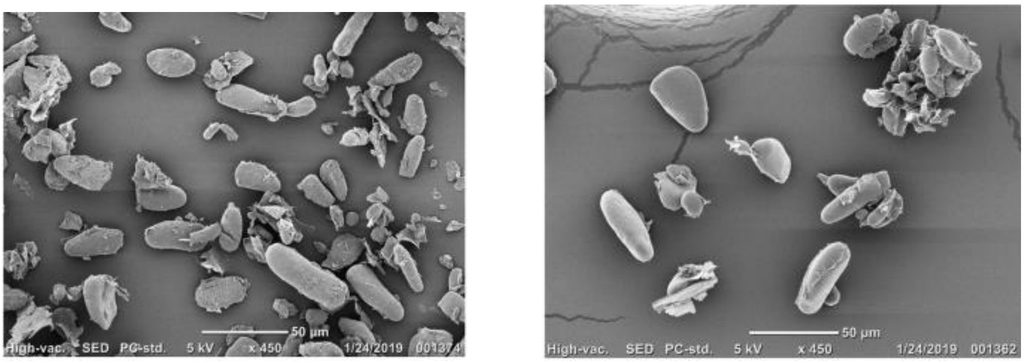


(f)

Figure 2.3 Morphology structure of (a) egg shell, (b)guava, (c) sapota, (d) banana peel, (e) mango tree leave and (f) bamboo [8-15]

2.1.2.1 Analysis of Morphology Structure

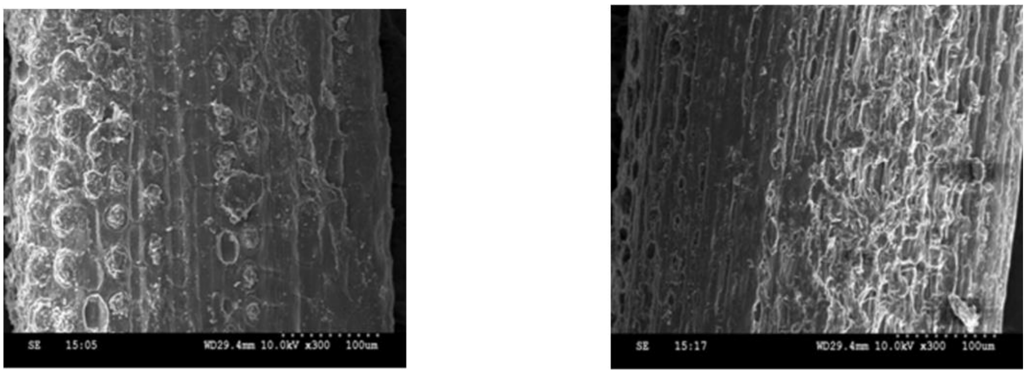
Jasim Ahmed et.al in 2020 [1] reported that the dielectric substrate can be fabricated by using green bananas. In this article, Jasim Ahmed et.al investigated how the dielectric properties of the material can change the morphology structure of the material. In this article, it was proved that the morphology structure influences the dielectric properties of the banana slice [1]. As figure 2.4(a), freeze-dried banana slices have more molecules and the molecules are in close contact and the gap between each molecule is smaller. Meanwhile, in figure 2.4(b), the tray-dried banana slice has a small number of molecules and the molecules are far from each other. This makes the molecules have a bigger gap between each molecule compared with freeze-dried banana slices. From this article, we can conclude that tray-dried have the best dielectric properties because the gap between the molecules is bigger and this makes the banana slice absorb the electromagnetic more easily compared with freeze-dried banana slice [1].



(a) (b)

Figure 2.4 SEM image of (a) freeze-dried banana and (b) tray-dried banana [1].

Govardhan Goud and R. N. Rao in 2011 [4] proved that the dielectric properties and morphology structure of material have close contact, where the morphology structure of the material changes according to the dielectric properties of the material. In this article, the factor which was observed in the morphology structure of the material is the roughness of the Roystonea Regia (Palma tree) [4]. The dielectric properties of a material can be varying depending on the roughness of the structure. The alkali-treated material surface shows coarser (rough) topography as shown in Figure 2.5(b) than the untreated material surface as shown in Figure 2.5(a). When the surface is getting rough the dielectric is decreasing because the ability for the surface to absorb the electromagnetic will be very low. This is because when the surface is getting rough, then the surface of the molecules will become uneven. Having an uneven surface in the morphology structure will make the process of absorbing the electromagnetic harder than usual, where it will make the material have a lower value of dielectric [4].



(a) (b)

Figure 2.5 SEM image of Palma tree with the untreated surface (a) and alkali-treated surface (b) [4].

Praveen Negi et.al in 2020 [23] investigated the dielectric properties of the mango leave and its effect on the morphology structure. Figure 2.6 shows the SEM images of Mango leaves, which clearly show the porous network formed within the sample having a pore size ranging from 1 μm to 5 μm. In figure 2.5 the diameter of the porosity is big. The diameter of the porosity is the void space inside the molecules. When the void space of a molecule increases it will make the surface area of the molecules decreases and at the same, it will decrease the absorption of the electromagnetic and effects the dielectric value of the material. Consequently, with an increase in porosity, the void space also increases which in turn decreases the dielectric properties of a material [23].

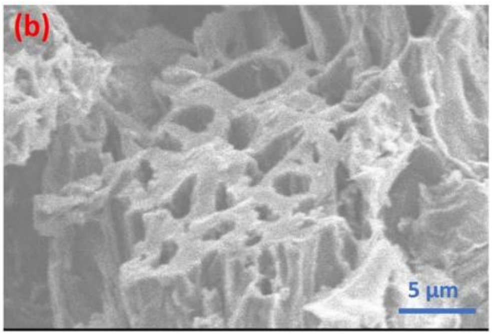
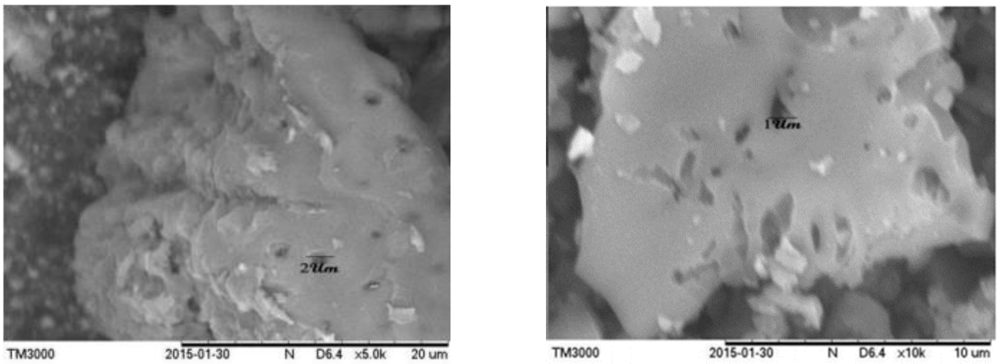


Figure 2.6 SEM image of dielectric susbtrate fabricated using mango leaves [23].

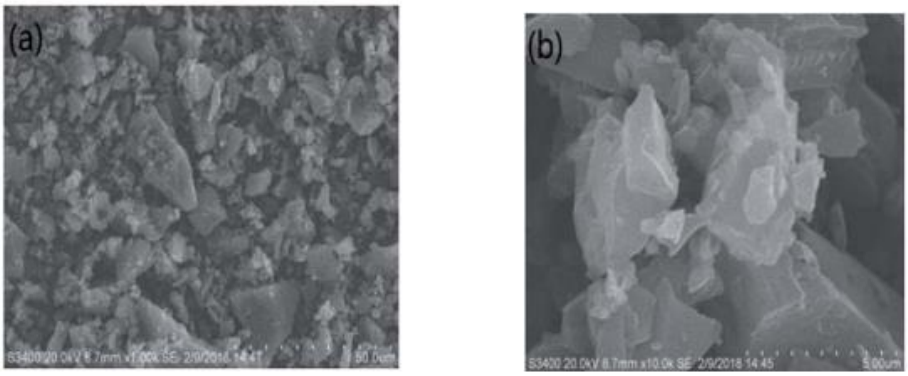
W.F.Hoon et al in 2015 [15] investigated the relationship between the dielectric properties of coconut shells and their morphology structure. Figure 2.7 shows the surface area of the coconut shell, where figure 2.7(a) shows the coconut shell powder (CSP), and figure 2.7(b) shows the coconut shell with activated carbon (CSAC). In figure 2.7(a) the morphology structure of the coconut shell has a bigger diameter of the porosity compared to figure 2.7(b). When the diameter of the porosity increases the ability of the coconut shell to absorb the electromagnetic will decrease. This is because the surface area acts as the absorption medium. When the area becomes smaller, the material can only absorb the electromagnetic in a very small amount. The dielectric value of the coconut shell will decrease when the absorption of the electromagnetic decrease [18].



