

**THE DEVELOPMENT OF MICROWAVE ABSORBER FROM OIL PALM  
SHELL CARBON**

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Dedicated to my beloved wife and family.....  
For the understanding and moral support  
throughout the years.....

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## ABSTRACT

A method for reducing palm shell residues has been investigated. Using pyrolysis technique, the residues are transformed into carbons, which are later used as a lossy elements in microwave absorber application. The microwave properties of permittivity, ( $\epsilon$ ), loss tangent, ( $\tan \delta$ ) and absorption performance of microwave absorber utilizing palm shell carbon mixed with unsaturated polyester resin were studied in the microwave region of 8 to 12 GHz (X-band). The measurement of ( $\epsilon$ ) and ( $\tan \delta$ ) emphasize on the influence of carbon concentration (mass %) and pyrolysis temperature in the production of the carbon. It was found out that by increasing carbon pyrolysis temperature, an increase in ( $\epsilon$ ) and ( $\tan \delta$ ) had been observed. The increase of carbon concentration inside each measured sample also influenced the increase of ( $\epsilon$ ) and ( $\tan \delta$ ) condition. The optimum ( $\tan \delta$ ) was found by using 30% carbon pyrolysed at 800°C temperature, suggesting significant contribution in dielectric loss properties of the material. The preparation of microwave absorber by utilizing 30% mass concentration of palm shell carbon mixed with unsaturated polyester resin had been tested for microwave absorption. The amplitude of the absorption was relatively measured to a metal plate reference, which resulted in a various microwave absorption with respect to the thickness of the absorber. Moderate microwave absorption around - 10 dB was achieved for most samples within the same frequency band, with maximum absorption of - 30 dB for a thickness up to 75 mm. All the data indicates the possibility of using pyrolysed carbon derived from palm shell residues in providing an affordable solution for microwave technology as well as an alternative in managing the increase of the residues throughout the country.

## ABSTRAK

Satu kaedah untuk mengurangkan sisa kelapa sawit kepada bahan berguna telah dikaji. Melalui proses pirolisis, sisa buangan tersebut diubah kepada karbon, yang kemudiannya digunakan sebagai elemen kehilangan dalam aplikasi penyerap gelombang mikro. Sifat gelombang mikro seperti kebertelusan, ( $\epsilon$ ), tangen kehilangan, ( $\tan \delta$ ) dan prestasi penyerapan penyerap gelombang mikro menggunakan campuran karbon kelapa sawit dan resin polyester telah dikaji pada frekuensi 8 hingga 12 GHz. (X-band). Pengukuran nilai ( $\epsilon$ ) dan ( $\tan \delta$ ) menekankan kepada pengaruh kandungan karbon ( jisim %) dan suhu pirolisis kepada penghasilan karbon. Pemerhatian mendapati dengan penambahan suhu pirolisis, satu peningkatan dalam nilai ( $\epsilon$ ) dan ( $\tan \delta$ ) telah didapati. Peningkatan kepada kandungan karbon di dalam setiap sampel juga mempengaruhi peningkatan ( $\epsilon$ ) dan ( $\tan \delta$ ). Nilai optimum ( $\tan \delta$ ) telah didapati pada kandungan 30% karbon yang dihasilkan pada suhu 800°C, yang memberi sumbangan besar terhadap sifat kehilangan dielektrik bahan. Penyediaan penyerap gelombang mikro dengan menggunakan 30% kandungan karbon kelapa sawit dicampur dengan resin polyester telah diuji untuk penyerapan gelombang mikro. Amplitud penyerapan diukur secara relatif kepada plat logam rujukan, yang menghasilkan pelbagai kesan penyerapan gelombang dari aspek ketebalan penyerap. Penyerapan gelombang mikro yang sederhana sekitar - 10dB diperolehi untuk semua sampel pada jalur frekuensi yang sama, dengan penyerapan maksimum -30dB pada ketebalan menjangkau 75 mm. Semua data menunjukkan potensi penggunaan karbon yang dihasilkan dari sisa kelapa sawit dalam menyediakan penyelesaian mudah kepada teknologi gelombang mikro selain daripada menjadi alternatif dalam menguruskan peningkatan sisa tersebut di seluruh negara.

