UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF LOW COST, LOSSY AND LOW DIELECTRIC CONSTANT OPEFB-HDPE COMPOSITE MATERIAL FOR MICROWAVE APPLICATION

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By

SUNDAY DAUDA BALAMI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2017

DEDICATION

I dedicate this work to my parents, guardians and members of my beloved family.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Zulkifly Abbas, PhD
Faculty : Science

Oil palm empty fruit bunch fibre and high density polyethylene (OPEFB-HDPE) composites have been used in a variety of applications. However, it's potentials as a lossy low dielectric substrate for microwaves applications has not been realized. To date, the application of biomaterials as fillers in composites for microwave applications have not been examined. Research on lossy low dielectric constant materials reported are limited to polymer and metal oxides composite which are much expensive, hence the need to study materials from organic source which are less expensive, biodegradable and abundantly available.

This thesis presents the development of a lossy, low dielectric constant substrate based on OPEFB-HDPE composites for various microwave applications such as LTCC based patch antenna. This antenna require low dielectric constant and high loss factor (ε' between 2.5 and 10.0, ε'' ranges from 0.1 to 0.4). OPEFB exhibit excellent mechanical properties when compared to other natural fibers. The OPEFB fibers are biodegradable, cheap and non-toxic compared to various other industrial materials. The higher the percentage of filler the more the absorption which is good for electromagnetic shielding as well various as microwave absorber application.

The conventional solid-state method based on melt blend technique was used to prepared the composites. Five OPEFB-HDPE composites with different filler percentage were prepared. The complex permittivity of the composites were measured using open ended coaxial probe (OEC). The rectangular waveguide (RWG) was used to evaluate the scattering parameters and absorption. Finally, the resonance frequency was determined from the measured S-parameters of the microstrip patch antenna. The

crystalline structure of the composites was analyzed using X-ray diffraction (XRD) machine. The dielectric properties, and the transmission and reflection coefficients were measured using PNA (N5227) Network Analyzer from 8 GHz to 12 GHz at room temperature. The theoretical calculation of the transmission and reflection coefficients and visualization of electric field distribution of the sample placed in the waveguide was computed using Finite Element Method (FEM) accomplished using COMSOL software. The permittivity of the composites was found to depend on the mixing ratio between OPEFB and HDPE. The dielectric constants of composites were found to be between 2.5 and 3.2 and the loss factor from 0.15 to 0.38 in the X-band frequency. Both ε' and ε" of the composites can be predicted from the regression equations by inserting values of the fractional composition of the fillers. Both ε' and ε'' of the OPEFB-HDPE composite increased with increasing percentages of OPEFB fillers. These, in turn, will lead to higher values of the magnitude reflection coefficient $|S_{11}|$ and lower transmission coefficient $|S_{21}|$ by the impedance matching theory. Comparison of the measured and calculated scattering parameters was also investigated. Furthermore, the results obtained from the scattering parameters were used to determine the effect of OPEFB on absorption properties of the composite samples. The electric field distribution through the waveguide was visualized using FEM simulation.

Finally, the effect of the different percentage of OPEFB filler on resonance frequency was investigated by fabricating the composites into microstrip patch antenna at frequency range 1 GHz to 4 GHz. The resonance frequency was found to be in the range between 1.98 GHz to 2.16 GHz. It increases with the decrease in the filler content. The return loss was in the range -11.93 dB to -4.43 dB.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN KOMPOSIT BAHAN OPEFB-HDPE BERKOS RENDAH, KADAR KEHILANGAN DAN PEMALAR DIELECKTRIK YANG RENDAH UNTUK APLIKASI MIKROGELOMBANG