(a) (b)

Figure 2.7 SEM image of coconut shell powder (CSP) (a) and shell activated carbon (CSAC) (b) [15].

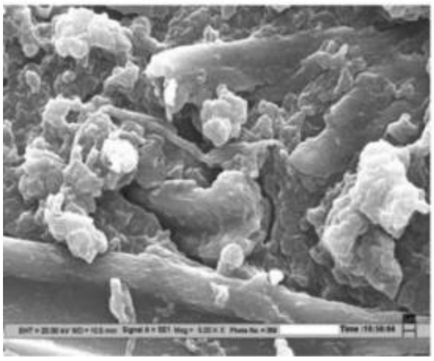
L.Wang et al in 2019 [25] used walnut shells to investigate the relationship between the dielectric properties and the changes in the morphology structure. Figure 2.8 shows an SEM image of the walnut shell whereas figure 2.8(a) shows the morphology structure with the magnification of × 1k meanwhile in figure 2.8(b), the same image as figure 2.8(a) but with a magnification of ×10k. Figure 2.8(a) shows the molecules in irregular shape, meanwhile, in figure 2.8(b) the porosity of the molecules can be seen very clearly. The large pores in the surface of the sample were founded in figure 2.8(b). L.Wang et al proved that having a larger surface of porous makes the material have lower dielectric. The dielectric value will decrease because the ability of the material to absorb the electromagnetic reduces [25].



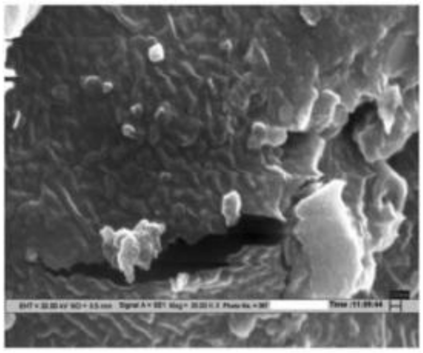
(a) (b)

Figure 2.8 SEM image of the walnut shell with the magnification of (a) ×1k and (b) ×10k [25].

V Kumar et.al 2012 [24] used bamboo to investigate the relationship between the dielectric properties and how it can affect the morphology structure of the material. The morphology structure of the pure bamboo is shown in figure 2.9(a) and with 3% of nanoclay content bamboo at figure 2.9(b). In figure 2.9(a) the molecules are orientated very well as compared to figure 2.9(b) [24]. The orientation of the molecules can be observed through the number of molecules orientated at the surface. When there is a very small number of molecules in the structure, it shows that the orientation process doesn't occur very well. When the orientation of the molecules is good, the dielectric properties of the material will increase.



(a)



(b)

Figure 2.9 SEM image of pure bamboo (a) and 3 % nanoclay content bamboo (b) [24].

Govardhan Goud and R. N. Rao [22] in 2011 also proved that the dielectric properties can also affect the polarity of the morphology structure of Roystonea Regia (palm tree) [22]. Figure 2.10 shows the morphology structure of the alkaline treated palm tree. From figure 2.10, we can observe that the material is having low polarization, this is because the number of molecules orientated in morphology structure is very less. The orientation of molecules in figure 2.10 is less because the alkaline treatment makes moisture absorption capacity is reduced and breaks down molecules into smaller ones. All these factors result in lower absorption of water and orientation polarization. Lower orientation polarization makes the time available for the molecules to orient themselves will be too short. Consequently, decreasing in orientation polarization is the main cause for the lower dielectric [22].

Figure 2.10 SEM image of alkali-treated palm tree [22].

2.1.3 Element Composition (EDX analysis) by SEM

EDX analysis is done by placing the material in the vacuum chamber where it is illuminated with a focused electron beam from above. Electrons bombarding the specimen surface are scattered into the material and may ionize the specimen atoms by knocking out secondary electrons from the stationary shells. The resulting gaps in the electron shell are filled by an avalanche of electrons from the outer shells of the atom. The ionized atoms emit X-ray quanta of discrete energy, which are characteristic of the chemical elements of the material under investigation. The photons from the X-ray emission are collected by an EDS detector placed near the sample and transmitted through an electronic system to the multi-channel analyzer, in which the pulses are separated according to their amplitude. The number of quanta (the intensity) of characteristic X-rays emitted in a given time interval by the atoms of the investigated element is proportional to the concentration of that element in the sample. The complete energy-dispersive spectra are transferred to the dedicated computer equipped with a special software system for the collection, observation, calculation and storage of the spectral data.

2.1.3.1 Analysis on element composition (EDX analysis) by SEM

Y.B. Seok et al in 2015 [15] have investigated the correlation between the element composition and the dielectric value of the dielectric substrate which was fabricated by using coconut shell. The element composition found in the dielectric substrate is carbon, hydrogen, nitrogen, sulphur, and oxygen. Table 2.3 shows the element composition and the dielectric value for coconut shell powder (CSP) and coconut activated carbon (CSAC) dielectric substrate. CSP has 46.70 percent of carbon meanwhile CSAC has 84.28 percent of carbon. CSP has a lower carbon element compared to CSAC. CSP has a lower carbon percentage and dielectric value compared to CSAC. This is due to the low composition of carbon in the dielectric substrate, which indicated the ability of the dielectric substrate to absorb the electromagnetic signal will reduce [15].

Table 2.3 The carbon percentage and dielectric value of the dielectric substrate [15]

Sample	Carbon (%)	Dielectric value
CSP	46.70	4.5769
CSAC	84.28	51.0198

Sk S. Hossain [33] et al investigated how the element composition affects the dielectric value of the dielectric substrate. This investigation was done by using eggshells. The element found in the dielectric substrate is oxygen, silicon, and carbon. Table 2.4 shows the element composition and the dielectric value of the dielectric substrate. Two conditions were tested throughout this investigation where the dielectric substrate is calcined (oxidized) at 1100 and 1200 degree Celsius. At 1100 degrees Celsius the carbon percentage is 30.28, meanwhile, at 1200 degrees Celsius is 31.53. For oxygen composition, the value is quite higher at 1100-degree Celsius which is 45.76 compare with 1200 which is 43.31. The dielectric value for 1100 and 1200 degrees Celsius is 5 and 6.1 respectively [33]. The dielectric value of the substrate is higher when the carbon percentage is higher, this is because carbon will increase the ability of the dielectric substrate to absorb the electromagnetic signal, meanwhile for the oxygen percentage, the value will decrease with increasing dielectric value. This is due to the porousness that was created due to the oxygen element [33]. When there are more oxygen elements, the porous of the dielectric substrate will increase too, which significantly will reduce the ability of the dielectric substrate to absorb the electromagnetic signal.

Table 2.4 The carbon percentage and dielectric value of the dielectric substrate [33].

Sample	Carbon (%)	Oxygen (%)	Dielectric value
1100	30.28	45.76	5
1200	31.53	43.31	6.1

2.3 Conclusion

According to the literature review, the morphology structure and the element composition can be investigated by using SEM to determine the ability of the of the dielectric substrate to absorb the electromagnetic signal. Other than that, an alkaline treated cellulose fiber is a better option to fabricate dielectric substrate as it has water resistance characteristic.

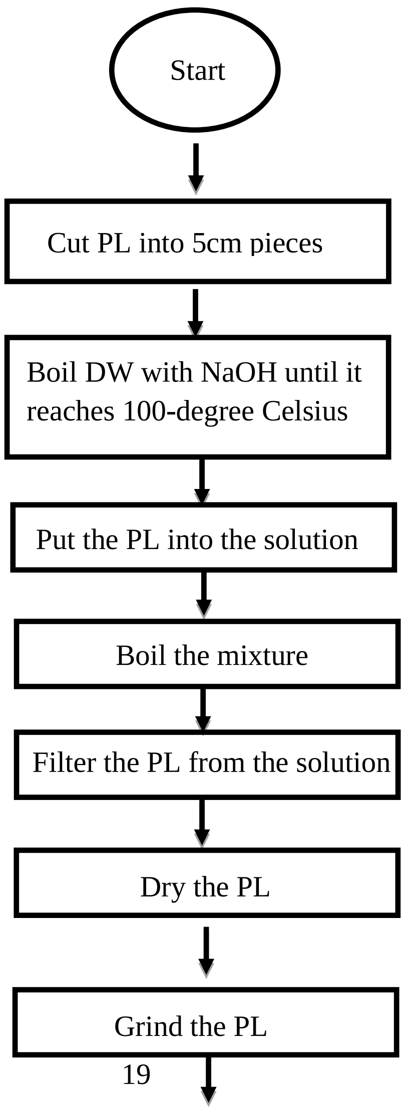
CHAPTER 3

METHODOLOGY

The main aim of this project is to investigate the correlation between bio-waste-biased dielectric substrate morphology and element composition with its dielectric properties. The fabrication of the dielectric substrate is made by using factor analysis.