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## LIST OF SYMBOLS

$E$	Vector electric field
$J$	Vector current density
$I$	Electric current
$A$	Cross-sectional area
$\rho_v$	Volume resistivity
$R$	Resistance
$V$	Voltage
$\sigma$	Conductivity
$\epsilon$	Permittivity
$\epsilon_0$	Permittivity of free-space
$\epsilon_r$	Relative permittivity
$\epsilon'_r$	Relative real permittivity
$\epsilon''_r$	Relative imaginary permittivity
$\tan\delta$	Loss tangent
$\mu_0$	Permeability of free-space
$\mu_r$	Relative permeability
$\mu'_r$	Relative real permeability
$\mu''_r$	Relative imaginary permeability
$\omega$	Angular frequency
$f$	Frequency
$k$	Wave numbers
$n$	Index of refraction
$Z_0$	Free-space impedance
$Z$	Intrinsic impedance
$\rho$	Reflection coefficient

$\Gamma$	Power reflection coefficient
$d$	Sample thickness
$l$	Sample length
$\lambda$	Wavelength
$\lambda_0$	Free-space wavelength
$V_{\min}$	Minimum voltage standing wave
$V_{\max}$	Maximum voltage standing wave.
$x_0$	The distance of first minimum position from the dielectric material.
$L_{sm}$	The location of the sliding probe during second minimum of standing wave pattern recorded without the sample inside the waveguide.
$L_{fm}$	The location of the sliding probe during first minimum of standing wave pattern recorded without the sample inside the waveguide.
$L_{nsm}$	The location of the sliding probe during second minimum of standing wave pattern recorded with the sample inside the waveguide.
VSWR	Voltage standing wave ratio
$\lambda_1$	Wavelength in medium 1 (waveguide)
$\lambda_2$	Wavelength in medium 2 (sample)
$\gamma$	Complex propagation factor
$\beta$	Phase constant
$\alpha$	Attenuation constant
$S$	Surface area
$A_m$	Area of occupied by single adsorbed gas molecule
$V_m$	The quantity of gas adsorbed, either using Langmuir or BET Theories. area of occupied by single adsorbed gas molecule.
$N_A$	Avogadro constant ( $6.023 \times 10^{23}$ molecules/mole).
$V_o$	Molar volume of the gas ( $22414 \text{ cm}^3$ ).
$m$	Mass of the adsorbing sample.



**LIST OF ABBREVIATIONS**

EFB	Empty Fruit Bunch
POME	Palm Oil Mill Effluent
CBP	Cement-Bonded Particleboard
GBP	Gypsum-Bonded Particleboard
NRL	Naval Research Laboratory
PAC	Pacific Activated Carbon
MEKP	Methyl Ethyl Ketone Peroxide

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## CHAPTER I

### INTRODUCTION

#### 1.1 General Background

Malaysian Oil palm plantations have seen unprecedented growth in the last four decades to emerge as the leading agricultural industry in the country. From a mere 55000 hectares in 1960, the oil palm plantation has grown up to 2.82 million hectares in 1997, which has a total of 8.55% coverage in total land-use in Malaysia (Fuad, *et.al* 1999). The process of extracting the palm oil has introduced significant amount of biomass by-products and waste as shown in Figure 1.1, which could present negative impact towards the environment if not monitored and managed effectively. It was revealed that in 1980 the oil extraction process had generated about six million tonnes of residues and was reported to be highly polluting (Ma, *et.al* 1982).