Oleh

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Serat tandan kosong kelapa sawit dan polyethylene berketumpatan tinggi (OPEFB-HDPE) komposit telah digunakan dalam pelbagai kegunaan yang berbeza. Tetapi, potensinya sebagai substrat dielektrik yang mempunyai kadar kehilangan yang rendah untuk aplikasi mikrogelombang masih belum ditemui. Sehingga sekarang, aplikasi bahan bio sebagai salah satu bahan dalam komposit untuk aplikasi mikrogelombang masih belum dikaji. Kajian mengenai bahan dielektrik mempunyai kadar kehilangan rendah yang telah dilaporkan hanya terhad kepada polimer dan logam oksida komposit sahaja di mana harga untuk barang-barang ini sangat mahal, oleh yang demikian, kajian bahan dari sumber organik sangat diperlukan kerana bahan tersebut lebih murah, senang lupus dan mudah diperoleh.

Tesis ini menerangkan mengenai pembuatan substrat dielektrik yang mempunyai kadar kehilangan yang rendah berdasarkan penggunaan OPEFB-HDPE komposit untuk variasi aplikasi mikrogelombang seperti LTCC berdasarkan antena tampalan. Antenna ini memerlukan dielektrik pemalar yang rendah dan factor hilang yang tinggi (ε' diantara 2.5 dan 10.0, ε'' berukuran dari 0.1 ke 0.4). OPEFB mempunyai ciri mekanikal yang baik apabila dibandingkan dengan serat semula jadi yang lain. Serat OPEFB mudah lupus, murah dan tidak bertoksik apabila dibandingkan dengan bahan industri yang lain. Semakin tinggi peratusan kandungan serat, semakin tinggi kadar penyerapan di mana ianya sangat sesuai untuk pelindung elektromagnetik dan juga sebagai aplikasi penyerap mikrogelombang.

Cara konvensional penggunaan teknik keadaan pepejal adalah berdasarkan teknik cair-gaul yang telah digunakan untuk penyediaan komposit. Lima komposit OPEFB-HDPE dengan kandungan peratusan berbeza telah disediakan. Kadar ketulusan kompleks komposit tersebut telah diukur menggunakan proba sepaksi hujung terbuka (OEC). Pandu gelombang bersegi empat (RWG) telah digunakan untuk memeriksa paramater penyebaran dan penyerapan. Akhir sekali, kekerapan resonans telah ditentukan dengan pengiraan parameter-S dari mikrostrip antena tampalan. Struktur kristal komposit tersebut telah dianalisis mengunakan mesin pembelahan sinar-X (XRD). Ciri dielektrik dan pekali penghantaran dan pemantulan telah diukur menggunakan PNA (N5227) Network Analyzer dari 8 GHz ke 12 GHz dalam suhu bilik. Teori pengiraaan pekali penghantaran dan pemantulan dan visualisasi pengagihan medan elektrik sampel tersebut yang menggunakan pandu gelombang segi empat telah dihitung menggunakan Finite Element Method (FEM) melalui perisian COMSOL. Ketulusan komposit telah disahkan bergantung kepada nisbah diantara OPEFB dan HDPE. Pemalar dielektrik komposit telah diukur dan mempunyai nilai di antara 2.5 dan 3.2 dan faktor penghilangan di antara 0.15 dan 0.38 dalam frekuensi X-band. Kedua-dua ε' and ε'' komposit boleh ditafsir daripada persamaan regresi dengan memasukkan nilai komposisi pecahan pengisi. Kedua-dua ε' and ε'' untuk OPEFB dan HDPE komposit bertambah apabila peratusan pengisi OPEFB bertambah. Oleh yang demikian, ini akan mengakibatkan nilai yang lebih tinggi dalam magnitud pekali refleksi $|S_{11}|$ dan nilai yang rendah untuk pekali penghantaran $|S_{21}|$ melalui teori persamaan impedans. Perbandingan diantara pengiraan dan pengukuran parameter penyebaran juga diperiksa. Tambahan lagi, keputuan yang diperoleh daripada parameter penyebaran telah digunakan untuk menentukan kesan OPEFB dalam ciri penyerapan sampel komposit. Pengagihan medan elektrik melalui pandu gelombang telah di visualisasi menggunakan simulasi FEM.

