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The Effect of Sodium Hydroxide (NaOH) Activator on Bamboo-Activated Carbon on the Shielding Effectiveness of Electromagnetic Wave Interference (SE-EMI)

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ABSTRACT

This study describes NaOH's role in synthesising bamboo activated carbon (BAC) for the effectiveness of electromagnetic wave radiation shielding (SE-EMI). The process begins with BAC 325 mesh sieving and continues with NaOH activation. The dissolved NaOH will become ions, activating the dipole force and causing a dipole moment. As the reaction between carbon and NaOH increases, the ions diffuse and damage the carbon wall. It opens new pores or widens existing pores and increases surface area. The results of this study show the influence of NaOH activators on bamboo-activated carbon, namely the formation of a microporous structure with an increase in specific surface area of 152.6320 m2 / g. High porosity and wide material surface affect the conductivity value of the material, thereby increasing the absorption of electromagnetic wave radiation indicated by the SE value of 13.2 dB. Adding NaOH has no significant effect on aromatic functional groups in BAC. The aromatic group will cause a magnetic moment on the surface of BAC, affecting the absorption of electromagnetic wave radiation. EMI radiation shielding materials prepared using simple treatment can produce materials with high porosity, large surface area and considerable effectiveness value. This could be an essential reference for subsequent EMI radiation shielding research.

1.Introduction

Electromagnetic waves can cause electromagnetic interference (EMI). The presence of electromagnetic interference (EMI) radiation causes serious problems, namely the deterioration ofthe precision performance of nearby devices and endangers human health [1,2]. Therefore, research on absorbing or protecting materials from electromagnetic wave interference (EMI) is a concern and an exciting discussion to solve the electromagnetic radiation problem.

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Recently, carbon-based materials have been widely used as the absorbing material's base material. Some of the advantages of carbon-based materials are strong EM wave attenuation ability, large surface area, lightweight [3] and low density [4], and porous [5].

Carbon sources can be obtained from organic matter/biomass from nature. Some organic/biomass materials from nature that have been used as carbon materials include water hyacinth [6], soybean pulp [7], grapes [8], walnut shells [9], eggshell membranes [10], rice husks [11], bamboo [12].The carbon material used in this study is bamboo because it consists of 87-97% carbon porous structure, and has high adsorption ability [13] as in Figure 1. The absorption performance of absorbing materials is influenced by the material's pore structure/low density [14] and wide surface [15].

The structure and surface area of activated carbon can be affected by several things, including time and temperature treatment. Different temperature treatments, e.g. 700 °C, 800 °C and 900 °C, have an impact on increasing surface area, total pore volume and pore diameter [6,16].

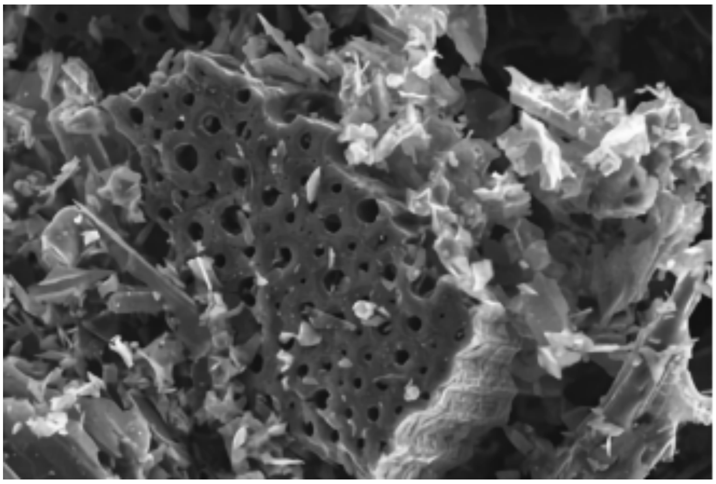


Fig. 1. The pore structure of bamboo activated carbon [17]

Carbon activation through chemical activation is one method to increase surface area and pore volume. This activation involves various chemicals such as NaOH, KOH, ZnCl2, and H3PO4 [18]. Researchers have yet to use NaOH activators in bamboo-activated carbon to improve the absorbency performance of absorbing material. According to Syahruddin *et al.,* [19], the NaOH activator for activated carbon nanoparticles applied in the hydro degumming process of vegetable oil has advantages, including creating new pores, producing microporous carbon, widening existing pores, and increasing specific surface area. In addition, compared to KOH activators, activated carbon activation with NaOH has the advantages of lower dose (weight measurement), cheaper, environmentally friendly, and less corrosive [20]. Using NaOH will effectively regulate the microstructure of the activated carbon material produced. It is one of the feasible strategies to prepare low-cost, reliable, high-performance microwave absorbing materials.