3.1 Material and Method

3.1.1 Sample preparation



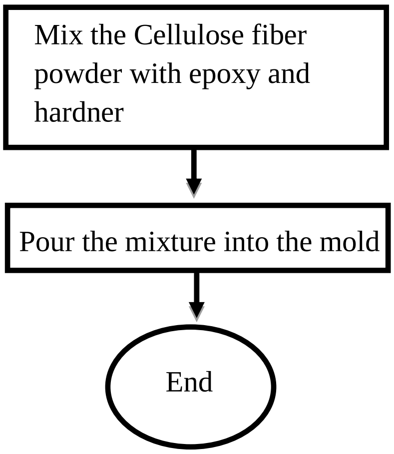


Figure 3.1 Steps of fabricating dielectric substrate using agricultural waste

Figure 3.1 shows the steps for this project. Firstly, the raw material for this project is collected. The agricultural waste that has been chosen is Pineapple Leave (PL). The pineapple leave is harvested from a pineapple plantation at Pekan Pina, Pekan, Pahang, Malaysia.

Figure 3.1 Raw material of agricultural waste (Pineapple Leave).

The harvested pineapple leaves in figure 3.2 were thoroughly cleaned to remove dirt, before being cut into pieces of 5 cm long. 1000 ml of distilled water with 45 grams of NaOH are boiled until it reaches 100 degrees Celsius (boiling point). Then, 100 grams of pineapple leaves are added into the solution. Figure 3.3 shows the boiling process of the mixture. The mixture have to be boiled in constant temperature of 100 degree Celsius.

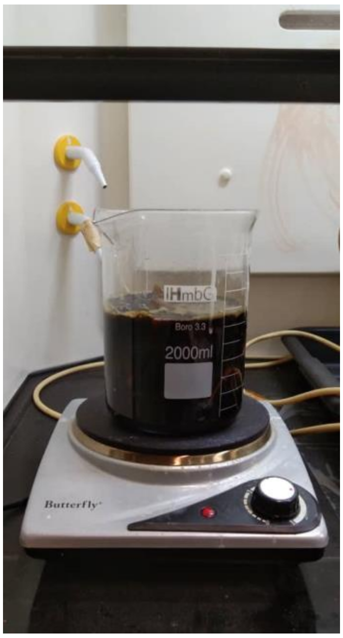


Figure 3.2	Boiling process of pineapple leave with distilled water and NaOH at constant temperature of 100-degree Celsius.

After the boiling process the mixture are removed from the hotplate and left out for 10 minutes to reduce the temperature of the mixture. The mixture is filtered out from the solution and placed on the board for drying process. Figure 3.4 shows the drying process of the sample under the sunlight. The sample are dried for 3 continuous days.

Figure 3.3	Drying process of sample under the sunlight.

After the drying process, the sample are grinded into some fine powder. The powder then mixes together with epoxy and hardener to produce composite. The mixture is poured into the mold to produce the composite. Figure 3.5 shows the mixture poured into the mold with the sizing of 2mm X 2mm X 2mm. Then, it will be left for two or three days in room temperature to ensure the mixture become hardened.

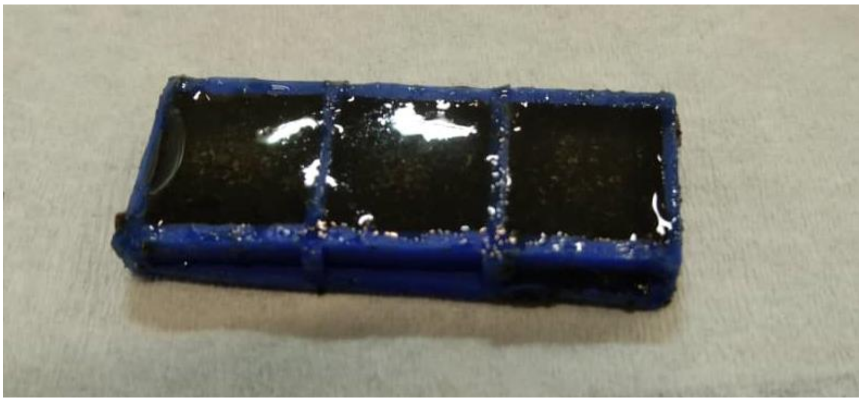


Figure 3.4 Mold.

The samples are submitted to the expert to measure the dielectric value. From all the sample, about 6 samples are selected for SEM analysis.

3.1.2 SEM analysis (Morphology structure and EDX analysis)

3.1.2.1 Morphology structure

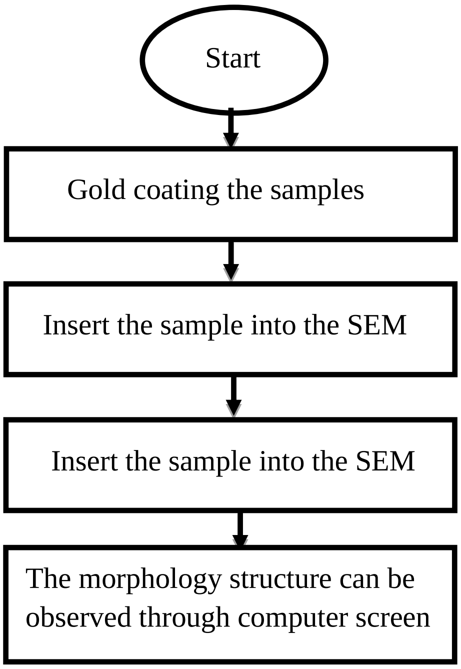


Figure 3.6 Process of obtaining morphology structure

Figure 3.6 shows the process of obtaining the morpghology structure for the selected sample. Firstly, the sample coated with gold. Figure 3.7 shows the sample coated with gold. This is to prevent charging of the surface and to improve the image of sample. Figure 3.8 shows Quorum Technologies Q300TD sputter coated which was used for the coating process.

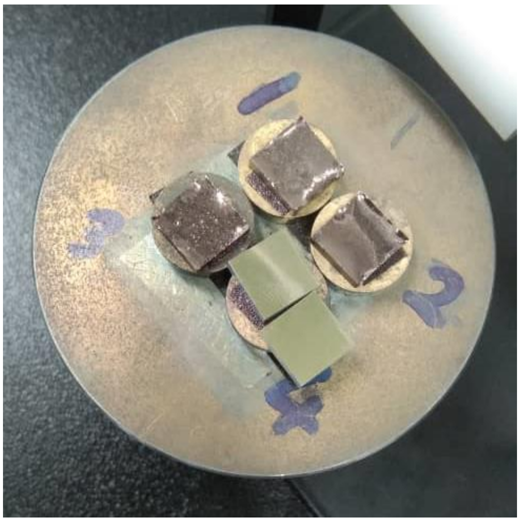


Figure 3.5 Gold coated sample

Figure 3.6 Sputter Coater

Then, the sample are inserted into the SEM. Figure 3.9 shows the TM3030 Plus Benchtop Scanning Electron Microscope (SEM) which was used to obtain the morphology structure of the sample. The morphology structure of the sample can be view through the computer screen. Figure 3.10 shows the morphology structure of a sample.

Figure 3.7 Scanning Electron Microscopy (SEM)

Figure 3.8 Morphology structure of a sample.