The recycling process of palm shell waste can reduce the residues impacts, which pave the way through a cleaner environment. The processing of palm oil has introduced biomass such as trunk, fronds, empty fruit bunches (EFB), shell, fibre and palm oil mill effluent (POME), which are being studied into further utilization in many areas. This chapter shows various studies that have been done on the oil palm residues, which involve shells, trunks and fibres that can be recycled into renewable materials for other practical applications. Fibres from chopped palm trunk have been studied to produce medium density fibreboard and pulps. The fibres and shells have been used as fuel for mill boilers, and as a potential material for tarring roads. Pyrolysis technique can be used in transforming lignocellulosic portion of oil palm

residues such as shells and fibres into practical charcoal or activated carbon. The process can also be modified to gain significant amount of chemicals derivatives and liquid fuels substitutes.

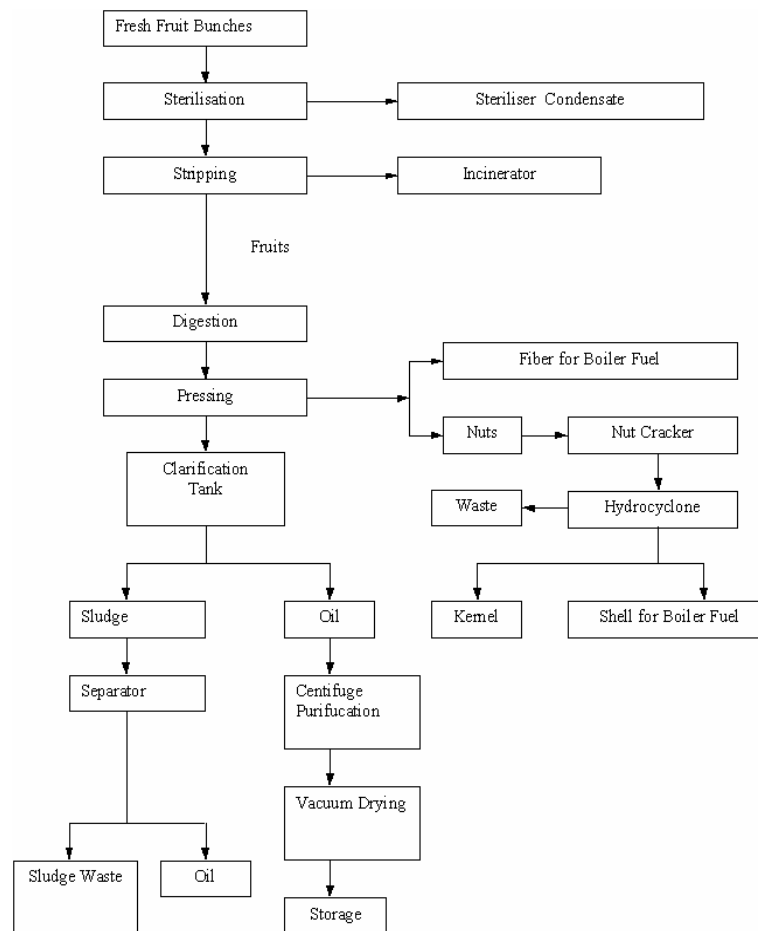


Figure 1.1 The steps of producing palm oil including biomass by-product and residues such as shells, fibre and sludge (Ma , *et.al* 1982).

## 1.2 Oil Palm Biomass Production in Malaysia

Beside oil production, Malaysian oil palm biomass has been studied into other useful materials. The major biomass resources from palms come from oil palm trunk, fronds and EFB. The growing of oil palm in plantation serve the co-product such as trunk and frond, while palm oil processing produce biomass in the form of fibre, shell, EFB and POME.

The bioconversion process for palm oil has resulted in a total export of Malaysian crude palm oil, which exceed 9.07 million tonnes, earning revenue of total income of RM 12.9 billion in 1997. The large quantities of biomass by-product that had been generated from palm oil processing are shown in Table 1.1.