2. Methodology

This study used activated carbon from bamboo and NaOH as activators and epoxy resins. Bamboo-activated carbon is purchased from CV. Subur Kimia Jaya, Bandung, West Java. Epoxy resin purchased from CV. MakmurSejati.

The procedure for preparing bamboo-activated carbon synthesis with NaOH treatment is shown in Figure 2. The first process is the sieving of 325 mesh activated carbon. The following process is the soaking of activated carbon. This method is often referred to as the maceration method. An 8 g of bamboo activated carbon measuring 325 mesh was added in a solution of 3 moles of NaOH and then stirred until evenly distributed.

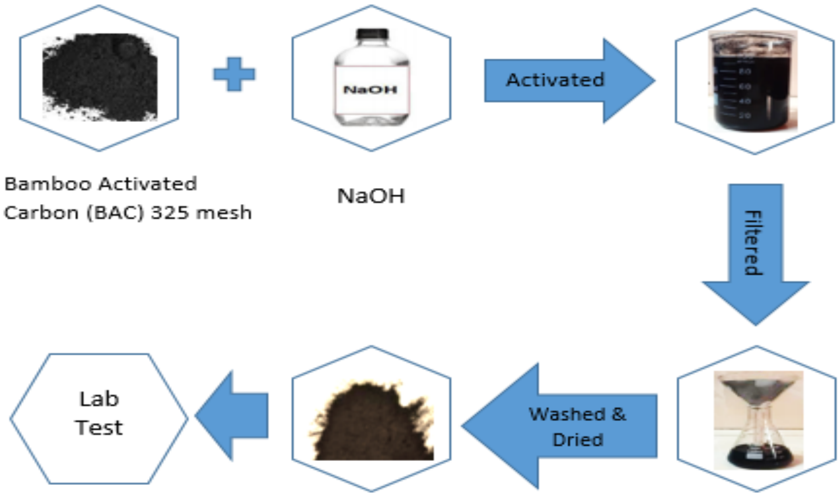


Fig. 2. Bamboo-activated carbon activation material preparation procedure

Furthermore, the solution can stand for 12 hours with the maceration method. The precipitate that occurs in the container is taken and disposed. The remaining activated carbon that floats in the NaOH solution is small particles, which are then filtered using Whatman filter paper. Then, the activated carbon filter results are washed with aquades and dried. The drying process is done directly in the sun for 2-3 days. The last stage is drying using an oven at 105°C for 3 hours.

NaOH treatment will impact BAC materials, creating nano-cracks and causing polar charges on the surface of carbon. In addition, it also causes positive surface charges or new pores and incorporates existing pores due to pore wall damage [19]. The The reaction of NaOH treatment in creating microporous carbon is as follows:

$$4NaOH + C \rightarrow 4Na + CO_2 + 2H_2O$$
$$4NaOH + 2CO_2 \rightarrow 2Na_2CO_3 + 2H_2O$$

Next, the fabrication of electromagnetic wave shielding material. The composition of this shielding material is 50% bamboo-activated carbon and 50% epoxy resin. A total of 5g by weight of bamboo activated carbon is prepared to be mixed with epoxy resin. Both materials are put into a magnetic hotplate stirrer and stirred evenly for 2 hours without heating. The dough mixture of bamboo-activated carbon solution and epoxy resin is then molded using the casting method custom mold dimensions = 22.86 x 10.16 x 3 mm. Pouring the solution is carefully carried out until it reaches a material thickness of ± 3 mm. Let the solution dry and harden, and then release the material from the mold. Next is the material characterization test.

