Electromagnetic wave absorbing properties of husk silica-based \( \text{SiO}_2/\text{Fe}_3\text{O}_4/\text{UPR} \) composite

Y Yusmaniar\textsuperscript{*}, W Ari A\textsuperscript{2}, D K Hutomo\textsuperscript{1} and E Handoko\textsuperscript{1}

\textsuperscript{1} Faculty of Mathematics and Natural Science, University of State Jakarta, Jakarta, Indonesia
\textsuperscript{2} Centre for Science and Technology of Advanced Materials, National Nuclear Energy Agency, Kawasan Puspiptek Serpong, Tangerang Selatan, Banten, Indonesia

*yusmaniar@unj.ac.id

Abstract. The research aimed to find out the effect of the compound composition of magnetite \( (\text{Fe}_3\text{O}_4) \) and silica \( (\text{SiO}_2) \) derived from natural materials silica are used as \( \text{Fe}_3\text{O}_4/\text{SiO}_2 \) composite within the matrix of the Unsaturated Polyester Resin (UPR) as an electromagnetic wave-absorbing material. The research conducted by extracting magnetite from iron sand using co-precipitation method and silica extracted from rice husk ash calcination method. The experiment was conducted with compositing both of extraction product with a certain ratio in the matrix. The next sample is used as an electromagnetic wave absorbent composite material along with the UPR. Electromagnetic wave absorption tested on 8 GHz-12GHz frequency. The results prove that \( \text{Fe}_3\text{O}_4/\text{SiO}_2/\text{UPR} \) material by the composition of the composite is 1:1 can absorb electromagnetic waves at a frequency of 10 GHz with an absorb range 14.5 dB.

1. Introduction
In the current era of technology, many products are produced that aims to facilitate in conducting activities, especially to communicate and seek information. One of the products produced is a smartphone (smartphone), using this technology then communication and information can be obtained quickly and briefly [1]. This technology is strongly influenced by electromagnetic waves as an intermediary in communicating and sending information. Electromagnetic waves (EM) are transverse waves that can propagate in air and empty environments [2]. Basically electromagnetic waves are very useful for humans in the activity and communicate but in some cases electromagnetic waves are very detrimental to human self and electronic equipment [3].

The disruption caused by the use of electromagnetic waves is called electromagnetic wave interference (EMI). The interruption caused is due to the different frequency used, so the need for protection of an electronic component (electromagnetic shielding). Currently much research is being done to reduce or eliminate interference from electromagnetic wave interference by forming a material that has an absorption to electromagnetic waves [4].

Electromagnetic wave absorber materials can reduce interference by absorbing energy. The absorption occurs due to the magnetic and dielectric components so that the reflected loss of reflected electromagnetic wave energy [5]. The requirement to form an electromagnetic wave absorbing material is to have permittivity (\( \varepsilon \)), permeability (\( \mu \)), and high resistivity [6]. Among the many materials studied, magnetite-based materials is a material that has a great chance to be used as a microwave absorber [7].
This material can absorb EM waves because it has a very wide range of absorption frequencies. Silica is used as an absorber material for electromagnetic waves because it has a good permeability that can have good dielectric loss [8]. In addition, silica is a raw material that is abundant, especially in agrarian countries, such as Indonesia Rice producer that many every year. The rice husk ash is a waste of paddy which utilization is not optimum, with wearing silica is expected to increase the added value to the silica[9][10].

In this research, we will make composites of silica and magnetite which are planted in unsaturated polyester resin polymer (UPR) as matrix. UPR is a relatively inexpensive local polymer product. UPR is a polymer material that is being developed as a matrix for applications of electromagnetic wave absorber materials [11]. The combination of UPR and silica for the application of electromagnetic wave absorber material becomes the main study. This Research beginning with extraction silica from rice husk ash, then iron extraction from iron sand then composite making with various compositions and the end result will be tested the capability of this composite power to electromagnetic wave.

2. Method

2.1. Materials
The tools used in this study were 50 ml, 250 ml, 500 mL glasses; glassware, furnace (thermolyne); FTIR (Fourier Transform Infrared); XRD (X-Rays Diffraction); SEM (Scanning Electron Microscopy); VNA (Vector Network Analyzer). The material used is rice husk; citric acid 5%; iron sand; hydrochloric acid (HCl) 37%; NaOH 6M; AgNO₃; Aquades; Polyester (Yucalac); Catalyst (Yucalac).

2.2. Extraction silica from rice husk
Rice husk ash soaked into 5% citric acid solution at a constant temperature of 50 °C. Then washed with hot water until the pH is neutral. Then heated at 100°C for 30 minutes, then proceed to the calcination stage reaching temperature 800°C until 2 hours. Magnetite is produced from iron sand extraction using coprecipitation method. At first the sand separation was done with magnet, then followed by coprecipitation process. Iron Sand in weigh as much 3 grams were fed into concentrated HCl solution then heated to 80°C and then added 6M NaOH solution Next washed with hot water until the pH is neutral.

The results of silica and magnetite extraction are used as composites in the UPR matrix. In this experiment the maximum composite used is 20% of the total mass, so the variations made are the percentage of the silica and magnetite masses used. The composite composite of magnetite and silica was performed on a ratio 2: 0; 1.5: 0.5; 1: 1; 0.5: 1.5; 0: 2. The composite is mixed with UPR inside the mold. In this process we produce Fe₃O₄/SiO₂/UPR composite material. The observed composite characteristic is the presence of functional groups with Fourier Transform Infra-red (FTIR), composite crystalline characteristics with X-ray Diffractometer (XRD), electromagnetic wave absorption test with Vector Network Analyzer (VNA)[12].