Akhirnya, kesan perbezaan peratusan pengisi OPEFB dalam frekuensi resonans telah diperiksa dengan mencantum komposit dengan mikrostrip antenna tampalan dalam jarak frekuensi 1 GHz hingga 4 GHz. Frekuensi resonans telah diperiksa dan mempunyai nilai diantara 1.98 GHz hingga 2.16 GHz. Ianya bertambah dengan pengurangan isi pengisi. Kadar faktor penghilangan adalah dalam julat -11.93 dB to -4.

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Thank you very much
God bless.

I certify that a Thesis Examination Committee has met on 6 December 2017 to conduct the final examination of Sunday Dauda Balami on his thesis entitled "Development of Low Cost, Lossy and Low Dielectric Constant OPEFB-HDPE Composite Material for Microwave Application" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

EMI	Electromagnetic interference
HDPE	High Density Polyethylene
OPEFB	Oil Palm Empty Fruit Bunch
EM	Electromagnetic
OEC	Open ended coaxial probe
RWG	Rectangular waveguide
EF	Electric field
HE	magnetic field
XRD	X-ray diffraction
FEM	Finite element method
NRW	Nicholson Ross Weir
FDM	Finite difference method
MOM	method of moment
FDTD	Finite difference time domain
MWO	Microwave office
HFSS	High frequency structural simulation
CEM	Computational electromagnetic
PNA-L	Professional network analyzer
VNA	Vector network analyzer
TRL	Thru, Reflect, Line
RF	Radio frequency
FWHM	Full wave half maximum
MUT	Material under test
ECAL	Electronic calibration
SMA	Sub-miniature
TE10	Transvers electric mode
TM	Transvers magnetic mode
TEM	Transmission electromagnetic mode
TR	Transmission/Reflection
S11	Reflection coefficient

S21	Transmission coefficient
ε_r	Complex permittivity
μ_r	Complex permeability
PTFE	Polytetrafluoroethylene (Teflon)
DIW	De-ionized water
JCPDS	Joint committee on powder diffraction standard
ECCD	Electromagnetic Compatibility Compliance Directive
MTI	Maximum transmitted intensity
MMC	Metal matrix composite
CMC	Ceramic matrix composite
PMC	Polymer matrix composite
LTCC	Low temperature co-fired ceramic
ULSI	Ultra-large-scale integration
ILD	Interlayer dielectrics
IC	Integrated circuit
UHF	Ultra high frequency
EHF	Extremely high frequency

CHAPTER 1

INTRODUCTION

Microwaves are a form of electromagnetic radiations with a range of wavelengths between one meter and one millimetre; with frequencies between 300MHz (100cm) and 300GHz (0.1cm) Pozar, (1993) and Sorrentino, (2010). This broad definition covers both UHF and EHF (millimetre waves), and various sources use different boundaries. In all cases, microwaves includes the entire SHF band (3 to 30 GHz, or 10 to 1cm) at minimum, but in RF engineering the range is often restricted to between 1 and 100 GHz (300 and 3mm).

Material scientist, researchers and industries have in the past decades been attracted to the use of natural fibres because of their specific advantages as compared to the conventional or synthetic fibers. This is because it is environmentally friendly, and the issue of environment is top at the national and international agenda. Hence, the natural fibre because of its biodegradable nature unlike synthetic fibres has become centre of attraction. This is in addition to low cost and low density (Mohanty, 2002) and (Singha, 2008).

Polymers, e.g. Polyethylene has been found to be applicable in various fields of research in the world today. They are frequently compounded with natural minerals so as to improve their properties. Glass fibre has been employed in the improvement of the stiffness and strength of thermoplastic material (Sanadi, 1995). Polymer-fiber composites are mostly cheap to produce because the natural fiber is readily available, also it possess improved mechanical and electrical properties (Ibrahim et al, 2011). This work is aim at finding out the dielectric properties of the composites prepared with different ratio of environmentally friendly HDPE and OPEFB at microwave frequency band. OPEFB is a solid waste and was chosen for this research so that excess waste will be reduced from the environment.