BAC's surface structure, morphology, and elemental composition were observed with scanning electron microscopy/SEM-EDX (Inspect-S50, FEI). SEM (Scanning Electron Microscopy) can study the morphological structure of a material's surface and cross-section. At the same time, EDX (Energy Dispersive X-ray Spectroscopy) can determine the elemental content and distribution of the material through its surface structure.

The surface area and adsorption-desorption isotherms of N2 from BAC were measured using the BET (Brunauer Emmett Teller) (Micromeritics TriStar II Version 3.01). The working mechanism of this tool is the adsorption of N2 gas on the surface of BAC at various pressures and constant temperatures (isotherms).

Functional groups in BAC were analyzed by IRSpirite-T, Fourier Transform Infrared Spectroscopy/FTIR (Shimadzu, Japan).

Furthermore, the effectiveness of electromagnetic wave shielding was analyzed using a Spectrum Analyzer (Advantest, TR4133A) and microwave Trainer (Feedback, 56-200). The electromagnetic wave shielding mechanism consists of 3 parts: reflection, absorption, and multiple reflection, as shown in Figure 3.

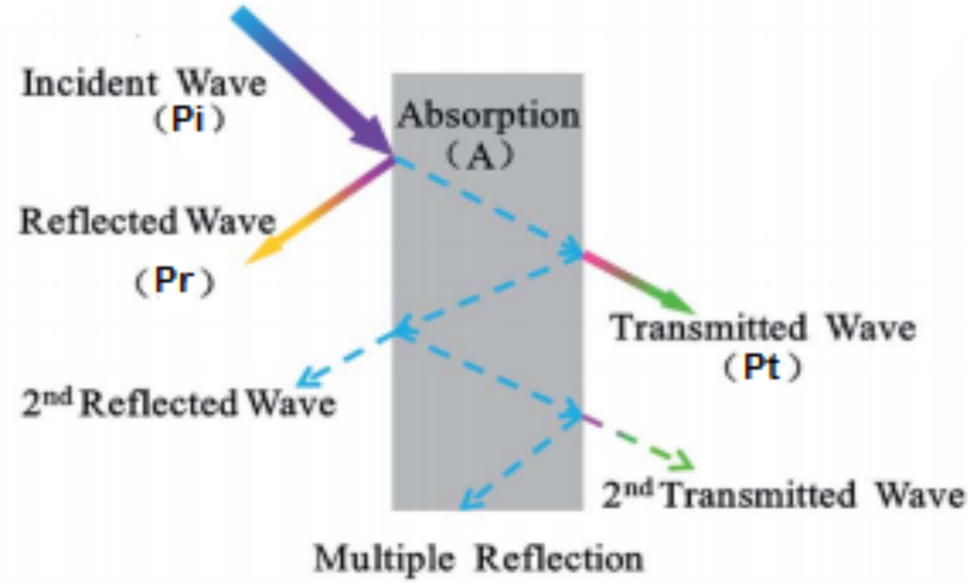


Fig. 3. Mechanism of shielding effectiveness of electromagnetic wave radiation [1]

The effectiveness of the EMI shield is defined as the ratio of the radiation power of the incoming electromagnetic wave (P_i) to the transmitted radiation power (P_t) according to the following equation [6]:

$$SE = 10\ log\left(\frac{P_i}{P_t}\right) \tag{1}$$

where P_i is the incident wave power, and P_t is the wave power transmitted or passing through the shield.

One critical parameter affecting the effectiveness of electromagnetic interference protective materials is the absorption coefficient, denoted by the symbol α. The value of the absorption coefficient corresponds to the following equation [21]:

$$\alpha = \frac{2{,}3026\ \log\left(\frac{1}{T}\right)}{d} \tag{2}$$

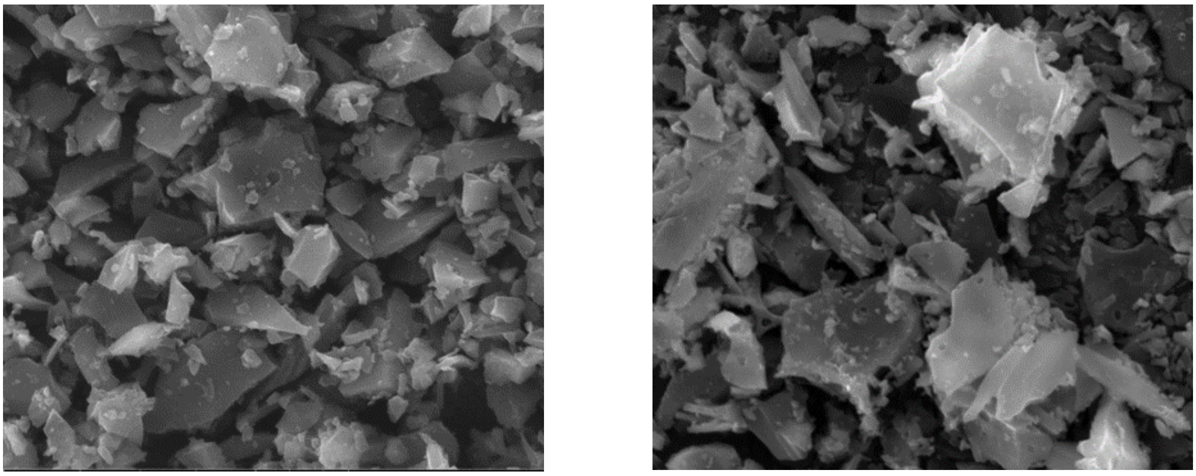
$$\alpha = \frac{2{,}3026 * \mathrm{A}}{d} \tag{3}$$

where α is the absorption coefficient, T is the transmitted wave, A is the absorbance, and d is the thickness of the material.

3. Results

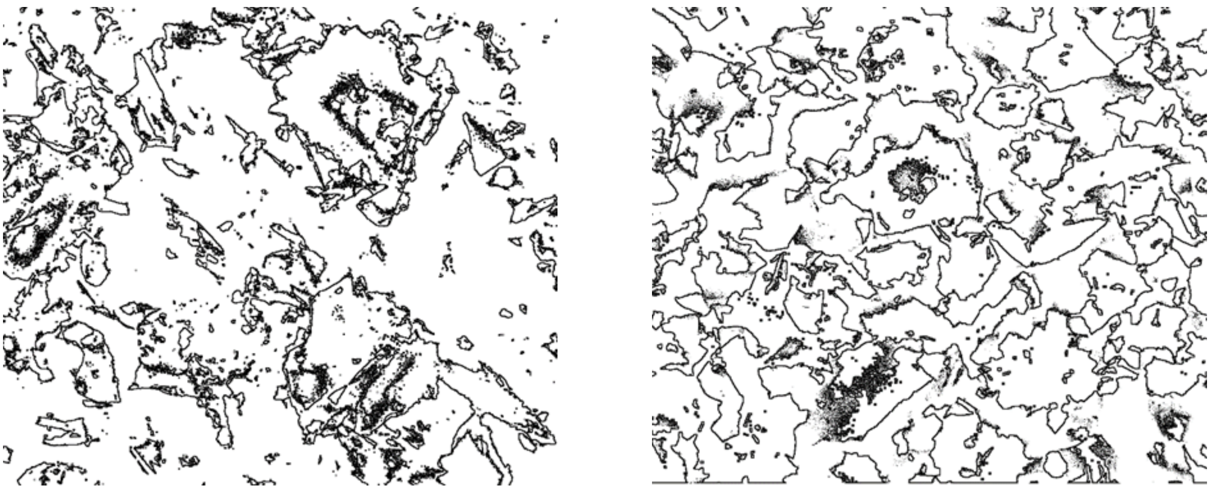
3.1 SEM (Scanning Electron Microscope) Test

A comparison of the morphological characteristics of the surface of BAC without NaOH activator and BAC using NaOH activator at 5000x magnification is shown in Figure 4. There are porous features in every part of BAC with various shapes. The pore distribution areas in both treatments are shown in the pore map in Figure 5. It can be seen that BAC has a scattered pore structure of various sizes. The pore map was created using ImageJ software to analyze pore distribution, count, and average pore size. The percentage of the number of pores on the BAC pore map using NaOH activator is around 75%-80%, while on the pore map without NaOH, it is around 60%-70%. At the edges also appear to be cut or deformed pores. The presence of defective areas in BAC has a positive impact when this material is used as a microwave-absorbing material. The BAC defective region will allow a significant charge to be trapped in it, causing microwaves entering the area to experience multiple reflections, which ultimately weakens the microwave energy. In addition, BAC that is multiporous or high porosity causes surface polarization losses. Of course, this will significantly support the increase in material dielectric losses as a reference for good absorbent performance.