3.1.2.2 EDX analysis

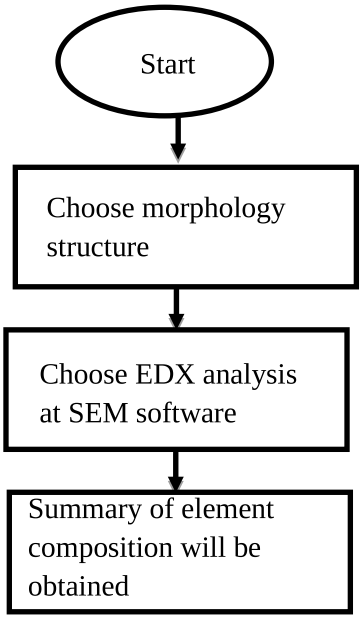


Figure 3.11 Process of EDX analysis

Figure 3.11 shows the process to obtain the EDX analysis for the samples. Firstly, the morphology structure of a sample was chosen, then EDX analysis was clicked on the SEM software. Lastly the summary report of the element composition will be produced. Figure 3.12 shows the summary report of the element composition.

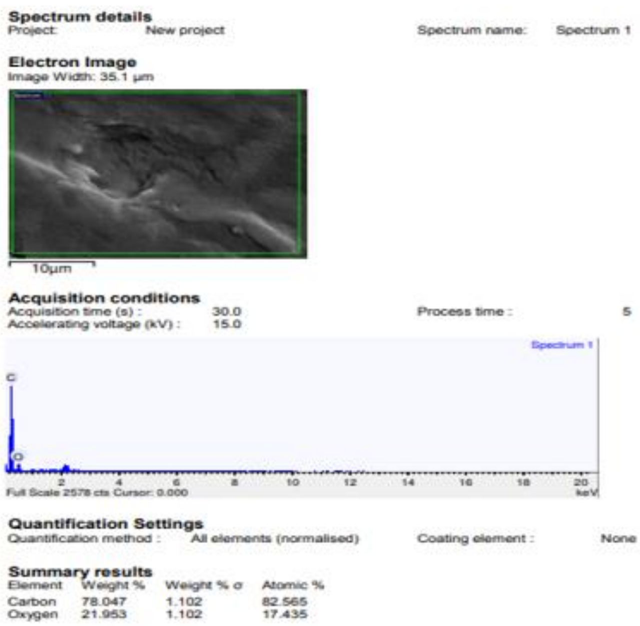


Figure 3.9 Element composition of a sample

3.1.3 Analysis Technique

There are a lot of researches had suggested the fabrication process of dielectric substrate using agricultural waste. As the objective of this researches is to produce newly develop dielectric material using agricultural waste, a new process of fabricating is proposed. The process purposed in this project is the combination of the contributing factor which was obtain throughout the literature review. About four contributing factor was obtained in this project, which are the ration of pineapple leave to distilled water, pulping time, heated or non-heated sample and lastly, the amount of cellulose fiber used for the composition of the dielectric substrate. All this factor is analysis by using Two-Level Factor Analysis (TLFA) and One-Factor=At a Time (OFAT) technique.

3.1.3.1 Factor Analysis using Design-Expert software

The contributing factor that increases the performance of the dielectric substrate is identified by using Two Level Factor Analysis (TLFA). This analysis is about controlling two variables of the project at the same time. There are four (4) factors that were controlled in this project such as ratio of pineapple leaf to Distilled Water (PL: DW) volume, pulping time, heating and non-heating the sample and cellulose fiber (CF) powder.

3.1.2.1 Flowchart for Two Level Factor Analysis (TLFA).

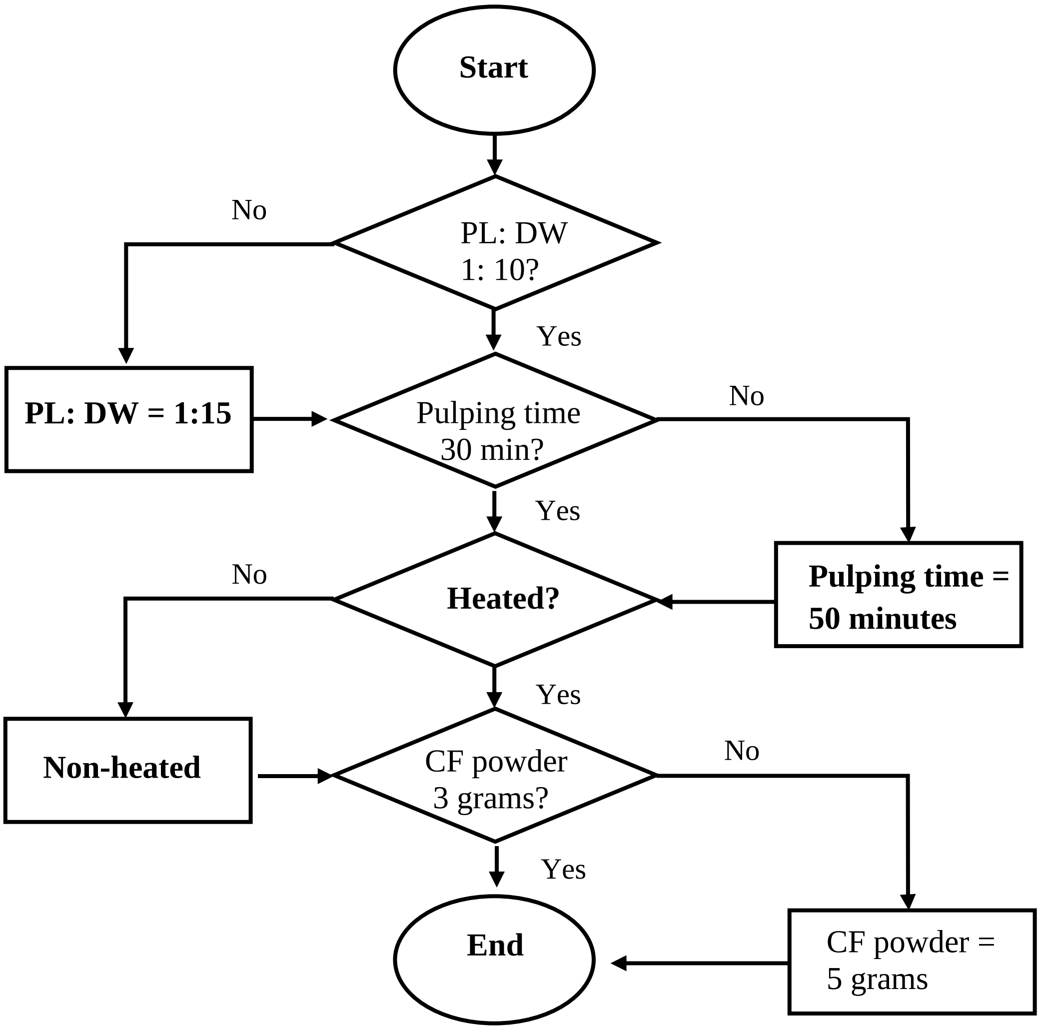


Figure 3. 13 Flowchart of constructing the condition of four factors using Two Level Factor Analysis (TLFA).

The first factor is ratio of pineapple leaf to Distilled Water (PL: DW) volume. The ratio of the pineapple leave and distilled water can be varying. For this project, we used two ratios which are 1:10 and 1:15. The mass of the distilled water is calculated by setting a specific mass of Pineapple Leave.The second factor is pulping time. The pulping time of the pineapple leaves also can be varying. For this project, we used 30 minutes and 50 minutes to see the effect of different boiling times on the pineapple leaves.

The third factor is heating and non-heating the sample. The pineapple leaves are drained from the distilled water before the drying process. After the sample is dried for 3 days under the sunlight the sample is either heated or non-heated. The sample is heated to reduce the moisture content and also to increase the carbon element in the heated sample. Last factor is Cellulose fiber (CF) powder. After the drying process, the sample is ground to some fine powder. Lastly, the powder will be mixed with the resin epoxy to fabricate the dielectric substrate. The amount of CF powder used in this project is 3 grams and 5 grams. This specific amount of CF is used because the maximum power that can be produced by using 100 grams of the pineapple leave (before pulping process) is 5 grams.

The two-level factorial analysis was applied to determine the significant factors and the best conditions contributing to the dielectric value of the dielectric substrate. This project is conducted according to the condition constructed in the Design-Expert software (table 3.1). About 16 different experimental runs are constructed by using two-level factor analysis.