3. Results and discussion
From the results of silica test using EDS in Figure 1. shows two elements of Si and O. The percentage of mass of Si element is 36.22% and the mass of O element is 63.78%.
Figure 1. The result of SEM-EDS from sample SiO$_2$.

The results of the Magnetite test using EDS in Figure 2. show that the composition of the sample is the content of iron (Fe) and oxygen (O) elements with percentage of mass composition 70.03% and 29.97%.

Figure 2. The result of SEM-EDS from sample Fe$_3$O$_4$.

The characterization of silica and magnetite extracted using XRD can be seen in figure 3. From the XRD pattern it is seen that the silica shows the Amorphous pattern. While the result of analysis magnetite obtained diffraction peak at 2θ = 30°, 37°, 48°, 57°, 63° with Miller indexes (002), (113), (115), (004). This result is adjusted to JCDD database and obtained by peak proximity to 96-901-0941 data. The shape of cubic crystals, with phase FCC (Face Center Cubic) is the center of the atoms in the cubic face phase, with a lattice parameter $a = 8.355$ Å, $b = 8.355$ Å, $c = 8.355$ Å, $\alpha = \beta = \gamma = 90^\circ$, and $\rho = 5.272$ gr.cm$^{-3}$. 
From the FTIR spectra of silica shown in Figure 4, At the wave numbers 450, 800, 1071.50, 1727.99, 3620.51 cm$^{-1}$, show a high peak. The absorption band at wavenumber 450 cm$^{-1}$ shows the bending vibration of the Si-O-Si siloxane group. The Si-O and Si-O-Si symmetrical stretching vibrations are indicated by absorption bands at 800 cm$^{-1}$ wavenumbers. The wide absorption band at the wave number 1071.50 cm$^{-1}$ is the Si-O vibration of Si-O-Si, while the wide band on the wave number 3620.51 cm$^{-1}$ is the vibration of the cluster of OH-OH from Si-OH. The absorption bands appearing in wave 1627.99 cm$^{-1}$ are vibrations of bound water molecules[13].

Based on FTIR magnetite test as shown in figure 5, the resulting peak graph that appears at 589 cm$^{-1}$ wavelength is a vibration of the Fe-O bonds present in the magnetite compound. The hydroxy bond (-OH) appears at wavelengths 3600-3000 cm$^{-1}$.
Composite Materials Silica and magnetite result from insulating natural material made composite into UPR with composition 2: 0; 1.5: 0.5; 1: 1; 0.5: 1.5; 0: 2. FTIR analysis for the composite is shown in Figure 6.

Based on the spectrum in figure 6 it can be seen that the absorption band at wavelength 3700-3200 cm\(^{-1}\) shows the vibration of the O-H bond. The absorption bands appearing at the wavelengths 3100-3000 cm\(^{-1}\) are the vibrations of the C-H bonds of the UPR-owned alkyl compounds. Strong absorption bands that appear at wavelength 1780-1710 cm\(^{-1}\) is the vibration of the C = O bond held by UPR. The strong absorption band at 1300-1250 cm\(^{-1}\) is a vibration of the Fe-O-Si bond of the composite. The absorption band is at 1200-1100 cm\(^{-1}\). The absorption band is at 1100-1000 cm\(^{-1}\). The absorbing band at the wavelength of 500-450 cm\(^{-1}\) is a resilient vibration of the Si-O bond.

The test results show that the material created has absorption to electromagnetic waves, based on the results of the higher absorption mean test at 10 GHz wavelength. The resulting graph shows the UPR as the matrix having the absorption at the same wavelength.
Figure 7. The pattern of curve reflection loss composite SiO$_2$/Fe$_3$O$_4$/UPR.

The UPR used as the matrix has the optimum absorption at 10.7 GHz wavelength with an uptake of 13.7 dB. The composition of the Fe$_3$O$_4$ / SiO$_2$ composite shows the effect on the uptake of the material. The composites in the sample were composed of two different compounds, namely magnetite (Fe$_3$O$_4$) and Silica (SiO$_2$) with a composition of 20%.

In a 20% magnetite composite (Fe 20) in the absence of optimum absorption silica occurs at a wavelength of 10.6 GHz with an absorption of 9.25 dB. 15% magnetic composite (Fe15) with 5% silica addition occurred optimum absorption at 10.7 GHz wavelength with absorption of 11.0 dB. 10% magnetic composite (Fe10) with 10% silica addition occurred optimum absorption at 10.7 GHz wavelength with absorption of 14.5 dB. A 5% magnetite composite (Fe5) with 15% silica addition was generated uptake at a wavelength of 10.7 GHz with an absorption of 12.2 dB. A silica composite with a composition of 20% (FeO) has an optimum absorption at 10.7 GHz wavelength with an absorption of 11.7 dB. The results on the basis of composite compositions have different absorptive strengths[14][15].

Based on the test using VNA concluded that the presence of Fe$_3$O$_4$ / SiO$_2$ composite in UPR matrix with composite composition ratio 1: 1 yielded optimum uptake at 10 GHz wavelength with absorption of 14.5 dB.

4. Conclusion
This research has succeeded in making Fe$_3$O$_4$ / SiO$_2$ / UPR composite with ratio of Fe$_3$O$_4$ and SiO$_2$ is 2: 0; 1.5: 0.5; 1: 1; 0.5: 1.5; 0: 2. While the UPR is fixed. The presence of Fe$_3$O$_4$ / SiO$_2$ composites affects the uptake changes to electromagnetic waves. The composition of Fe$_3$O$_4$ / SiO$_2$ composites having optimum uptake in composition ratio 1: 1 and Absorption optimum electromagnetic waves occur at a frequency of 10.7 GHz with an absorption of 14.5 dB.

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