New types composite copper (Cu) and activated carbon (C) for electromagnetic wave absorber materials

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Abstract. Carbon copper (CuC) as an electromagnetic wave absorber has been designed by compaction method. The XRD characterization was performed to determine the size of the crystal, FTIR to determine the chemical bond and Vector Network Analyzer was determined the absorption of electromagnetic waves (return loss) and the voltage standing wave ratio (VSWR) at 100 kHz - 8GHz. The XDR data shows the smallest crystal size value of ± 2θ = 74.20° with spectrum had recorded in the wavelength range at 4000 cm⁻¹ to 500 cm⁻¹ that indicated the bond type of absorber. Characterization of VNA shows maximum RL absorption of -25.05 dB at frequency 5.26 GHz with a thickness of absorber on 3 mm. The RL value had influenced by the concentration of activated carbon (AC) and the temperature of the heating process. Spectrum RL at 5 GHz - 6 GHz frequency has an excellent RL absorption frequency and the best value of VSWR at 1.13. This experiment shows activating carbon CuC is a good material to designed absorber which has VSWR approximating value at 1 that indicates the input power transmitted almost entirely into the air and only a small part reflected.

1. Introduction
The quality of electromagnetic devices is developing quickly that working on gigahertz (GHz) [1]. Electrical and electronic industries increases is a cause of operational damage to electronic instruments [2]. This causes the occurrence of electromagnetic wave interference called pollution. An electromagnetic interference (EMI) uses to shield electronics and communication device from pollution electronic [3]. The shield must be able to absorb and reflect EM pollution. The properties of EMI attract attention many researchers to develop material absorber that effectively to reduce electromagnetic pollution.

Since 2008 for the first time, the absorber based material has been studied [4]. In the last decade, carbon materials have been interesting material as an absorbent EM [1] because it has the ability to absorb and reflect electromagnetic radiation. Carbon-based substances are nano-capsules [5], carbon nanotubes [6, 7], carbon-bers [8], and carbon foams [9,10]. According to research that has been studied about absorber of EMI, a good shielding material must absorb electromagnetic interference which has effectively shielded at 30 dBs with 99.9% attenuation of EMI radiation [11, 12]. Based on the description above, so in this research we uses CuC based compaction method as material absorber.
2. Experimental

2.1. Materials
Powder Copper (Cu) obtained from CV. Intraco with purity ≥99.7%, M = 63.55 g / mol, grain size <63 μm, smoothness level> 230 mesh. Activated carbon (AC) supplied from local company PT. Indonesia Indo Abadi Light with diameter size <10 μm, purity> 95%, surface area> 240m / g. PVA (Polyvinyl Alcohol) 100% obtained from LIPI.

2.2. Sample preparation
Temperature-treated of Cu (600°C and 800°C) mixed with activated carbon (10% and 20% from 5 gram mass of each sample). Copper mixed with AC by using Retsch MM 400 (Mixing) for 30 minutes at 10 Hz Frequency to homogeneous the sample.

2.3. Compaction Process
Compacting sample starting with the sample (Cu mixed AC) added 2 ml Polyvinyl Alcohol (PVA) with a 4.5% concentration of each sample as adhesive. After that, the sample stirred by a magnetic stirrer and molded into a pellet in the sample mold (each sample was printed on 2 types with a thickness of 1.5 mm and 3 mm)

By using hydraulic comparator the sample that set in the mold got pressed with 1 Pa for 10 minutes. The compaction processed to produce a solid sample. Then the sample heated on temperature 800°C for 5 hours to remove a water contents on the sample.

2.4. Characterization
XRD used for determining the crystallite size and FTIR spectroscopy use for determining the chemical bonding. Vector Network Analyzer (VNA) with frequency range 1 GHz to 8 GHz is used for reflection loss (RL) to determine the absorption frequency of the electromagnetic waves.

