Exploring the Potential of Palm Oil Fuel Ash (POFA) in EMI Shielding Effectiveness

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ABSTRACT

The issue of environmental pollution resulting from disposal of palm oil fuel ash (POFA) in Malaysia has drawn the interest of many researchers. It is reported that it can be incorporated into the cement based composite as the electromagnetic field (EMF) absorber to reduce the EMI radiation. This paper explores the performance of each layer of POFA in EMI shielding. In this work, the POFA is split into four layers after the stirring process in the water. The first layer of the POFA tends to float as based on the SEM morphology, it possesses high porosity compared to other layers. Based on the transmission measurement using a network analyser, it is found that the 7 mm of layer 1 which contains 85.89 wt.% of carbon can provide shielding effectiveness (SE) of -25.76dB in between 50 MHz to 2 GHz. Besides the high carbon content, the porosity of layer 1 enhances its capability as shielding material too.

Keywords: *Palm Oil Fuel Ash, EMI Shielding Effectiveness, Carbon Precipitation Process, POFA Layer Performance.*

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Introduction

Most of advanced technologies in electric and electronic devices especially the wireless and communication systems are polluted by electromagnetic wave (EW) pollution which can be harmful to health and may cause of death [1], [2]. Electromagnetic pollution has become part of people's daily life due to the proliferation of the high speed electrical and electronic systems such as mobile phone based station, mobile phone, radar, television and radio transmitters and so on that ease our daily life. The studies on electromagnetic fields (EMF) has been motivated primarily by public for health considerations [3].

A high frequency range of electromagnetic wave is able to increase human's body temperature of approximately 1–5 °C. Researchers have reported the severity of the physiological effects produced by small temperature surge. Some of the effects include, organs malformations, temporary infertility in males, brain lesions, and blood effect [4], [5]. The human brain is sensitive to EMI field and it promotes the brain tumor risk [1], [6]–[8]. Besides that, the device such as cordless telephones, home entertainment systems, computers, and certain medical devices can fail to operate properly in the presence of strong RF fields [8], [9]. Hence, it is important to reduce the EMI radiation.

In recent years, the issue of environmental pollution resulting from disposal of palm oil fuel ash (POFA) in Malaysia has attracted the attention of researchers to explore its potential as an alternative fuel [10] or other field. Some researchers have reported that the elements in POFA contribute the most to the microwave absorption is carbon (C) and iron III oxide (Fe2O3) [3], [11]–[17].

To further understand the research in microwave absorber, this paper will explicate the POFA in terms of its element content and performance for EMI shielding. The frequency range is from 50 MHz to 2 GHz.

The highlight of this work is to show the important process in refining the POFA for removing the dust, sand, and soil as it is a by-product where palm mill industries gather as waste at landfills. The dust, sand, and soil are not contributing towards in EMI shielding effectiveness.

Methodology

The main raw material used in this research is Palm Oil Fuel Ash collected from Genting Plantations Oil Mill Ayer Hitam branch in Johor, Malaysia. In this work, the POFA is split into different layers. Each layer was examined by Energy Dispersive X-ray Spectroscopy (EDS) to identify the element content in POFA. Then the microstructure characteristic of each layer was explored using Scanning Electron Microscope (SEM). Next, the SE of the POFA will be measured based on the transmission measurement.

Sample preparation

500 grams of POFA is filled into a graduated cylinder. The water from laboratory is then added into the same cylinder until it is 80% full. The mixture of POFA and water is stirred for 30 minutes by using a portable stirrer. After the stirring process, the cylinder is left for 48-hours. After 48-hour of precipitation, 4 layers of POFA appeared. The layer 1 POFA is withdrew using spatula as it is floating. Then each of the layer is removed one by one by using syringe withdrawal method [18]. All layers are dried in the oven for 5 hours at the temperature of 100ºC. Figure 1 shows the schematic diagram of syringe withdrawal method.