At present, the demand of wireless technologies is increasing rapidly where small size, light weight, ease of installation are constraints, low profile microstrip antenna is required. The antenna has become a necessity in wireless communication system. Microstrip antenna has wide range of applications in high performance aircraft, spacecraft and missile, and satellite application. In today’s world, microstrip antenna play a significant role in communication system due to its attractive features such as light weight, low volume, low power handling, low cost, easy to fabricate & easy in construction (Singh et al, 2012). A microstrip antenna have the ability to provide superior performance of radiation and the gain is better compared to other forms of antennas because of its capacity to concentrate energy into a tight beam through a direction to provide better radiation performance (Rakesh et al, 2011). As the microelectronics industry constantly grew through the 21st century, there was high demand of more advanced processes and materials. After the discovery of microprocessor, the number of active devices on a chip has increased exponentially, approximately doubling yearly, legendarily forecast by Gordon Moore in 1965. All of this was driven by the necessity for optimal electrical and practical performance.

The composite product from this research can be used as a substrate in many applications such as electromagnetic shielding, integrated circuits (IC), microstrip antenna and transmission lines components which can be found in mobile communication, aerospace and defence industry.

Detailed study in measurement of permittivity of solid materials using open ended coaxial probe (OEC) have not been carried out. In the light of the above, measurement of complex permittivity using OEC technique would be investigated and results would be compared with standard recommended technique like the rectangular wave guide method (RWG). Other investigations would involve the effect of different % OPEFB inclusion in the host matrix on materials complex permittivity, scattering parameters, absorptions and resonance frequency. Further understanding in the applications of dielectric materials can be found in (Pozar, 2009; Laverghetta, 2005).

1.1 Composites

Composites are materials consisting of two or more different substance chemically and physically in phases separated by a distinct interface. The divergent frameworks are consolidated together so as to accomplish a framework with more beneficial structure or practical properties non-achievable by the individual constituent alone. Composites today are turning into an irreplaceable piece of materials because of the points of interest like low weight, imperviousness to erosion, high exhaustion quality, quicker to assemble and rigid nature. They have extensively found application as materials in fabricating aircraft components, electronic packaging, medical equipment, space vehicle and home building (Shaw et al, 2010). Blends and composites differ in the sence that the two main elements in the composites are distinguishable, this is not so in blend, they might not be recognizable. Composites are blends of materials contrasting in structure, where the individual constituents hold their different behaviours. These different constituents act together to give the essential mechanical quality or firmness to the composite part. They are composed of distinct phases i.e. matrix phase and dispersed phase with significant bulk properties that are not similar to those of any of the constituents. Matrix phase is also referred to as primary phase, it has a constant character. Matrix is generally more ductile and soft phase. Dispersed phase grasps and shares a load with the matrix. Dispersed, otherwise known as reinforcing or secondary phase is embedded within the matrix in a discontinuous form. Usually it is tougher than the matrix, hence the name reinforcing phase.

Materials predominantly used everyday are wood, concrete, ceramics, etc. Be that as it may, the most essential polymeric composites are found in nature and are alluded to as normal composites. In warm blooded animals, the connective tissues have a place with the most exceptional polymer composites in the world where the stringy protein, collagen is the support. It capacities both as delicate and hard connective tissue. According to (Mayer et al, 1998), composites for structural application posseses characteristics such as;

- Two or more physically distinct and mechanically distinguishable materials.
- Prepared by mixing the distinct materials so as to achieve controlled and even dispersion of the constituents.
- Having greater mechanical properties and may be uniquely distinct from the properties of their constituents

Typically, two goals are achieved in composite making. The first goal is to develop the strength, stiffness, toughness, or dimensional strength by embedding particles or fibers in a matrix or binding phase. Secondly, to use cost efficient, readily obtainable fillers than the reversed; this goal is important as petroleum product become expensive and unreliable. Other applications, fillers such as glass spheres are imploy to improve processability. Incorporation of dry-lubricant particles such as molybdenum sulfide to make a self-lubricating bearing, and the use of fillers to reduce permeability have also been achieved. Propelled composites have superior fiber fortifications in a polymer matrix material, for example, epoxy. Cases are graphite/epoxy, Kevlar/epoxy, and boron/epoxy composites. They are generally pertinent in the aviation ventures, yet have now discovered applications in commercial industries too.