3. Results and Discussion

3.1. Characterization of XRD

Figure 1. XRD Spectra (a) Cu, (b) 10% AC 600°C, (c) 20% AC 600°C, (d) 10% AC 800°C, (e) 20% AC 800°C
Characterization with XRD can be seen in figure 1. The crystal orientations that appear for pure Cu are (111), (200) and (202). Figure 1 shows a peak shifted from the pure Cu positions $2\theta$. Figure 1 (a) peaks characterization occurs to $43.36^\circ, 50.52^\circ$ and $74.58^\circ$. Figure 1 (b) peaks characterization occurs to $45.68^\circ, 50.90^\circ$ and $74.58^\circ$. Figure 1 (c) peaks characterization occurs to $45.34^\circ, 50.50^\circ$ and $74.16^\circ$. Figure 1 (d) peaks characterization occurs to $43.24^\circ, 50.44^\circ$ and $74.10^\circ$. Figure 1 (e) peaks characterization occurs to $43.32^\circ, 50.44^\circ$ and $74.10^\circ$.

XRD spectra to determine a crystal size of a range of angles $2\theta$ at 300 to 800 can use the Scherrer equation.

$$D = \frac{0.9 \lambda}{B \cos \theta_B}$$

where D is the size of the crystal (nm), $\lambda$ is the wavelength of X-Ray (nm), B is FWHM (Full Width at Half Maximum) and $\theta_B$ is the angle of diffraction.

| Temperature ($^\circ$C) | Sample | $2\theta$ | hkl | Crystal Size (nm) | Average Kristal (nm) |
|-------------------------|--------|-----------|-----|------------------|---------------------|
|                         | 10% AC | 43.36     | 111 | 19.74            |                     |
|                         |        | 50.52     | 200 | 16.75            | 17.72              |
|                         |        | 74.20     | 202 | 16.67            |                     |
|                         | 20% AC | 45.34     | 111 | 21.94            |                     |
|                         |        | 50.50     | 200 | 20.70            | 21.55              |
|                         |        | 74.16     | 202 | 21.99            |                     |
| 600                     | 10% AC | 43.24     | 111 | 22.10            |                     |
|                         |        | 50.38     | 200 | 19.07            | 20.23              |
|                         |        | 74.04     | 202 | 19.53            |                     |
|                         | 20% AC | 43.32     | 111 | 39.46            |                     |
|                         |        | 50.44     | 200 | 38.36            | 40.92              |
|                         |        | 74.10     | 202 | 44.94            |                     |

Based on the table 1 can be seen that the effect of temperature changed and AC concentration on crystal size. In this study, there is a change of crystal size as temperature increases and the addition of AC to Copper (Cu). Can be seen in table 1. For Cu 10% AC at a temperature of 600°C crystal size 17.72 nm, at temperature of 800°C crystal size of 20.23 nm. For Cu 20% AC at a temperature of 600°C crystal size of 21.55 nm and at a temperature of 800°C crystal size of 40.92 nm. The changing crystal size shows in figure 3.

The changed occur because the AC role to trap the copper (Cu) into the AC. The more the number of ACs in the sample the more number of traps that is formed, this causes the number of Cu trapped at the hole. Thus the large size of crystals is formed.

Based on table 2. It appears that the purity of Cu decreases to the AC concentration increases and the temperature rise. This cause the possibility of forming a new bond after doping and temperature changes. At a temperature of 600°C Cu purity to 67.2% and 62.1% while in temperature at 800°C Cu purity to 53.7% and 66.1%. Temperature changes may form new oxide bonds, thus affecting the purity of Cu.
Figure 2. The effect of temperature changed to crystal size at 10% AC and 20% AC

| Temperature (°C) | Sample       | Unsure | Purity (%) |
|-----------------|--------------|--------|------------|
|                 | Cu           | Cu [13]| 99         |
| RT              | Cu 10% AC    | Cu [14]| 67.2       |
|                 | CuO [15]     | 18.8   |
|                 | CuO₂ [16]    | 13.9   |
| 600             | Cu 20% AC    | Cu [17]| 62.1       |
|                 | CuO [18]     | 19.6   |
|                 | CuO₂ [15]    | 18.3   |
| 800             | Cu 10% AC    | Cu [18]| 53.7       |
|                 | CuO [16]     | 24.9   |
|                 | CuO₂ [15]    | 21.4   |
|                 | Cu 20% AC    | Cu [19]| 66.1       |
|                 | CuO [14]     | 17.8   |
|                 | CuO₂ [15]    | 16.2   |
3.2. Absorber Characterization with VNA (Vector Network Analyzer)
Analysis of VSWR (Voltage Standing Wave Ratio) and SWR (Standing Wave Ratio)