(a) (b)

Fig.4. Surface SEM test BAC magnification 5000x (a) BAC (b) BAC+NaOH



(a) (b)

Fig.5. Pore map (a) BAC (b) BAC+NaOH

3.2 EDX (Energy Dispersive X-Ray) Test

After a morphological structure test using SEM to determine the composition and distribution of elements from BAC and BAC + NaOH materials, the EDX test was carried out. Based on Figure 6, it can be known that the composition of BAC elements consists of 88.5% C, 9.4% O, 0.2% Mg, 0.2% Al, 0.8% Si, 0.3% S, 0.4% K, and 0.3% Fe. At the same time, the composition of BAC + NaOH elements is known from Figure 7, which consists of 89.2% C, 9.1% O, 0.1%, 0.2% Na, 0.1% Mg, 0.2% Al, 0.5% Si, and 0.6% Fe. The highest C content indicates that the BAC has a structure resembling hexagonal graphite, and aromatic rings dominate the most functional groups. At the same time, the high O content affects the polarity and character of the texture.

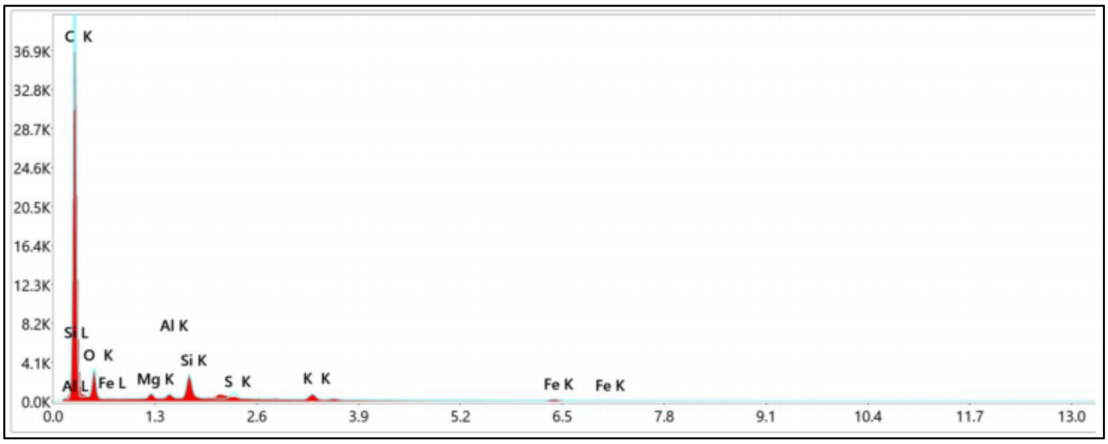


Fig.6. EDX BAC composition test

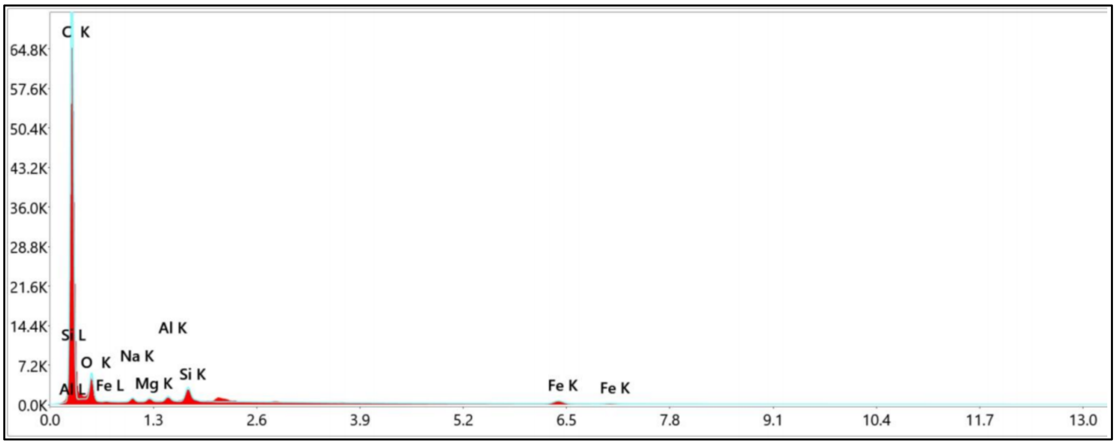


Fig.7. EDX BAC+NaOH composition test

3.3 Texture Characteristics

Once the morphology and composition of BAC and BAC+NaOH are known, the next step is to conduct surface area testing. Figure 8 shows the isotherm curve of N2 BAC adsorption/desorption before and after adding NaOH. According to IUPAC, the shape of this curve is similar to the type 1 fissorption isotherm known as Langmuir. This type of isotherm also shows a high affinity between