1.2 Classification of Composites

On the premise of matrix stage, composites are characterized into metal matrix composites (MMCs), ceramic matrix composites (CMCs), and polymer matrix composites (PMCs) (Avila et al, 2003). Depending on the type of reinforcements, classifications are particulate composites, fibrous composites and laminate composites. Fibrous composites are further grouped on the basis of natural/biofiber or synthetic fibre. Biofiber encompassing composites are referred to as biofiber composites. On the basis of matrix, they are grouped as biodegradable and non-biodegradable matrix (Nicoleta and Hickel, 2009). Bio-based composites produced using natural/biofiber and biodegradable polymers are alluded to as green composites. These can be additionally subdivided as crossover composites and material composites. Crossbreed composites contain a mix of at least two sorts of fibres.

1.3 Properties of Polymer composite

The dielectric properties of polymer composite are mainly depended on the conductive fillers. Consequently, the type or nature of fillers determines the dielectric characterisation of polymer composites. Typical conductive fillers are semiconductors, metals, carbonic materials and intrinsic conductive polymers (Xu et al, 1999). Conductive Polymers have attracted a lot of interest in recent time due to their excellent flexibility and easy preparation procedures as against the use of conventional inorganic semiconductors. They have found application in areas of electronics as flexibility conductors and shielding devices especially with regards to electromagnetic radiation (Ma, et al, 2005). In conventional conductive composites, carbon black particles of micro-meter sizes are used to achieve desired electrical characteristics. Researches have shown however that using high amount of filler contents can leads to a poor composite (Liang, 2007).

1.3.1 Fiber-polymer composite

A natural fiber composite with an exceptionally good combination of properties is not a dream today. Fiber-reinforced composites are known to be strong and light. This means that with proper processing techniques, fiber treatments, and compatibilizers/coupling agents, composites with optimum properties can be used to make automobiles lighter, and thus much more fuel efficient.

Few decades ago, polymers have replaced many of the conventional metals/materials in various applications. This was made conceivable because of the favorable circumstances polymers offer over regular materials. The absolute most essential points of interest are the simplicity of handling, efficiency and cost decrease. In a large portion of these applications, the properties of polymers are modified utilizing fillers, for example, fibers to suit the high quality and modulus necessities. Fiber-fortified polymers give different preferences over regular materials when specific properties are analyzed (Schneider et al, 1995). These composites are finding widespread applications in diverse fields from appliances to space crafts. Over the years, the attention of scientist and technologist have been drawn to the use of natural fibres instead of conventional reinforcement materials. These natural fibres are low-cost fibres with low density and high specific properties. They are biodegradable and nonabrasive, unlike other reinforcing fibers. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements (Colberg and Sauerbier, 1997). However, disadvantages such as incompatibility with the hydrophobic polymer matrix, the tendency to form aggregates during processing, and poor resistance to moisture serve as drawbacks to the potentials of natural fibers as reinforcement in polymers (Schloesser and Knothe, 1997).