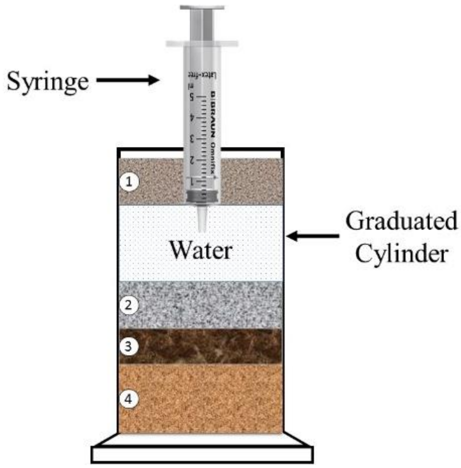

Figure 1: Schematic diagram of syringe withdrawal method

Transmission measurement

Transmission measurement is experimental measurement method of the POFA SE. The signal is in radio frequency (RF) form. The RF is supplied from port 1 to port 2 where the sample is placed in between port 1 and port 2 transmission lines. Hundreds of data was obtained by NA and calculated in MATLAB by using Equation 1. Standards, such as ASTM D4935, EN 50147-1 and IEEE 299-1997, are not suitable for powder type specimen; thus, APC-7 connectors are used. This measurement is carried out by using APC 7 connectors as sample holder. During this measurement, both APC 7 connectors are connected to a NA. NA is a device used to measure the ratio of transmission and reflection of electromagnetic waves through a device under test. In this work the device under test is the APC 7 connectors. The APC 7 connectors are shown in Figure 2 and Figure 3 which show how the powder-formed-samples are placed into the APC 7 connector.

Figure 2: APC 7 connector male (1) and female (2)

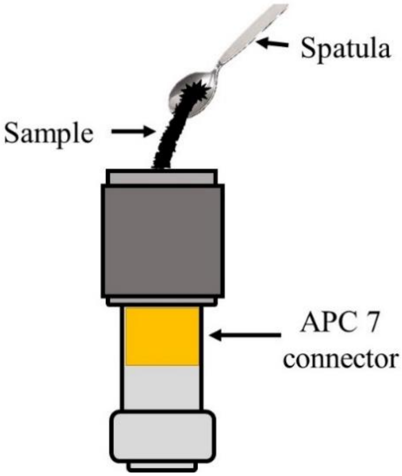

Figure 3: The method of insert sample into the APC 7 connector

The inner diameter of the APC 7 connector 3 mm and outer diameter is 7 mm. The sample is toroidal form when it is inside the APC 7 connector. The sample in the APC 7 connectors is compressed by using a heavy metal bar, where the pressing load is approximately $1kg/mm^2$. This is to ensure the sample is completely occupied in the APC-7 connector space. After the measurement is completed, the APC-7 connector was cleaned using high pressure air. The blow process was needed to remove the remaining sample in the APC 7 connector before the next measurement. Figure 4 shows the schematic diagram of dielectric measurement method. In this measurement, the SE is obtained based on Equation (1). S_{21} represents the power reserved at antenna 2 relative to the power input to antenna 1. Two types of S_{21} are used here which are $S_{21\text{-}without}$ and $S_{21\text{-}with}$. $S_{21\text{-}without}$ represents the S_{21} when the APC 7 connector does not contain any sample, while $S_{21\text{-}with}$ represents the S_{21} when the APC 7 connector is filled with the sample which is in the powder form.

$$SE(dB) = \text{Forward gain} = 20\log\left[\frac{S21-with}{S21-without}\right] \tag{1}$$

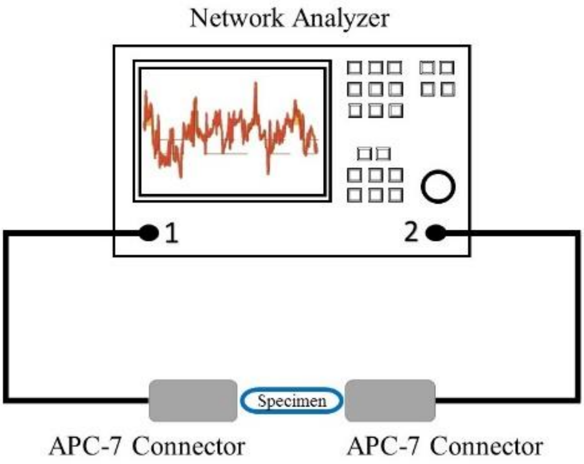

Figure 4: Schematic diagram of transmission measurement method

Result and Discussions

The EDS, SEM and SE results were discussed in this section. From the precipitation process, the POFA is split into four layers as in Figure 5. Based on the observation, layer 1 was floating on the top of water, layer 2 was the second top layer within submerged layer, layer 3 was the thinnest layer in between layer 2 and 4, and layer 4 was the layer that submerged at the bottom.