Table 1.1 Oil Palm residues and by-products in 1997. (Ma, *et.al* 1999)

Biomass	Quantity (Million Tonnes)	Moisture Contents (%)	Oil Contents (%)	Dry Heat Value (Kcal/kg)
EFB	10.6	65	5	3700
Fibre	6.6	42	5	4420
Shell	2.7	7	1	4950
POME	32	95	1	-

Note: EFB - Empty fruit bunch. POME - Palm oil mill effluent

An oil palm tree produces significant amount of biomass at the average of 231.5 kg dry weight a year, including palm oil and all lignocellulosic material from the tree itself (Mohamad Husin, *et.al* 2002). Each tree produces fresh fruit bunches, which weigh about 90.5 kg of total produced biomass. Extracting the crude palm oil and palm kernel oil, the total of oil produced is about 21.36 kg. It is obvious that only a small fraction of usable portion have been extracted from the growing of oil palm

trees each year. Thus, the processing of other component of biomass, especially the lignocellulosic portion and other biomass residues will definitely benefit the industry, without affecting the mainstream of the oil production industry.

### 1.3 Processing Biomass Residues into Renewable Resources

In general, biomass is a complex structure that is classified as an element of carbon, hydrogen, oxygen and small amount of nitrogen and minerals. It is commonly studied in different component such as cellulose as shown in Figure 1.2, hemicelluloses, lignin, extractives and ash. In practical terms, biomass is also known as a resource that is capable of supplying safe, non-polluting fuel, and yet renewable in every circumstances.

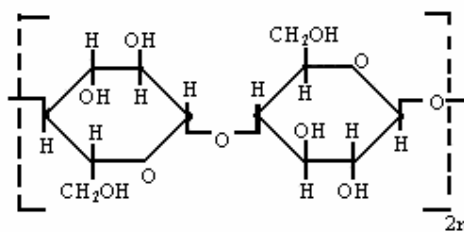


Figure 1.2 The structure of cellulose,  $(C_6H_{10}O_5)_n$ , which is the primary component in biomass.

The optimisation of biomass residues requires classifications over the utilisation of biomass renewable resources, which is either in the form of renewable energy or materials (Gielen, *et.al* 2001). The issues on renewable energy are becoming a growing importance in continuing environmental concerns over pollution caused by fossil fuel usage. Wood and other forms of biomass residues are recognised as the main renewable energy resources available in supplying the only source of renewable liquids, gaseous and solid fuels. Bridgewater, *et.al* (1999) had

classified a variety of ways in providing renewable energy resources using wood and biomass residues, such as:

- i. Direct combustion to provide heat for use in heating, for steam production and hence electricity generation.
- ii. Gasification to provide a fuel gas for combustion for heat, or in an engine or turbine for electricity generation.
- iii. Fast pyrolysis to provide a liquid fuel that can substitute for fuel oil in any static heating or electricity generation application. The liquid can also be used to produce a range of specialty and commodity chemicals.

Beside renewable energy resources, wood and biomass residues are studied in many countries in order to extract renewable material or potential products that can be utilised in other areas. Cheremisinoff (1980) in his review mentioned that biomass component such as lignin and cellulose from any plants such as oak and coconut tree can always be converted into other form of products such as ethanol and methane. Feedstock of dry biomass can be cracked into methanol or fuel by partial combustion and gas synthesis. Wet biomass such as algae and waste liquor can be converted into chemicals such as methane through anaerobic digestion. Alcohol and ethanol can be extracted by using either enzymatic digestion or fermentation, and aerobic digestion process can create compost and humus, which is suitable in agriculture and crops. Distillation process provides methanol and other wood chemicals, while destructive pyrolysis techniques can produce carbonaceous plant into absolute form of fixed and activated carbon.