1.4 Low dielectric constant material

The procedure with change in materials thickness and its capacity to perform has significantly affected on the element size and many-sided quality of the wiring structure for on-chip interconnects. As the material least measurements abatement to past 0.18 µm, the ascent in propagation delay, crosstalk commotion, and power dissipation of the interconnect plan ends up plainly constraining components for ultra-vast scale integration (ULSI) of integrated circuits. In this way, with a specific end goal to address these difficulties new materials for use as metal lines and interlayer dielectrics (ILD) as an option auxiliary outline are being produced to supplant the Al (Cu)/SiO_2 interconnect ability. However this require the presentation of low dielectric constant materials as the interlayer dielectric and low resistivity conduits, for example, copper. The industry has been commited to adopting the change to copper metallization (Edelstein, 1997) and (Venkatesan et al, 1997), and is working intensely to implement ILD using low dielectric constant materials.

The inability to identify a better and more reliable low-k dielectrics can be fundamentally attributed to the numerous challenges associated with the successful incorporation of these materials into future on-chip interconnects. Added to low dielectric constant, material intra and inter level dielectrics must satisfy a large number of various requirements in order to be effectively integrated, (Lee WW, 1997).

The requirements include;

- High thermal and mechanical strength
- Good adhesion to the additional interconnect materials
- Resist processing chemicals
- The moisture absorption should be low
- Cost effective

Recently researchers have intensify efforts to develop low dielectric constant materials that can simultaneously satisfy all of these requirements. The fundamental test for the time being is to create material with mix of low dielectric constant, great thermal and mechanical quality. For the most part, the sorts of chemical structures that grant basic quality are those having solid discrete bonds and a high density of such bonds. In any case, the most grounded bonds are regularly the most polarizable and expanding the bond density gives a relating increment in polarization. For instance, the solidness and thermal quality of SiO_2 is mostly due to the dense (2.2–2.4 g/cc) substance arrange. Unfortunately, the high bond and material density in SiO_2 result to high atomic polarizability, henceforth result in high dielectric constant. Natural polymeric materials because of their low density (~1.0 g/cc) have a tendency to have a lower dielectric constant and lower singular bond polarizabilities. Likewise, most natural polymers thermally break down at regular back-end of-the-line (BEOL) subtractive Al preparing temperatures ($\geq$400 ^{0}C) in light of the fact that CC bonds are less solid as the Si-O bonds, and the polymers commonly have much lower crosslinking densities than SiO2. The Cu damascene process offer the likelihood of diminishing the most extreme BEOL treating temperature to ~350 ^{0}C, in this manner expanding the treating temperature window for potential low dielectric materials. The mechanical properties of the natural polymers are in like manner substandard compared to those of oxide for comparative reasons. The natural materials that are most impervious to thermal decay and mechanical deformation are those containing twofold and triple bonds, which tend to increase the dielectric constant of these materials. The low dielectric natural polymers demonstrating sensible stability over 400 ^{0}C regularly have dielectric constants between 2.5 to 3.5. Since it is not easy to reduce the dielectric constant below 2.5 with fully dense materials, it therefore become necessary to introduce micro or mesoporosity to achieve very low dielectric constant values (≤2.0). Mesoporous characteristically describes materials with voids 2‑50 nm in diameter, while micro-porous is used to describe materials encompassing voids ≤2 nm in diameter. Micro-porous solids are referred to as very low density materials rather than porous materials. The voids are introduced with purpose of decreasing the dielectric constant by reducing the density of the material. In principle, we can vary the percentage of the porosity and then the material density and dielectric constant. The pores are fused into a system material that can be natural, inorganic, or a hybrid material. Since the presentation of voids in the composites will adjust other material properties, for example, mechanical strength, the chemical structure of the permeable system should be cautiously intended to achieve sufficient thermo-mechanical strength. To achieve this, we imploy the use of OPEFB to provide an alternative filler material because of its porous nature if compounded with polymer. The OPEFB has a very low density and the grain size would provide the required voids within the composites.

1.5 Characterization Techniques

When dealing with propagation of waves, the characteristics of microwaves and light waves are typically the same since both components travel in a straight line. The characteristics of travelling in a straight line enable them to reflect, refract, diffract, scatter, and interfere at boundary points with interacting media. Hence, their mode of interaction at the interface of these media varies due to their different wavelength. Microwave wavelengths range from 1 m to 1 mm corresponding to frequency range of 0.3 GHz to 30 GHz. This singular characteristic allows microwaves to interact with materials and structures on a macroscopic scale. For example, microwaves are capable of penetrating most non-metallic materials, reflecting and scattering from internal boundaries and interacting with molecules (Bahr, 1982) as cited by (Soleiman, 2009).