Table 3.1 Two-Level Factorial design table for bio-waste-based dielectric substrate

STD	Factors			
	A: PL:DW (g/ml)	B: Pulping Time (min)	C: Heated or Non-Heated	D: Cellulose Fiber Powder (gram)
1	1:10	30	Heated	3
2	1:15	30	Heated	3
3	1:10	50	Heated	3
4	1:15	50	Heated	3
5	1:10	30	Non-Heated	3
6	1:15	30	Non-Heated	3
7	1:10	50	Non-Heated	3
8	1:15	50	Non-Heated	3
9	1:10	30	Heated	5
10	1:15	30	Heated	5
11	1:10	50	Heated	5
12	1:15	50	Heated	5
13	1:10	30	Non-Heated	5
14	1:15	30	Non-Heated	5
15	1:10	50	Non-Heated	5
16	1:15	50	Non-Heated	5

3.1.3 One-Factor-At-A-Time (OFAT)

This analysis approach is to change one cause while keeping everything else constant. This analysis is done for all 4 factors mentioned previously. This technique is to investigated, the best condition of a factor which can produces a good performing dielectric substrate. Table 3.2 shows the OFAT analysis for the ratio of pineapple leave to distilled water. From this table, we able to find the ratio which able to increase the performance of the dielectric substrate. By doing this analysis technique for all four factors, we able to get the best condition from each factor. From that condition we able to correlate the conditions with the dielectric value of the dielectric susbtrate.

Table 3.2 OFAT analysis for Pineapple Leave: Distilled water factor

Factors			
Distilled water	Pulping Time (min)	Heated or Non-Heated	Cellulose Fiber Powder (gram)
1000	30	Heated	3
1000	30	Heated	3
1000	30	Heated	3
1000	30	Heated	3
1000	50	Non-Heated	5
1000	50	Non-Heated	5
1000	50	Non-Heated	5
1000	50	Non-Heated	5

3.6 Conclusion

Chapter 3 is about the material and method used to complete this project. Pineapple leave are used as the base material in this project. The procedure of fabricating the dielectric substrate using agricultural waste are discussed well in this chapter. About four contributing factor was used and all these factors are combined by using TLFA technique. This techniques way implemented by using Design-Expert software. OFAT analysis was done to find the best condition to fabricate the dielectric substrate. The morphology structure of the fabricated substrate was observed by using XSEM. Meanwhile the element composition of the dielectric substrate was obtained by using EDX analysis in SEM.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction to result

The results obtained from the above tests are presented and discussed in detail in this chapter. Firstly, the contributing factors to fabricate good performing dielectric substrate was chosen from the literature review. By using TLFA analysis all the four factor was combined together. About 16 experimental run was constructed by using TLFA analysis. The fabrication process was done according to TLFA analysis. The fabricated samples were submitted to expert to measure the dielectric value of each sample. Few samples were selected for SEM analysis which involves morphology structure and EDX analysis. Lastly OFAT analysis was done for each contributing factors to find the best condition to fabricate the dielectric substrate.

4.2 TLFA analysis

TLFA analysis was used to combine all the selected contributing factor. This analysis constructed the best possible condition to fabricate the dielectric substrate. Table 4.1 shows the condition which constructed by using TLFA analysis. The range of the dielectric value in this project are d.7126 to 3.3103. The value is varying with different conditions. The highest dielectric value that can be seen from the table is 3.3103. This value is obtained from the third condition from The TLFA analysis meanwhile the lowest value was obtained from thirteenth condition of the analysis.

Table 4.1 Dielectric value for 16 samples

STD	Factors				
	A: PL:DW (g/ml)	B: Pulping Time (min)	C: Heated or Non-Heated	D: Cellulose Fiber Powder (gram)	Dielectric Value
1	1:10	30	Heated	3	2.8354
2	1:15	30	Heated	3	2.9099
3	1:10	50	Heated	3	3.3103
4	1:15	50	Heated	3	2.9115
5	1:10	30	Non-Heated	3	2.8187
6	1:15	30	Non-Heated	3	2.7411
7	1:10	50	Non-Heated	3	2.9444
8	1:15	50	Non-Heated	3	2.8746
9	1:10	30	Heated	5	2.9951
10	1:15	30	Heated	5	2.8867
11	1:10	50	Heated	5	2.8867
12	1:15	50	Heated	5	3.1253
13	1:10	30	Non-Heated	5	2.7126
14	1:15	30	Non-Heated	5	3.0034
15	1:10	50	Non-Heated	5	2.8030
16	1:15	50	Non-Heated	5	2.8244

According to the dielectric value provide by the expert, about three samples were selected, which is the highest, the average, and the lowest dielectric value. Another three sample were selected between the previous three samples. Table 4.2 shows the selected dielectric substrate that was selected to do morphology structure and element composition.

Table 4.2 The 6 sample which was selected for SEM analysis

STD	Factors				
	A: PL:DW (g/ml)	B: Pulping Time (min)	C: Heated or Non-Heated	D: Cellulose Fiber Powder (gram)	Dielectric Value
1	1:10	30	Heated	3	2.8354
2	1:15	30	Heated	3	2.9099
3	1:10	50	Heated	3	3.3103
4	1:15	50	Heated	3	2.9115
5	1:10	30	Non-Heated	3	2.8187
6	1:15	30	Non-Heated	3	2.7411
7	1:10	50	Non-Heated	3	2.9444
8	1:15	50	Non-Heated	3	2.8746
9	1:10	30	Heated	5	2.9951
10	1:15	30	Heated	5	2.8867
11	1:10	50	Heated	5	2.8867
12	1:15	50	Heated	5	3.1253
13	1:10	30	Non-Heated	5	2.7126
14	1:15	30	Non-Heated	5	3.0034
15	1:10	50	Non-Heated	5	2.8030
16	1:15	50	Non-Heated	5	2.8244

4.3 Analysis of Morphology structure

4.3.1 Comparison between raw and ground cellulose fiber

The morphological study of the dielectric substrate was carried out by using Scanning Electron Microscopy (SEM) images in magnified form. Figure 4.1 shows morphological structure of two samples with the same conditions. The morphological structure of both samples is different because figure 4.1 (a) shows the raw cellulose fiber which was not grinded, meanwhile figure 4.1(b) shows the grinded cellulose fiber. It can be seen that the morphological structure of the raw cellulose fiber can be seen clearly. This is because the pineapple leave's fiber is still visible. But for the grinded cellulose fiber, the fiber can't be seen because the fiber was grinded into small particles or in another term the cellulose fiber is in powdered form.

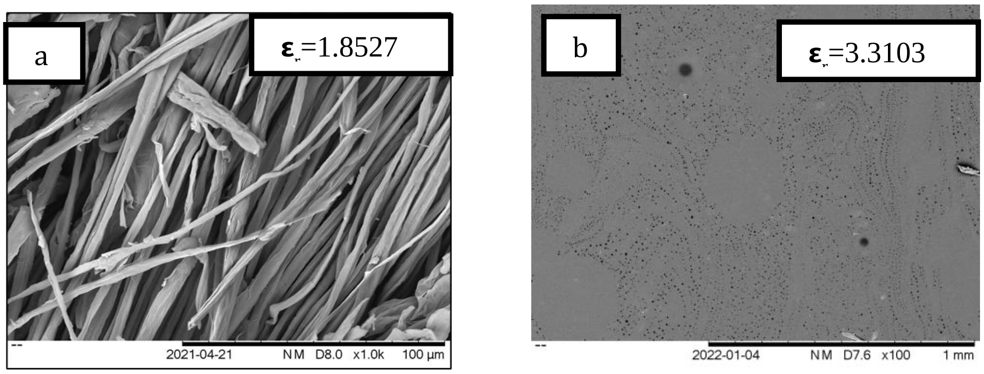


Figure 4.1 Cellulose fiber (a) raw (b) grinded

In terms of dielectric value, grinded cellulose fiber has a higher dielectric value than raw cellulose fiber. This is because the amount of cellulose fiber in powdered form is more compared with the raw cellulose fiber. This is due to the raw cellulose fiber occupying more space compare with ground cellulose fiber. The best way to fabricate a good performance dielectric substrate is by grinding the cellulose powder.