A direct relation of renewable material such as fixed carbon and biomass component such as lignin had been suggested by Dermirbas (2002), which correlated the possible amount of fixed carbon with respect to lignin content of biomass sources such as corncob, almond shell, walnut shell, and olive husk. It simulated the potential of fixed carbon that can be processed from any percentage of lignin content in each biomass. Hayashi, *et.al* (2002) on the other hand had generated activated carbon from lignin content by using chemical such as  $ZnCl_3$ ,  $H_3PO_4$  and alkali metal compounds. The chemical activation of lignin content had resulted in a good

activated carbon with superb quality of surface area, reaching about 2000 m<sup>2</sup>/g. In this case, the relationship between lignin content of biomass and biomass fixed carbon content will be a useful manual in areas that favours the extraction of carbon for further industrial application. Thus, the application of biomass in producing renewable resources can be beneficial in not only reducing environmental problems but also enhancing opportunities in industrialisations aspects.

## **1.4 The Recycling of Oil Palm Biomass**

### **1.4.1 Fibreboard**

Fibre is amongst the biomass produced as residues after the fresh fruit bunches are pressed during the extraction of palm oil. It can also be reprocessed directly from oil palm trunks and fronds. The researches on palm fibres had resulted in several palm-based panel products such as particleboard, medium density fibreboard, mineral-bonded particleboard and even gypsum board. Ashari, *et.al* (1981) had produced medium density fibre board (MDF) by pressing palm trunk fibre and chips into one solid fibreboard. Koh, *et.al* (1999) had given a review on an improved MDF, produced using a mixture of refined rubber wood chip and palm frond fibre strand. The utilization of palm-based element in the improved MDF has given a significant influence onto the appearance and strength properties of the fibreboard.

Further development of palm-based fibreboard was studied by Rahim and Khozirah (1991), which introduced gypsum-bonded particleboard (GBP) using fresh oil palm trunk particles in the forms of chips and flakes mixed with gypsum hemihydrates. The consumption of palm shell biomass in a mineral bonded particle board such as cement-bonded particleboard or CBP had been attempted by Mohamad Husin (2002), although little success had been recorded due to the high level of carbohydrate which affecting the cement mixture.



### **1.4.2 Pulp and Paper**

The oil palm trunks, oil palm fronds and empty fruit bunch (EFB), which primarily come up from cellulose and lignin compound can also be used in paper production. Mohamad Husin (2002) had clearly stated that the use of whole empty fruit bunch, EFB would yield 26 to 32% of pulp production, with 6% of high lignin content. The pulp yield also improved up to 40% if the EFB is pre-treated with 3% soda at controlled temperature and time. Pulps processed from the oil palm fronds in similar manners could achieve maximum yields of 44%, with excellent strength properties. Evaluation on oil palm trunks would yield up to 50% of pulps. It is mentioned that the pulp yield can be increase at higher percentage with slight penalty in the strength.

It is also reported that empty fruit bunches (EFB) offer the best prospects for commercial production of pulp and paper, with at least 1.5 million green tonnes of empty fruit bunches per year. Such production had been studied into providing direct employment of 200-300 personnel in the process of preparing the EFB until the production of commercialised pulp and paper (Kamarudin , *et.al* 1999).

### **1.4.3 Fuels**

In generals, large quantities of oil palm biomass residues have been recycled into burning fuels. Oil palm biomass such as shells and fibres are regularly end-up as solid fuels, which is used to heat boilers to acquire steams (Chan, 1999). Although being effective and simple, scientists are currently evaluating the use of biomass residues into other type of fuels, far better than being used only as solid fuels.

Ma, *et.al* (1999) had described the extensive research done by PORIM and Petronas on converting crude palm oil and palm kernel oil into liquid fuels such as methyl esters. It has similar properties as petroleum diesel and can be used in either direct fuel in unmodified diesel engines or can also be used as diesel enhancer. The palm oil methyl ester had been extensively tested as a diesel substitute in wide varieties of engines in buses, trucks and cars with promising results. The advantages

of palm-based methyl ester are the absence of black smoke and sulphur dioxide emission, thus providing less negative impacts on the environment.