Based on the EDS result (Table 1), carbon content of layer 1 is the highest among other layers, which is 85.89%. The carbon content was reduced followed by the sequence of layers. Layer 4 was rich in silicon dioxide (SiO_2) which is about 53.78%.

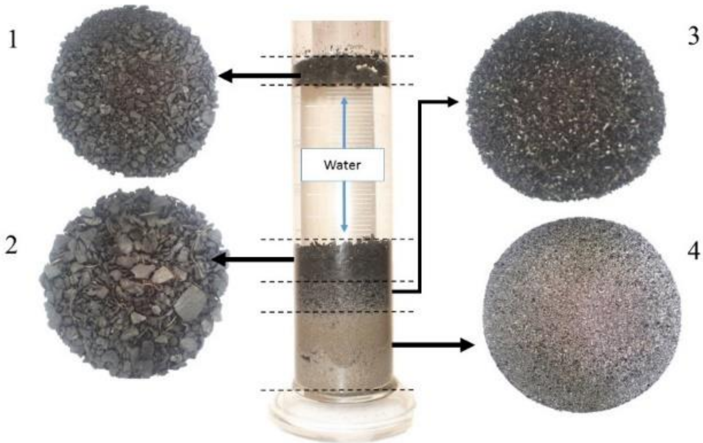

Figure 5: The layer of POFA

Table 1: Compound in each layer

Compound	layer 1*(%)*	layer 2*(%)*	layer 3*(%)*	layer 4*(%)*
C	**85.89**	**81.68**	**71.57**	**15.55**
MgO	1.27	1.12	1.45	3.99
Al_2O_3	-	1.72	1.38	6.85
SiO_2	5.60	8.22	12.09	53.78
P_2O_5	-	-	-	3.49
K_2O	3.25	2.52	4.51	6.75
CaO	3.98	2.01	6.30	3.23
FeO	-	2.73	2.70	6.36
Total	**100**	**100**	**100**	**100**

Figure 6 shows the SEM morphology images of all layers. It can be seen that layer 1 (Figure 6(1)) shows that the particle is fully porous like light foam. This explains the reason why layer 1 is floating on the surface. The SEM morphology image of layer 2 (Figure 6(2)) shows it is less porous as compared to layer 1. It is observed that layer 2 still contains the unburn palm shell. The SEM morphology image of layer 3 (Figure 6(3)) shows it is less porous as compared to layer 1 and layer 2. Layer 3 might contain empty palm fruit bunch or boughs of palm tree. Lastly, layer 4 (Figure 6(4)) presents a high density element which is the silica. Hence, layer 4 sinks at the bottom of the graduated cylinder.

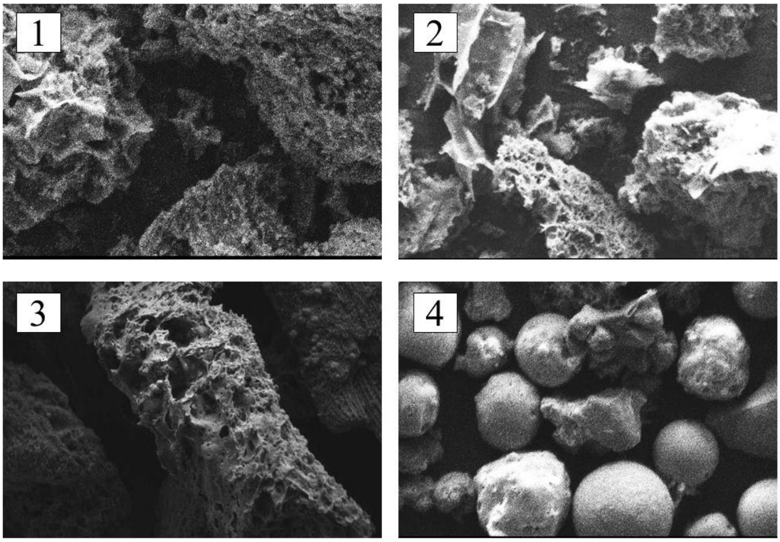

Figure 6: Morphology image of (1) layer 1, (2) layer 2, (3) layer 3 and (4) layer 4

The SE result of each layer is shown in Figure 7. The highest SE is achieved by layer 1 with about -25.76 dB (94.84 % of EMF power is reflected). The compound shows that layer 1 contains 85.89 % of carbon. The second highest SE is achieved by layer 2 with about -14.11 dB (80.29 % of EMF power is reflected). The compound shows that layer 2 contains 81.68 % of carbon. The third highest SE is achieved by layer 3 with about -11.60 dB (73.69 % of EMF power is reflected). The compound shows that layer 3 contains 71.57 % of carbon. The lowest SE is achieved by layer 4 with about -0.05 dB (0.58 % of EMF power is reflected). The compound shows that layer 4 contains only 15.55 % of carbon. Layer 4 shows the lowest EMI SE because silica does not contribute in SE.