1.5.1 Permittivity

Measurement of complex dielectric constant is required not only for scientific but also for industrial applications. Areas in which knowledge of the dielectric properties of materials at microwave frequencies found application are microwave heating, biological effects of microwaves, and non-destructive testing (Weir, 1974).

Dielectric properties measurement is an important factor in defining the physical and chemical properties related to storage and energy loss in various kind of materials (Wee, et al, 2009).

The term dielectric constant is some time misleading, the dependence on frequency of dielectric materials causes it to have two parts, that is the real and imaginary permittivity. The ratio of the imaginary part to the real part of permittivity is called loss tangent (Kittel, 1996). Permittivity are complex numbers of which the imaginary part is associated with losses.

Scattering parameter and permittivity of materials measured using microwaves components are controlled by the basic properties of microwaves. In good conducting materials, microwave has low penetrating depth. For this reason, they are usually used to test non-conducting materials which include low-loss and lossy dielectric materials. To investigate the interaction between microwaves and materials, Maxwell's equation is often employed. Properties like propagation mode, reflection, refraction, transmission and impedance are defined from the equation. The broad nature of material properties allows the use of different techniques for measurement at microwave frequency range. A number of methods have been used in the measurements of electromagnetic properties at microwave frequencies. Amongst these methods are the transmission and reflection line technique, open ended coaxial probe technique, and resonant method (Agilent Tech, 2011). Details of these techniques would be discussed in the ensuing chapters.

1.5.2 Morphological Properties

X ray diffraction (XRD) is a non-destructive technique for the characterization of semi crystalline and crystalline materials. XRD investigates crystalline materials structure, phases, atomic orientations, and other structural parameters, such as average crystallite size, crystallinity, strain, and imperfections. X ray diffraction peaks are produced by constructive interferences of monochromatic beam of x rays scattered at specific angles from each set of lattice planes in a sample. The XRD technique is based on observing the scattered intensity of an X-ray beam hitting a sample as a function of incident and scattered angle, polarization, and wavelength or energy.

1.6 Problem Statement

About half century, low dielectric constant materials have been intensively investigated by ceramic and polymer scientists. Though, these materials possess an enormous myriad of electrical, thermal, chemical, and mechanical properties that are as crucial as the name that categorizes them. The choice of low dielectric constant material could have a tremendous influence on device's performance and lifespan. In the field of microelectronics and antennas, many of the early low dielectric constant materials have been satisfactorily fabricated. Despite this progress, a low dielectric constant and high loss factor was never achieved before now.

OPEFB-HDPE composites has been used in a variety of applications. However, it's potentials as a lossy low dielectric substrate at microwave frequencies has not been fully exploited due to lack of detailed information on the relationship between the filler composition and electromagnetic properties. Most researches on lossy low dielectric constant materials are targeted on polymer and metal oxides composite which are much expensive, hence the need to study polymer (HDPE) and OPEFB material from organic source. This work has been focus on developing the potentials of OPEFB-HDPE composite as a lossy low dielectric constant substrate which over the years has found application in the field of low temperature co-fired ceramic (LTCC) patch antenna in the microwave frequency range.

Cellulose extracted from OPEFB has attracted growing interest because of their unique characteristics, such as low cost, low density, high specific strength, good thermal properties, and biodegradable. Oil palm EFB fiber is a natural fiber which has great relevance to Malaysia, as a large quantity of the biomass is generated by oil palm industries. The total amount of OPEFB produced was estimated to be more than 10 million tons per year, and only about 10% is used and the rest are in abundant as industrial waste product.