There are also researches that are considering the use of crude palm oil as direct diesel substitute in diesels engine. Many researches introduce the possibilities of using the crude oil as a substitute of diesel fuels with the exception in disadvantages due to high viscosity and low volatility. M.M. El-Awad, *et.al* (2002), had attempted an experiment on using mixture of crude palm oil and diesel engine to increase the performance of diesel engine. It was reported that mixtures up to 75% of crude palm oil-diesel mixture produce more power than unmixed diesel fuels.

#### **1.4.4 Carbon and Activated Carbon**

The preparation of oil palm residues into carbon and activated carbon had been thoroughly discussed by Asiah (1993), Hussein , *et.al* (1996), and Lua and Guo (1998). Asiah (1993) and Hussein , *et.al* (1996) had studied the manufacturing of activated carbon from oil palm shells while Lua and Guo (1998) concentrated on the use of oil palm fibres as the precursor in manufacturing the activated carbon. The studies included the preparation of carbon using pyrolysis techniques, while the manufacturing of activated carbon was prepared by using either physical or chemical activation. Pyrolysis parameters such as heating temperature, inert gas flow rate and resident time was taken into account. The study concentrated on achieving good quality of carbon in term of surface area, an important parameter in the application of gas adsorption and other related areas. The results on porosity and surface area of the samples were followed by nitrogen adsorption analysis.

The preparation of oil palm shell residues into carbon and activated carbon by Asiah (1993) involved the preparation of activated carbon by methods of physical and chemical activation. The samples were prepared by physical activation in CO<sub>2</sub> and steam, and by using phosphoric acid in the chemical activation. High surface area up to 862 m<sup>2</sup>g<sup>-1</sup> was found by using activated carbon prepared in the combination of physical and chemical activation. Hussein , *et.al* (1996) had studied the manufacturing of activated carbon from oil palm shells by using chemical

activation based on impregnation of  $\text{ZnCl}_2$ . Surface area up to  $1500 \text{ m}^2 \text{ g}^{-1}$  was found by using this method.

The pyrolysis or carbonisation and the activated of oil palm shell which resulted in the production of carbon and activated carbon, can be utilized in many applications. High surface area carbon black and activated carbons, besides contributing to the significant amount of conductivity (Pantea, 2001), had been used in air cleaning system and industrial solvent recovery. Farid and Tan (2002) had studied the possibility of turning oil palm shell residue into high quality carbon known as carbon molecular sieves, in which the extreme porosity and surface area condition had shown good results in gas separation involving mixture of  $\text{O}_2/\text{N}_2$ .

#### 1.4.5 Chemicals

Pyrolysis offers a simple way of processing all of the complex polymeric structure found in biomass lignocellulosic residue materials. It can offer high yields of liquid product that retains the elements needed for chemical analysis and products. The mixture of phenolics, which resulted from lignin cracking and pyrolysis, can be reprocessed into standard product such as phenolics resin or phenol-formaldehyde condensation resin (Goldstein, 1981).

Pyrolysis of palm shell residues resulted in biomass chemicals such as methyl derivatives, acetic acid and most certainly phenols derivatives (M.N. Islam, *et.al* 1999). Studies had shown that pyrolytic oil, which is produced from pyrolysed palm shell, contains chemicals of 6.9 % acetic acid, 28.3% phenols plus other phenol and methyl derivatives. Further development by Wong, *et.al* (2002) on the phenols derived from the pyrolysis oil of palm shell residues had resulted in the production of palm shell-based adhesives, which is comparable to the petroleum-based adhesive.

#### **1.4.6 Tar**

The oil palm shell had been studied as a suitable material for surfacing roads. In general, fibre and shell are used as fuel in boilers. This boiler will usually produce slag, caused by the burning of biomass residues. Chan (1999) mentioned that the use of boiler slag, after sieving it properly to remove the ash, could be used as biomass tar for surfacing the roads. The idea of surfacing roads by using the last form of biomass residues proved to be a cheap yet practical way in using residues to its utmost potentials.