The result of the characterization by VNA is Standing Wave Ratio (SWR). Figure 3 (a), (c) and figure 4. (a), (c) shows the SWR value as a result of characterization and. The most expected conditions for the best VSWR values are 1 and the largest VSWR that tolerated is 2 [20]. Previously converted SWR values to VSWR, because it has a relationship. Based on the VSWR conversion value in figure 3. (b), (d) and figure 4. (b), (d). It can observe the working frequency of VSWR in the range 5 GHz - 6 GHz has a good value.

| Temperature (°C) | Sample  | Thickness (mm) | VSWR  | Frequency (GHz) |
|------------------|---------|----------------|-------|-----------------|
| 600              | 10% AC  | 1.5            | 1.1419| 5.75            |
|                  |         | 3              | 1.1426| 5.29            |
|                  | 20% AC  | 1.5            | 1.5886| 5.75            |
|                  |         | 3              | 1.1392| 5.75            |
| 800              | 10% AC  | 1.5            | 1.1545| 5.75            |
|                  |         | 3              | 1.1397| 5.78            |
|                  | 20% AC  | 1.5            | 1.1409| 5.78            |
|                  |         | 3              | 1.1440| 5.82            |

Based on table 3, the excellent VSWR absorber values were obtained on CuC samples, 20% AC at 600°C with a thickness of 3 mm. Based on this the absorber is capable, either emitting or receiving electromagnetic waves into the air and from the free air.

3.3. Analysis of RL (Reflection Loss)
Absorption ability has been measured using VNA for the 2 GHz - 8 GHz frequency range as shown in figure 5. The reflection loss value (RL) affected by the concentration of activated carbon and the temperature for each absorber. Figure 5 shows the VNA spectrum of the reflection loss (RL) for each sample and shows that in the 5 GHz - 6 GHz frequency range is an excellent RL.

Absorption ability shows the difference in each temperature and AC concentration in each sample for each thickness. The result of RL successively is 1.5 mm and 3 mm thickness. For figure 5 (a) -23.65 dB and -25.05 dB, figure 5 (b) -19.12 dB and -23.29 dB, figure 5 (c) 23.38 dB and -21.64 dB and for figure 5. (d) -24.72 dB and -23.05 dB.
Figure 5. Absorption of RL on absorber material (a) 10% AC at 600°C, (b) 10% AC at 800°C, (c) 20% AC at 600°C, (d) 20% AC at 800°C

Table 4. Electromagnetic Growing Electrophoresis from Carbon Copper (CuC)

| Temperature (°C) | Konsentrasi (%) |Thickness (mm) | Frequency (GHz) | Reflektion Loss (dB) |
|------------------|-----------------|---------------|-----------------|----------------------|
| 600              | 10              | 1.5           | 5.75            | -23.65               |
|                  | 3               | 5.26          | -25.05          |
| 20               | 1.5             | 5.82          | -23.38          |
|                  | 3               | 5.40          | -21.64          |
| 800              | 10              | 1.5           | 5.75            | -19.12               |
|                  | 3               | 5.29          | -23.29          |
| 20               | 1.5             | 5.78          | -24.72          |
|                  | 3               | 5.71          | -23.05          |

The table 4 shows that the highest absorption capacity of RL is -25.05 dB for a 10% AC sample of a thickness of 3 mm at a frequency of 5.26 GHz. These results indicate that the absorption of RL is better than the results obtained by Shuai Xie, et al. [21] and Qiang , R. et al [22] is -23.00 dB and -22.6 dB. The results from table 3 show that with the 5 GHz - 6 GHz frequency range is a good absorption of electromagnetic waves.

4. Conclusions
Copper carbon (CuC) has been made with a simple method by using the combination of composition and temperature variations. This sample is capable of showing a maximum RL absorption of -25.05 dB at 5.26 GHz with a thickness of 3 mm. It can be used for coatings to protect the EM.

Acknowledgments
This work was supported by the PBK (Penelitian Berbasis Komputer) Grant: 1625/UN4.21/PL.00.00/2018 funded by the Indonesia Government (Ristek-Dikti) and KLN Grant: 3083/UN4.21/PL.00.00/2018 funded by Hasanuddin University, Makassar Indonesia.
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