The first three layers (layer 1, layer 2 and layer 3) show better SE results because of the high carbon content. With the existence of carbon in POFA, this helps to transform the EM field into heat [11], [19], as carbon has good conductivity [20], [21]. The carbon found in this study is similar to carbon black because its properties are the same. The carbon/carbon black has been used as floor heating elements, electronic equipment related material in various display components, magnetic recording materials [20], and electromagnetic interference (EMI) shielding [21].

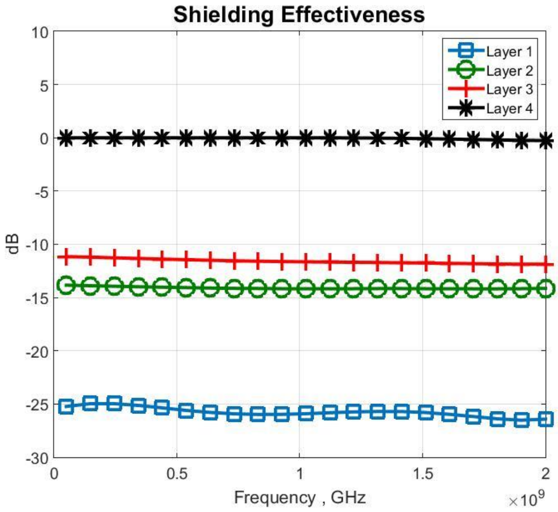

Figure 7: Shielding effectiveness of each layer

In short, Figure 8 shows the percentage of EMI shielding effectiveness of every layer. It is found that SE decreased due to the lower percentage of carbon in each layer. Layer 1 can shield 94.84% of EMI power, layer 2 can shield 80.29% of EMI power, layer 3 can shield 73.69% of EMI power and layer 4 can shield only 0.58% of EMI power.

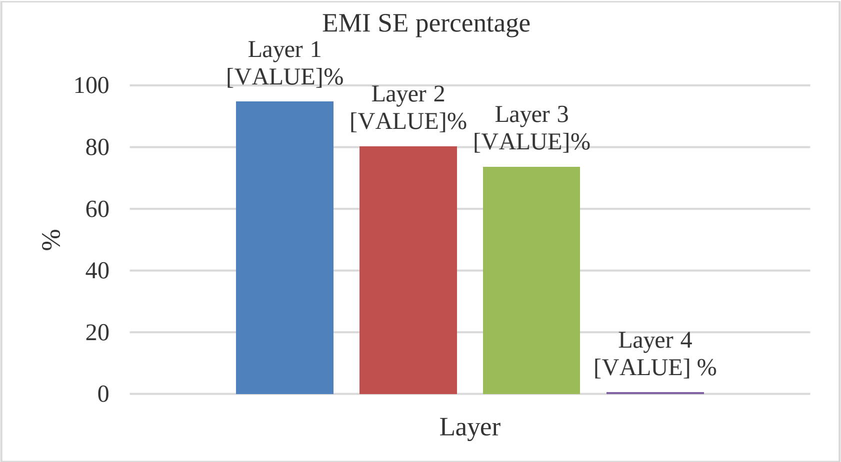

Figure 8: EMI shielding effectiveness percentage

Conclusion

In conclusion, this study has proven that the POFA has the potential to be used as the additive for cement based material to enhance the shielding in building. The element that contributed the most to EMI shielding in POFA is carbon. The precipitation process has been proven to be an important step to split out the unwanted element, and it is shown that not all elements in the POFA are contributing to EMI shielding. The silica (SiO_2) which is poor in EMI shielding should be reduced from the POFA. Layer 1 which can block 94.84% of EMF is strongly recommended for shielding application as this also reduces the pollution problem of the POFA to the environment.

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