4.3.2 Morphology structure of each condition for carbon element composition

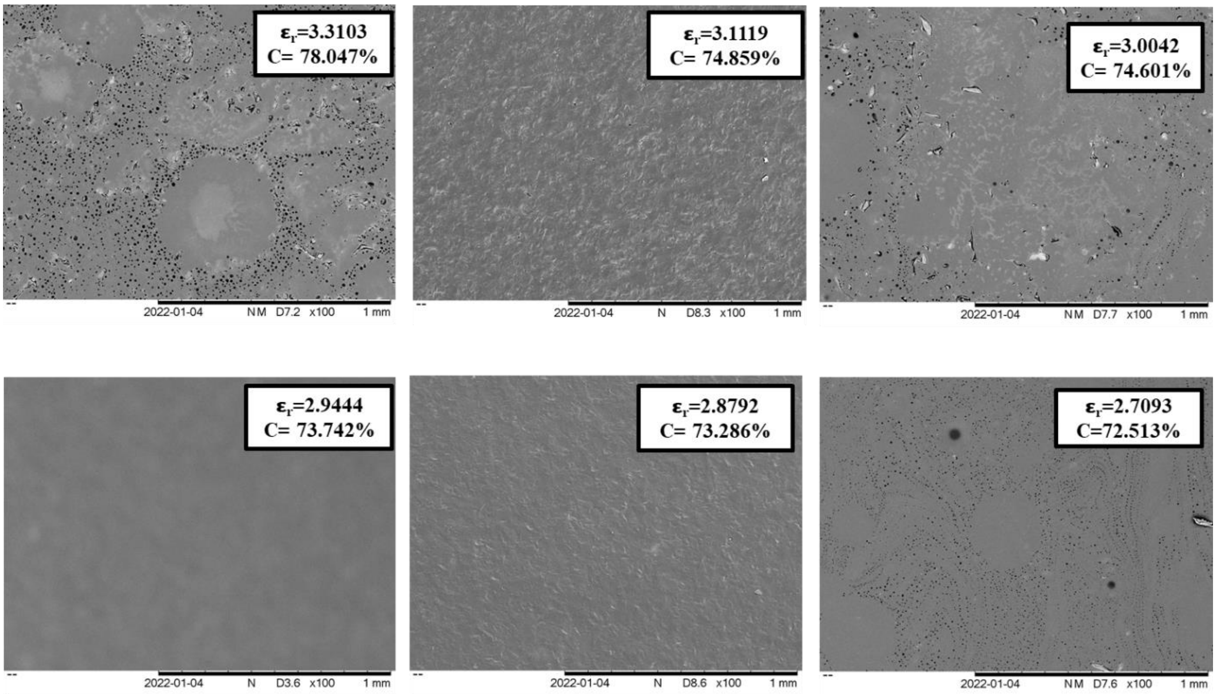


Figure 4.2 Morphology structure of six selected samples with a carbon percentage

The morphology structure of these selected six samples was obtained by Scanning Electron Microscopy. The dielectric value of the sample was obtained by using Network Analyzer and the Carbon percentage of the sample was obtained by doing EDX analysis on the morphology structure.

4.3.2.1 Comparison between carbon element and dielectric value

Figure 4.3 shows the comparison between the carbon element percentage with dielectric value. As we can see from the graph the lowest carbon percentage obtain is 72.513 with the dielectric value of 2.7093, meanwhile, the highest dielectric value is 3.3103, is the carbon percentage is 78.047. From here, we can see that as the carbon elements percentage increases the dielectric value also increases. W.H.Foon et al have stated that carbon element plays a big role in absorbing the electromagnetic signal [15]. In simple words, the amount of carbon element in the dielectric substrate affects the dielectric value of the substrate. This is because carbon is the main element that helps the dielectric substrate to absorb the electromagnetic signal [4]. Having more carbon elements in the dielectric substrate helps the dielectric substrate absorb and store more electromagnetic signals. Meanwhile, for the lower carbon percentage dielectric substrate, it will have a lower dielectric value because when the carbon value is lower in the dielectric substrate it will reduce the ability of the dielectric substrate to absorb the electromagnetic signal.

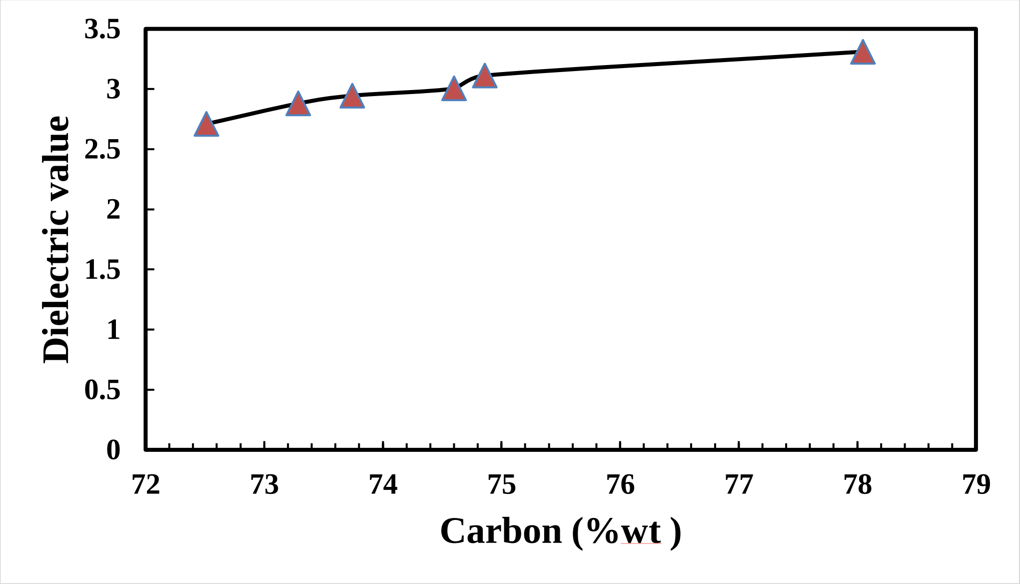


Figure 4.3 Comparison between carbon percentage with dielectric value

4.3.2.2 The morphology structure of each condition for Oxygen element composition

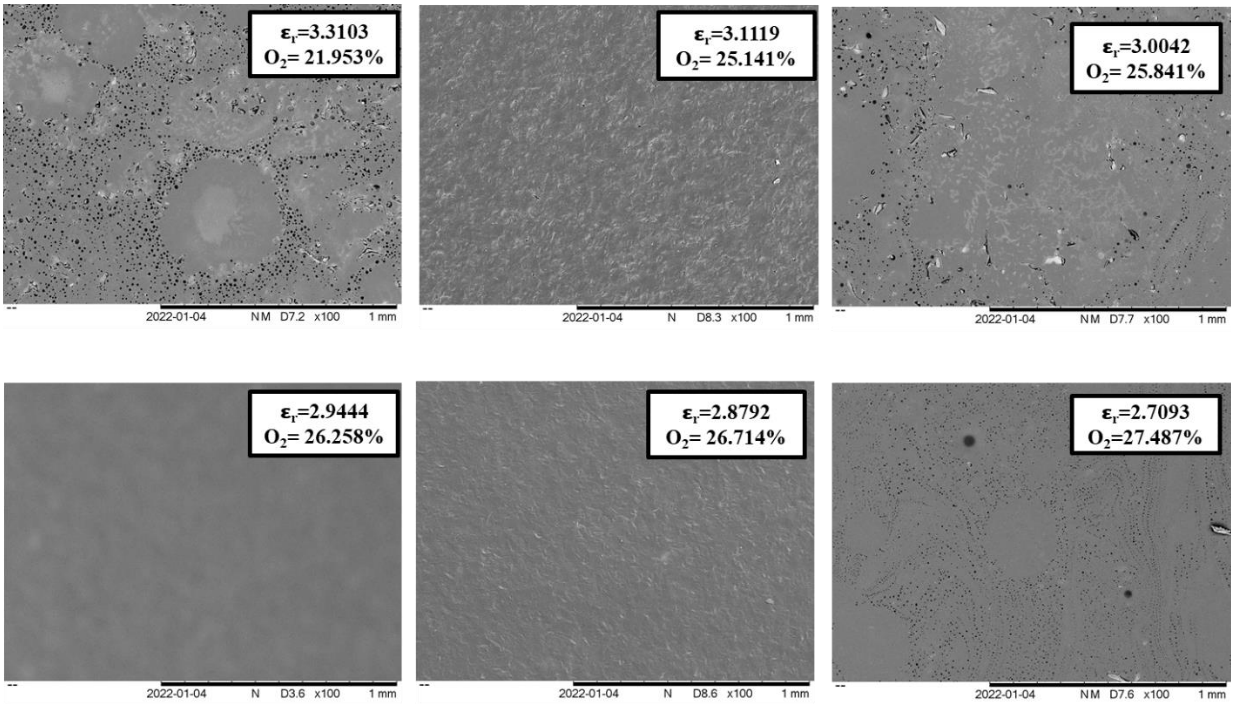


Figure 4.4 Morphology structure of selected 6 samples with an oxygen percentage

The morphology structure of this selected six samples was obtained by Scanning Electron Microscopy. The dielectric value of the sample was obtained by using Network Analyzer and the Carbon percentage of the sample was obtained by doing EDX analysis on the morphology structure.