This work proposes to develop the potentials of OPEFB-HDPE composite as a lossy low dielectric constant substrate for electromagnetic shielding and antenna application. The focus is on the developing a material with low dielectric constant but strong thermo mechanical properties with OPEFB as a filler in the composite. This is followed by a description of the material characterization techniques.

The dielectric properties, transmission and reflection coefficients of the OPEFB-HDPE composite of various filler content and types of host matrix and material properties were not analysed in details theoretically and experimentally.

1.7 Objectives

The main objective is to a prepare substrate from oil palm empty fruit bunch as filler and high density polyethylene as host material using the method of hot pressure and characterize their crystalline phase formation. The specific objectives of this study are enumerated below;

1. To determine the dielectric constant, loss factor and loss tangent of the OPEFB-HDPE composites in the frequency range from 8 GHz to 12 GHz.
2. To determine the effect of % OPEFB filler on the values of the transmission and reflection coefficient of the OPEFB-HDPE composites.
3. To visualize the electromagnetic field distribution in the waveguide loaded with OPEFB-HDPE composites using finite element method (FEM).
4. To determine the resonance frequency of OPEFB-HDPE composites using microstrip patch antenna.

1.8 Scope of Study

In this study, an easy and lesser time consuming technique for preparing OPEFB-HDPE composites using the melt blending technique via Brabender melt blending machine would be carried out.

The effect of the different % OPEFB filler on the dielectric properties would be measured using the open ended coaxial probe, rectangular waveguide and microstrip techniques. The effect of the OPEFB filler on the transmission and reflection coefficient of the HDPE-OPEFB composite pellets are also studied. It also proposes to use FEM COMSOL software in calculating scattering parameters and for simulating electromagnetic wave excited through OPEFB-HDPE composites samples when placed inside a rectangular wave guide. The result obtained for scattering parameter through measurement and simulation also compared. The micro-structural characteristics of materials with respect to grain size of the prepared OPEFB-HDPE composites. The morphological characterization would be carried out using the XRD.

1.9 Thesis layout

There are five chapters in this thesis with appendices attached at the end of the chapters. Chapter 1 briefly elaborates generally on polymer composites, morphological and dielectric characterization, problem statements, and objectives of study, the scope of the study and finally, the thesis layout.

Chapter 2 presents reviews on OPEFB-POLYMER composites, electromagnetic radiation (EM) measurement technique and limitations of some measurement techniques. Amongst others, the free space methods were also discussed. Numerical methods associated with rectangular wave guide were also discussed.

Chapter 3 is the theory chapter, the chapter started with emphasis on Bragg's law and continued with discussion on Maxwell's equation and wave equation. It finally anchored discussion on the transmission and reflection coefficients calculation procedures with FEM formulation techniques.

Chapter 4 encompasses the entire method used in this study. The preparation of OPEFB-HDPE composites were explicitly discussed. The use of FEM, OEC, RWG methods and the resonance frequency measurement are fully discussed in relation to microwave characterization. The morphological characterization using the XRD, is discussed in details.

Chapter 5 is divided into six subsections. Section 5.1 deals with the morphology characterization of all the samples used in this work. The characterization tool used was XRD. Section 5.2 deals dielectric characterization of different OPEFB grain sizes to determine the effect of grain size on the permittivity. Section 5.3 deals with the dielectric characterization of the all the composites used in this research work using the open ended coaxial probe and rectangular wave guide methods. The effect of % OPEFB on the permittivity of the composites was also investigated. Comparison between dielectric constant obtained using the two methods are also shown. Section 5.4 deals with the effect of OPEFB-HDPE composite ratio on the scattering parameters using rectangular wave guide and FEM. Variation in scattering parameters of sample with OPEFB and absorption of the electromagnetic waves based on the scattering parameters were also discussed. Lastly, the effect of OPEFB on OPEFB-HDPE composites resonance frequency was investigated.

Finally, chapter 6 will draw conclusions based on findings and postulate suggestions for future studies.

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