absorbate and absorbent, and the sample material consists of micropores [20,22]. The adsorption quantity of BAC+NaOH is higher than that of BAC. The addition of NaOH affects the amount of adsorption quantity of the material. The total surface area of BET BAC is 131.0654 m2/g, while BAC+NaOH is 152.6320 m2/g.

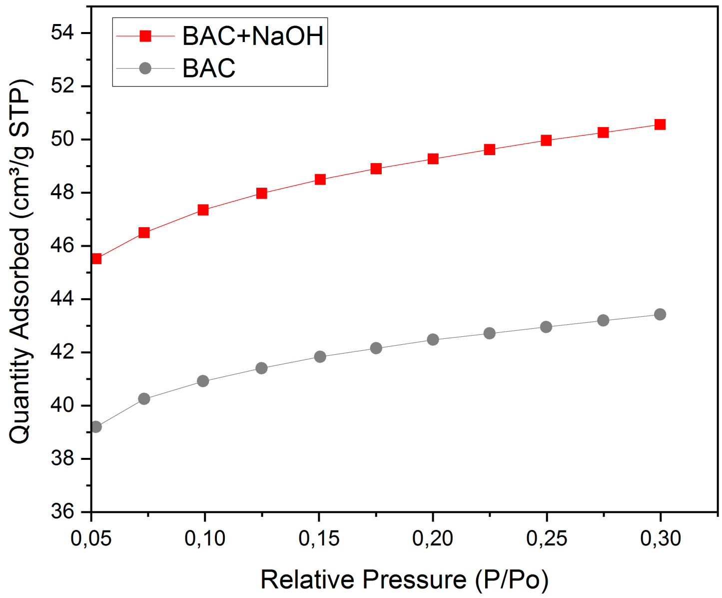


Fig. 8. N2 adsorption-desorption isotherms

An increase in surface area in BAC+NaOH will affect the polarization losses of the interface. It is one of the important factors for improving the absorption performance of materials, So this material is very suitable if recommended as a shielding base material from electromagnetic wave interference.

3.4 Characteristic of functional groups

The FTIR (Fourier transform infrared) test results are shown in Figure 9, which shows that both samples of BAC and BAC+NaOH materials have the same functional group range. There was no significant change with adding NaOH to the change in functional groups. The peak of the functional group formed is in the spectrum of 1500-1600 with the functional group C=C, which is the aromatic ring. In addition, the peak range of the 1000-1300 spectrum of 1032 and 1038 corresponds to the C-Car functional group in the aromatic ring band [23]. The Magnetic fields can be generated by electrons delocalized in the aromatic ring group, so that BAC can induce magnetic moments that affect the absorption rate of electromagnetic wave radiation.