4.3.2.1 Comparison between carbon element and dielectric value

Figure 4.5 shows the comparison between the oxygen element percentage with dielectric value. As we can see from the graph the highest oxygen percentage obtain is 72.487 with the dielectric value of 2.7093, meanwhile, the lowest dielectric value is 3.3103, with the oxygen percentage of 21.953. From here, we can see that as the oxygen elements percentage increases the dielectric value will decrease. S.K.Hossai et al had said that as the oxygen element increases in the dielectric substrate, the dielectric value will decrease[33]. This is because when there is more oxygen in the dielectric substrate, the oxygen forms bubbles inside the dielectric substrate. The bubbles are also called porous. The porous is a void space in the circular form filled with oxygen. Significantly, when there is more oxygen, there will be more porous at the dielectric substrate at the void space, the dielectric substrate unable to absorb the electromagnetic signal, so when there are more voids the ability of the dielectric substrate to absorb electromagnetic signal will reduce, which results in lower dielectric value. A higher dielectric value can be obtained when there is a lesser oxygen percentage or porous in the dielectric substrate.

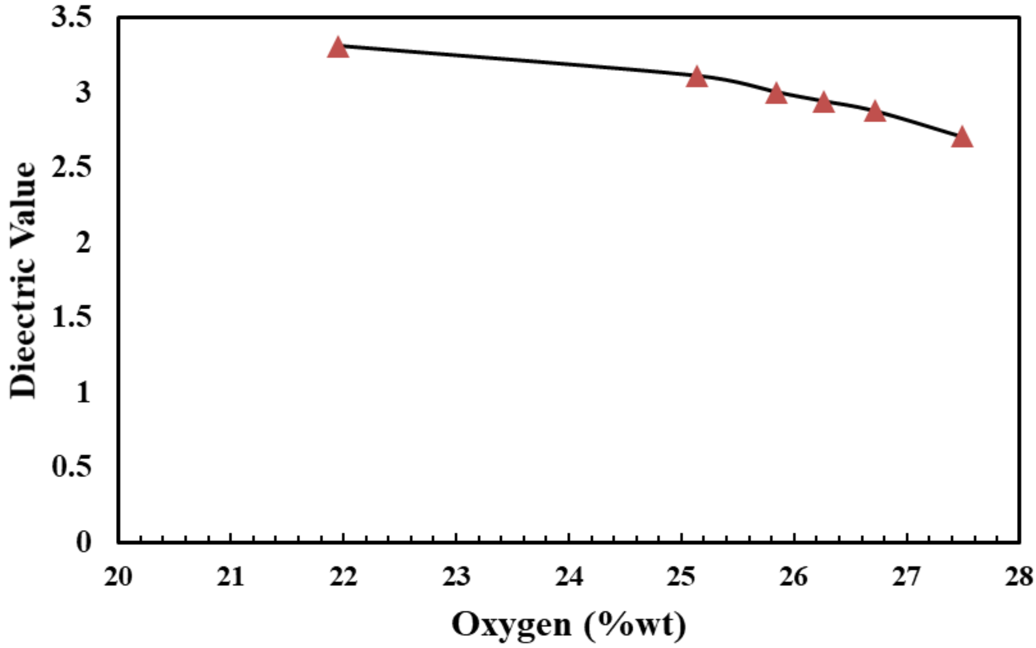


Figure 4.5 Comparison between oxygen percentage with dielectric value

4.4 One-Factor-At-a-Time (OFAT) analysis

OFAT analysis was done to see which factor contributes the best performance to the dielectric substrate fabrication. This analysis is applied by keeping one factor as constant and other factors as a variable. OFAT analysis technique was used for all four factors that was mentioned before.

4.4.1 Pineapple Leave: Distilled Water (PL: DW)

Two ratios were used throughout this project which are 1:10 and 1:15. For the 1:10 ratio, the distilled water is 1000ml meanwhile for 1:15, the distilled water used is 1500 ml. Figure 4.6 shows the effect of distilled water to the dielectric value of the dielectric substrate. When 1000ml of distilled water was used the average dielectric value is higher compared with when we used 1500ml of distilled water. This is because, during the pulping time, the distilled water will evaporate and increase the concentration of the mixture. When the concentration of the mixture increases the cellulose extraction will occur faster because there will be more Sodium Hydroxide (NaOH) which helps the cellulose extraction in the mixture. When there is more distilled water the concentration of NaOH will decrease, resulting in the extraction process occurring slower.

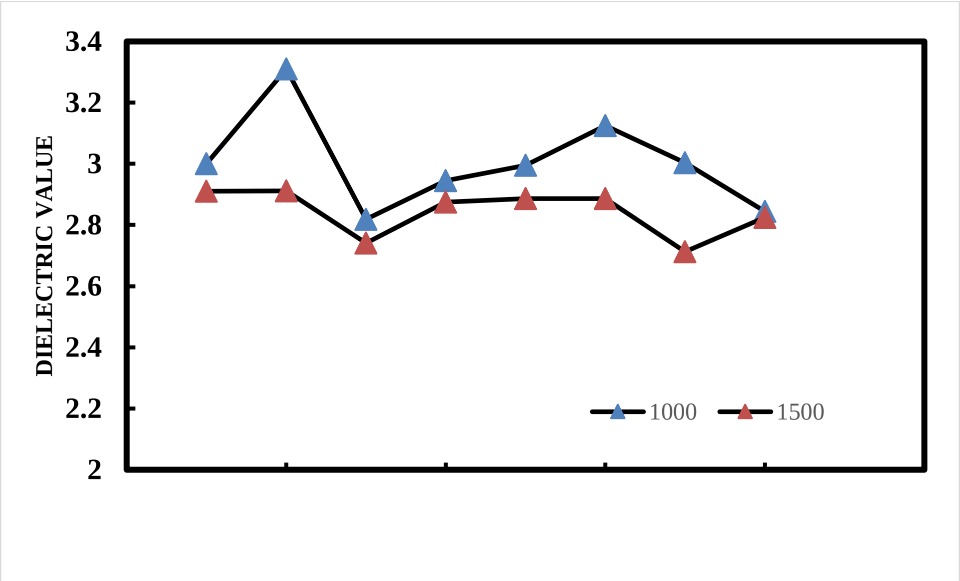


Figure 4.6 OFAT analysis on the volume of distilled water

4.4.2 Pulping time

Pulping time also called the boiling time that was used in this project is 30 minutes and 50 minutes. Figure 4.7 shows when the pulping time is higher the average dielectric value of the substrate also becomes higher. This is because the higher the pulping time the more distilled water will evaporate into the air and makes the NaOH concentration in the mixture increase. When the NaOH concentration is higher this is making the cellulose extraction process happen faster.

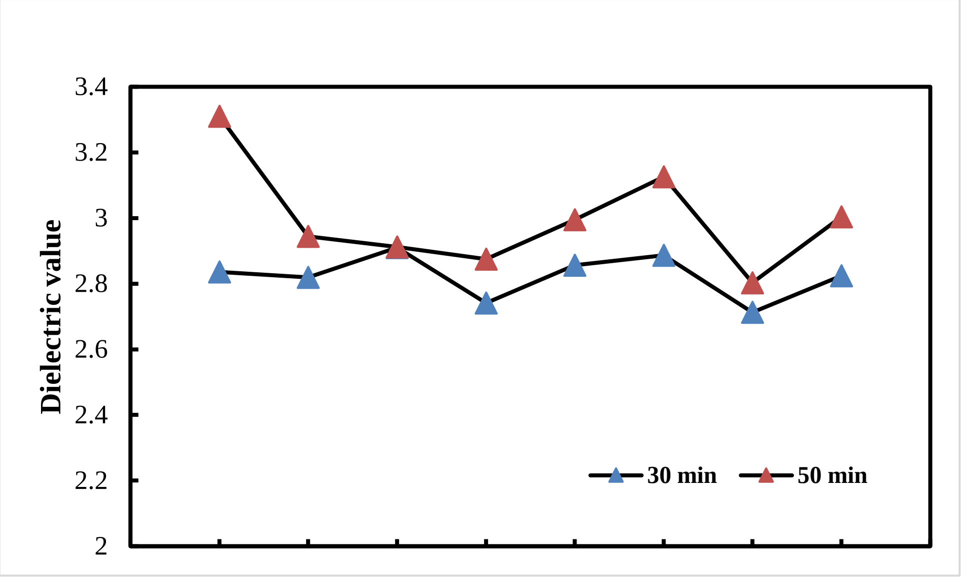


Figure 4.7 OFAT analysis on pulping time

4.4.3 Heated or Non-heated

After the drying process, the sample is either heated using a hotplate or non-heated the sample. The heating process is to reduce the moisture content of the sample and also to increase the carbon element in the dielectric substrate. As the sample is heated on the hotplate, the sample will burn and turn into carbon. When the carbon element in the dielectric substrate is high the dielectric value of the substrate also will be high. Figure 4.8 shows that the heated sample has an average dielectric value higher compared with the non-heated sample. This is because the heated sample produces carbon during the heating process.