### **1.5 Potentials in Microwave Absorbers Application**

In general, microwave absorber was utilized in many applications involving domestic and industrial areas (Vinoy and Jha, 1996). In household applications, microwave absorber was used as a form of protective shields in microwave ovens. It was also used for ghost image removal that interrupts the performance of television pictures due to reflections from nearby buildings. Research on microwave absorbers also concentrated on suppressing noise from cellular phones. In microwave engineering, a number of microwave components utilized the use of microwave absorbers. Basic microwave components such as attenuators and terminators implemented the full use of microwave absorption using heating mechanisms, which reduced microwave energy to required values.

The development of microwave absorbers using palm shell carbon has not been discussed in any literature, but many studies and patented designs have shown extensive use of fine carbon or graphite as the dissipative element in microwave absorbers. Tomonaga (1976) had patented a design of a microwave absorbing material using carbon microspheres, which are prepared using coal or petroleum-based precursors. In this case, the mixture of conductive carbon and non-conducting thermosetting resin was used in the design of the absorber, which exhibits satisfactory microwave properties to be used as a microwave absorber. A different

patent by Natio, *et.al* (1989) had designed an electromagnetic wave absorber using mixtures of magnetic and carbon material, which was immersed in a binding medium by weight proportion. A minimum reflection of -13dB was recorded by using 50:50 proportional to the use of carbon and magnetic material. Miyazaki and Tanoue (1990) had also used small resistive particles made from carbon powder to improve the absorption characteristic of lossy composite multilayers. The absorber was moulded into a disk-shaped composite using vinyl chloride as the binder, incorporating carbon and aluminium powders as the element of absorptions. The plastic absorption plates showed reflection and transmission loss results of -17dB and -26 dB at 11.6GHz.

In reference to the recycling or waste utilization areas, several literatures had included interesting reviews on the implementation of residue towards potentials in microwave absorbing performance. McCauley, *et.al* (1986) had studied the possibilities of processing ferrite sludge from industrial wastewater into a cheap magnetic microwave absorber. Previously studied by Nippon Electric Co. (NEC) of Japan, the availability of innovative ferrite precipitation treatment in removing heavy metal ions from industrial wastewater had stimulated an interest for the potential use in microwave-absorbing studies. The ferrite sludge was firstly characterized and later fabricated into large samples tiles of 30.5 cm by 30.5 cm size. The results showed absorption over -5 dB from 3 to 4.5 GHz and -6 dB from 10 to 13 GHz. In Japan, Yamamoto (2001) pyrolysed a variety of local Japanese biomass residues such as Japanese cypress, lead oak, and bay pines into carbon, which was later used in the fabrication of carbon-loaded microwave absorber. He had introduced an electromagnetic wave absorber composed of carbon and polyester resin, capable of microwave absorption up to -18 dB in 1 to 3 GHz regions. The absorber was studied to become a potential material for reducing problem with escalating wood residues, as well as representing an innovative method to reduce electromagnetic interferences related to Japan's highway automatic fare collection system. The polyester resin was also used in conjunction with fly ash residues collected from thermal power station, in producing cheap PEFA microwave absorbing panel. The PEFA or Polyester-fly ash composite has been tested by Raghavendra, *et.al* (2002) in measuring the reflection and radiation properties of the composite in the X-Band range. It had been

reported that the optimisation of fly ash residue inside polyester composite play important role in reducing the reflection of electromagnetic signals.