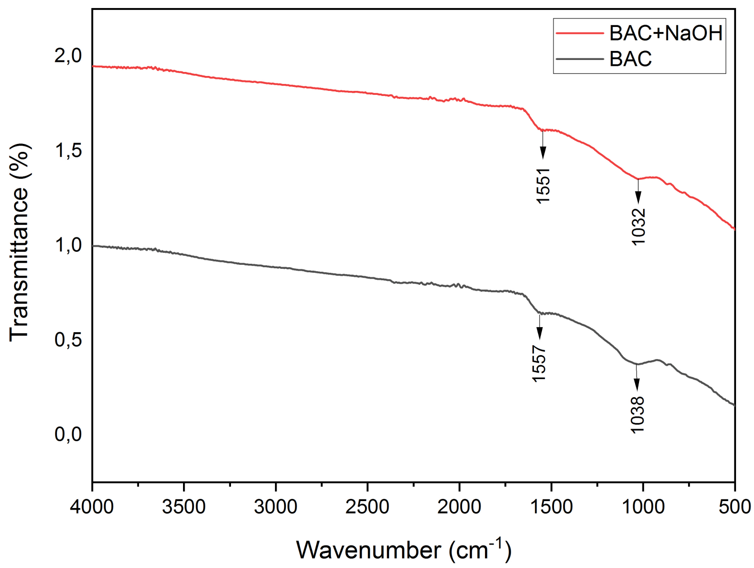


Fig. 9. FTIR test results

3.5 Shield Effectiveness Test (SE) and Absorption Coefficient Calculation

After the material characterization test is carried out, the next stage is to test the effectiveness of the electromagnetic wave shielding (SE), as shown in Figure 10 and then calculate the absorption coefficient.

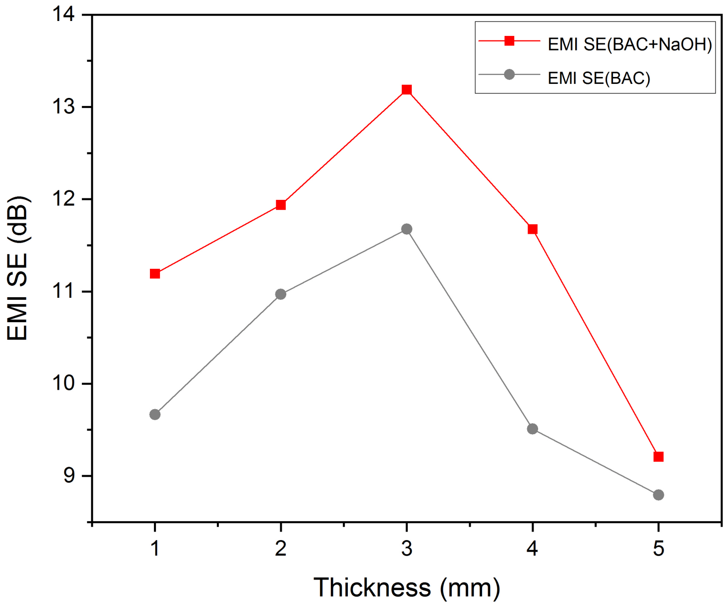


Fig.10. Comparison of EMI SE values on BAC+NaOH and BAC**.**

Based on the test results of shielding effectiveness (SE) value against electromagnetic wave interference (EMI), the highest SE value was obtained on BAC + NaOH material with a thickness of 3 mm of 13.2 dB and the lowest SE value with a thickness of 5 mm of 9.2 dB. Meanwhile, the BAC material obtained the highest SE value of 11.7 dB with a thickness of 3 mm and the lowest SE value with a thickness of 8.8 mm. SE values of 13.2 dB and 11.7 dB are included in the range of 10 – 30 dB, indicating that shielding effectiveness is acceptable [24].

Figure 10 shows that SE values ranging from 1 mm – 3 mm tend to rise and, after exceeding 3 mm, tend to fall. This can happen because the saturation of the shielding material is that the material has reached the limit of absorbing or reflecting electromagnetic wave radiation. In addition, it can also be caused by decreased conductivity of the material, resulting in waves that have exceeded 3 mm reflected so that the shield's effectiveness decreases. Based on the previous literature, a decrease in the material's electrical conductivity can cause a decrease in the shield's effectiveness [25].

Then, the value of the absorption coefficient (α) can be calculated based on equation 3, and the value of α is 0.7.

4. Conclusions

Adding NaOH activators affects the texture characteristics of microwave-absorbing base materials. This is proven by the formation of new pores or mergers of old pores that have been damaged, and there is an increase in the surface area of BAC. The addition of NaOH does not affect changes in existing functional groups. The aromatic functional group causes the appearance of a magnetic moment that affects the absorption rate of electromagnetic wave radiation, which is indicated by the shielding / protective (SE) effectiveness value of 13.2 dB and the absorption coefficient value of 0.7. The SE value belongs to the category of medium shield efficiency or describes acceptable effectiveness.

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