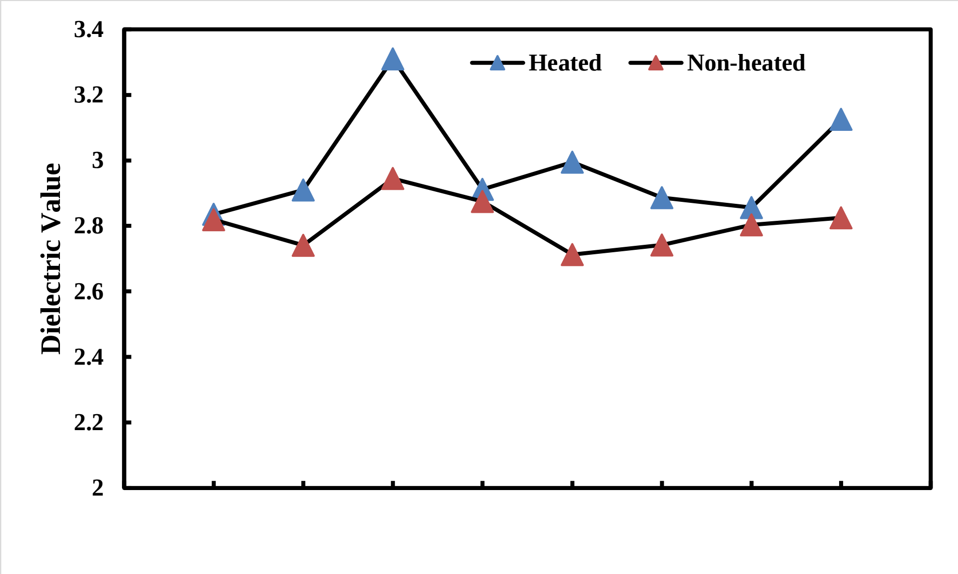


Figure 4.8 OFAT analysis on heated or non-heated sample

4.4.4 Cellulose Fiber Powder

Cellulose fiber (CF) powder is mixed together with resin epoxy to fabricate the dielectric substrate. The amount of CF used in this project is 3 grams and 5 grams. Figure 4.9 shows that when a higher amount which is 5 grams of CF powder used, the dielectric value will increase. This is because the CF of the pineapple leaves in that dielectric substrate will be higher. Naturally, pineapple leaves contain carbon [8]. So, having a large amount of CF powder of the pineapple left in the substrate helps the dielectric substrate to absorb more electromagnetic signals.

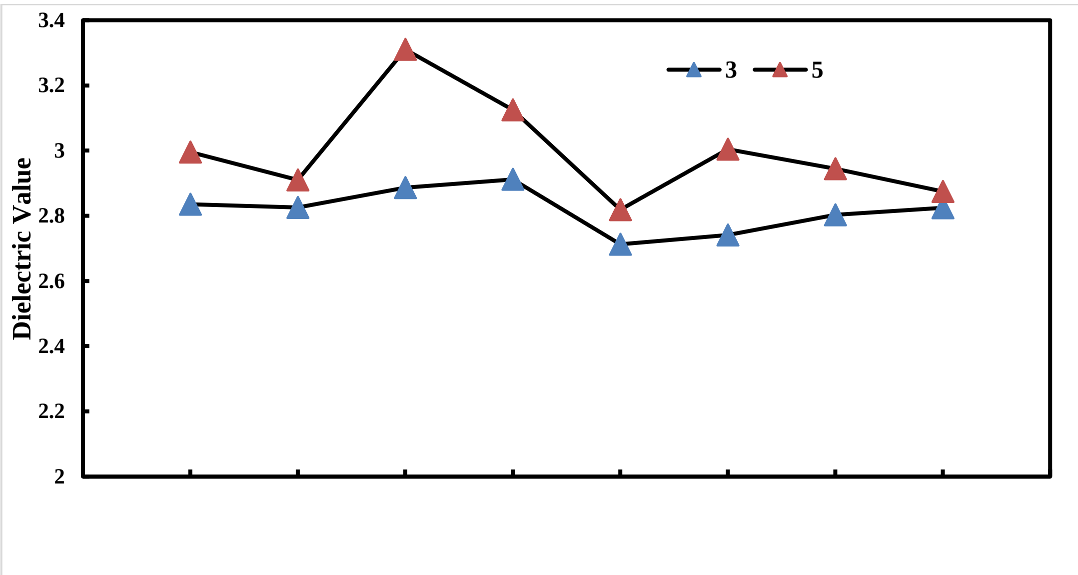


Figure 4.9 OFAT analysis on cellulose fiber powder

4.5 Conclusion

From the result, we can conclude that the morphology structure analysis, the morphology structure of the raw cellulose fiber can be seen, where the fiber can be seen clearly, meanwhile for the powdered cellulose fiber the morphology structure, the fiber can't be seen because the cellulose fiber are in powdered form. In term of element composition the dielectric value increases with increasing carbon elements in the dielectric substrate. This is due to the ability of the carbon to absorb the electromagnetic signal is higher. The dielectric value decreases with increasing oxygen element in the dielectric substrate. This is because when there is more oxygen, there will be more void space or also called porous. This porous will reduce the absorbent ability in the dielectric substrate. By using OFAT analysis we able to identify the contributing factor to fabricate a dielectric substrate with good performance.

Chapter 5

CONCLUSION & FUTURE PLANNING

5.1 Conclusion

As to summarize my project, the highest dielectric value reported in this study was 3.3103 with an experimental condition of 1:10 (PL: DW), 50 minutes of boiling time, heated sample, and 5 grams of cellulose fiber powder. The objective of this research is achieved by finding a newly developed dielectric material using pineapple leave, where this dielectric substrate has higher dielectric value from previous bio-waste agricultural waste that was investigated by many researches before.

Through this research I able to find best four contributing factors, where by combining these four factors able to produce a good performing dielectric substrate. The four factors are the ratio of pineapple leave to distilled water, pulping time, heated or non-heated sample and lastly the amount of cellulose fiber powder.

The dielectric value reported in this study indicates that pineapple leaf could be a potential dielectric material, and can be used in electronic appliances. Most of the electrical appliance are using a dielectric substrate with a dielectric value of more than 2.5, and the range of the dielectric substrate that was fabricated in this project is in the range of 2.7 to 3.3, where this Pineapple-based dielectric substrate can be the alternative for the current dielectric substrate that was used in the electrical appliance.

5.2 Future Planning

For the next approach, the morphological analysis can be done on the cross-section area of the dielectric substrate. By visually examining the cross-sectional area, the diameter of the particles maybe can be seen through the SEM. And the correlation of the diameter of the particles with dielectric value can be analyzed.

As the carbon element has the competency to increase the dielectric value, adding more carbon baaed bio-waste material during the fabrication of the bio-waste based dielectric substrate in the future may increase the dielectric value of the substrate

More factors can be analyzed to increases the performance of the dielectric substrate, as semiconductor industries are using a dielectric substrate with dielectric values of more than 7. There is possibility to use this bio-based dielectric substrate in semiconductor industries as an alternative for the current dielectric substrate.

5.3 Impact on the society

Implementing this idea have many advantages for future generations. Fabricating bio-waste-based dielectric substrate can reduce the waste. Significantly able to reduce the pollution such as air pollution, water pollution, and global warming in our country.

The price of the appliances will be cheaper when this bio-waste-based dielectric substrate is used. As no need to pay to collect the waste, the fabrication won’t cost much and this will make the price of the electrical appliance drop. Where all the society can purchase and use the appliances that they like.

Other than that, this bio-waste-based dielectric substrate is not hazardous for society. There no dangerous chemicals involved in fabricating this dielectric substate, which makes this dielectric substrate is safe and eco-friendly.

In conclusion, fabricating this dielectric substrate by using bio-waste material gives a lot of advantages for society. Implementing this idea in semiconductor industries, chemical industries, etc able to reduce the production of chemical waste at the same table to make our country one of eco-friendly country.

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