## **1.6 Objectives and Scope of The Research**

### **1.6.1 Objectives of The Research**

The main objectives of the research is to study the effectiveness in utilizing oil palm shell residues into practical material such as carbon and activated carbon, which later used in microwave absorbing application. The research will concentrate on the significant material properties related with the microwave absorption as well as the performance of the material when introduced as a microwave absorber. Below are the overall objectives of the research:

- i. To study the microwave and reflection properties of microwave absorber by optimising carbon content from local palm shell residue, and its feasibility for microwave absorption application.
- ii. To characterize the physical and microwave properties of the absorber under the influence of pyrolysis temperature ( $^{\circ}\text{C}$ ) during carbon production and carbon concentration (%) inside polyester resin matrix.

### **1.6.2 Scopes of the research**

- i. To survey and study the literatures about information related to the renewable energy and products, especially those that is related to the recycling of oil palm shell biomass and residues into carbon and activated carbon for further commercial or industrial application.

- ii. To study all the information about microwave absorber and their working principles and mechanism, basic theories of microwave absorption, and the feasibility of utilizing carbon and activated carbon from oil palm shell residues into the elements that influence the absorption of microwave.
- iii. To characterize and analysed the physical properties of carbon and activated carbon from palm shells by the use of nitrogen adsorption analysis at 77.35K for specific surface area.
- iv. To characterize microwave properties of the sample composed from termoset polyester resin and pyrolysed palm shell carbon by using waveguide transmission line measurement in the X-Band region from 8 to 12 GHz.
- v. To undertake measurement on the absorption and reflection properties of microwave absorbing panel by utilizing mixture of termoset polyester resin and pyrolysed palm shell carbon using free space reflection measurement in the X-Band region from 8 to 12 GHz.

### **1.6.3 Thesis Overview**

The thesis was divided into seven main chapters. Chapter one introduces the background, objectives and scope of the research. The literature on renewable material and carbon production from palm shell residue and its application were referred from various resources. Chapter two reviewed the significant of carbon in microwave absorption, which includes the study on the utilization of carbon in microwave technology and the parameters that are important in understanding absorption criteria. The microwave absorber working principles, their classifications, and methods in measuring microwave and reflection properties using microwaves characterization and free space reflectivity measurement were studied.

Chapter three determined all the physical and microwave properties on samples using mixture of polyester resin and palm shell carbon. It involved analysis method and the results based from the experiment. The characterization result will develop substantial understanding on microwave absorption phenomena, before continuing in designing actual size absorber, which was tested in free space reflectivity measurement in order to search for the absorption or reflection properties. Chapter four reviewed on the preparation and reflection characterization of the microwave absorber using free space reflectivity measurement setup. The results of free space reflectivity measurement were also discussed in the same chapter. The analysis of the results based on all measurements was discussed in Chapter five. It would give a review on the efficiency in optimising palm shell carbon as practical microwave absorber. Chapter six would conclude on the research works and lay down a discussion on the future utilization of palm shell carbon.

#### **1.6.4 Limitation of The Study**

Although the objectives and scopes in this thesis had been thoroughly investigated and studied, there are few limitation regarding to the research:

- i. The reflection properties on the microwave absorber panel fabricated in this research were only based on the experimental result. Today, the research on microwave absorber have been update with the use of state of the art simulation and algorithms, which later include relevant information which could reduce cost and time consumption during the production of practical microwave absorber.
- ii. The measurement was done in the X-Band Frequency (8-12GHz), due to the limitation in experimental equipments constrained and time factor. The results of the test involving free space measurement would be best



executed in a more wideband condition i.e.: 1-18GHz, where most research on the practical absorber was done.

- iii. The parameter studied in the reflectivity measurement involve reflection properties based on lossy condition contributed by different thickness of a flat samples. Other parameters were not included in the testing, such as in depth analysis on the surface resistivity, various reflection angles, absorber shape etc.
- iv. In this research, the preparations of microwave absorber involve a robust design and rough mechanical production, which could influence the result of the measurement. A design in producing practical microwave absorber usually done in a controlled condition, including sensitive tools and precise workmanship, as well as other factors such as durability, maintenance and practicality.