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Innovative Pyramidal Microwave Absorber: Eco-friendly Utilization of Biomass and Silicon Carbide for Enhanced EMI Reduction

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ABSTRACT

This study presents an innovative approach to developing pyramidal microwave absorbers, addressing environmental concerns associated with conventional polymer materials. The research focuses on integrating silicon carbide, a ceramic material, into the absorber's composition to enhance performance and align with sustainable practices. The absorber is constructed using a blend of cement, water, carbon, aluminum powder, and silicon carbide, showcasing attributes such as heightened fire resistance, super-thermal properties, workability, and environmental friendliness. A comprehensive analysis of the absorber's reflectivity performance is conducted through the NRL free space method. The empirical data culminates in a graph illustrating reflectivity versus frequency, revealing a significant enhancement in absorber performance with the incorporation of 10% silicon carbide, compared to the absence of this compound especially at C-band and X-band. The study also advocates for eco-conscious practices, emphasizing the use of locally sourced biomass materials, particularly in Malaysia's biomass sector. In conclusion, the carbon-ceramic pyramidal microwave absorber emerges as a promising solution for commercial applications, offering efficiency, sustainability, and environmental compatibility in communication technology and electromagnetic interference reduction in anechoic chambers.

Keywords: microwave; absorber; anechoic chamber; biomass; ceramic.

1. INTRODUCTION

An anechoic chamber is a structure that has been covered with an electromagnetic wave-absorbing substance known as an absorber on the surface of a wall, ceiling, or floor so that reflected waves do not interfere with the operation of measuring instruments or devices (Rabelsa et al., 2019). Absorbers are employed in a variety of applications to get rid of unwanted or stray radiation that might impede the functioning of a system (Xie et al., 2020). Due to the widespread and active development of wireless telecommunications technology, which has improved modern lifestyles and made it the most efficient communication platform in terms of data transmission and reception, microwave absorber popularity has rapidly increased in the field of electric communication (Elmahaishi et al., 2022). Commercial pyramidal absorbers are typically made out of polymer materials such as polyurethane, polypropylene, polyethylene, polystyrene, and other polymer materials that are not environmentally friendly and are difficult to dispose of (Basyigit et al., 2023). Due to benefits like cost effectiveness and customizability, as well as the environmental consequences of chemical compounds employed in the manufacturing of these material, the use of various natural materials such as agricultural products and waste has grown significantly (Basyigit et al., 2023). With the growth of the communications industry, the initiative to create better application for microwave absorbers in anechoic chamber needs to be highlighted. Malaysia's biomass sector has achieved notable strides towards a positive carbon balance relative to fossil fuels, as well as towards sustainability and economic growth as a result of the use of locally renewable materials (Osman et al., 2014). Thus, it is suggested to use biomass material as an absorbing material in this study as an effective way to employ waste material.

Table 1. Previous Studies of Microwave Absorbers using Biomass Material

Material	Frequency (GHz)	Shape	Reflectivity (dB)		Ref
			Min	*Max*	
Banana leaves and resin	6-8.5	Pyramidal	-33.9	-43.1	(Mezan et al., 2014)
Carbon saw dusk & cement	1-12	Flat (brick)	-	-29.5	(Narudin et al., 2023)

From Table 1, the reflectivity performance of the pyramidal microwave absorber made of banana leaves and resin was found to be better than the flat microwave absorber made of sawdust and cement. However, microwave absorbers using biomass materials and resin undergo degradation, while cement-based absorbers provide better durability. The use of silicon carbide, a ceramic material, will be the subject of novel studies in this project. Ceramics have excellent mechanical properties, including high hardness, low density, high strength, and excellent wear resistance—even at extremely high temperatures (Bouanga et al., 2011). By modifying the shape from flat to pyramid and adding SiC as RAM, the creation of a carbon-ceramic pyramid microwave absorber has the potential to provide better reflectivity performance.

2. METHODOLOGY

The initial part of this project involved researching microwave absorbers and gathering information on the structure and composition of pyramidal microwave absorbers. This work uses the NRL (Naval Research Laboratory) arch free-space approach to determine the pyramidal microwave absorber's reflectivity performance.

2.1. Development of Pyramidal Microwave Absorber

In this project, the development process shown in Figure 2 is divided into 4 phases; 1) material preparation and proportioning, 2) mixing, 3) molding, 4) drying and curing. Preparing the raw materials was the initial step in the procedure. In this study, cement, carbon, ceramic, water, and aluminium powder are utilised to construct the pyramidal microwave absorber. All of the material will be weighted and proportioned according to the chosen ratio throughout this phase.

Next would be the material mixing procedure with a concrete mixer. To ensure complete blending, the proportional material will be stirred for 5-8 minutes. Subsequently, the mixture will be placed straight into the mould to begin the moulding process. The pyramidal microwave absorber will then be covered with plastic for a minimum of seven days throughout the drying and curing process.

2.2 Measurements

The reflectivity measurements were performed to analyse the characteristics of pyramidal microwave absorbers, using the NRL free space method. The NRL arch is the mainstream technology for testing material reflectivity (Hofmann et al., 2019). The NRL free space method consists of two horn antennas, one acting as a transmitter and the other as a receiver. These two antennas are directed towards the metal plate at an appropriate 0° angle (Kharber et al., 2017). It employs an intuitive methodology in which the reflection of a metal plate with and without absorbers is compared (Hofmann et al., 2019). The comparison of both data provides the absorbers' reflectivity (Kharber et al., 2017).

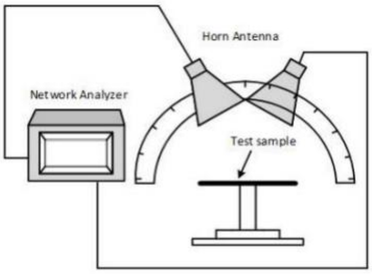

Figure 1. NRL arch free space method (Kharber et al., 2017)

3. RESULTS AND DISCUSSION

Figure 2 displayed reflectivity versus frequency graph of a pyramidal microwave absorber with 0% SiC and 10% SiC. The minimum and maximum data obtained by four different bands are tabulated in Table 2. The maximum value of the absorber indicates its highest level of reflectivity, while the minimum value indicates its lowest level. If the minimum and maximum reflectivity value of a pyramidal microwave absorber is higher, the performance of the pyramidal microwave absorber is better.

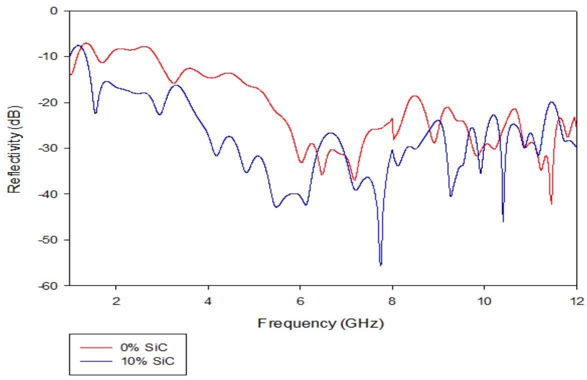

Figure 2. Reflectivity Performance of Pyramidal Microwave Absorber with 0% SiC and 10% SiC

Table 2. Minimum and Maximum Reflectivity Performance

Band	Frequency (GHz)	SiC (%)	Reflectivity (dB)	
			Minimum	Maximum
L-band	1-2	0	-7.1917	-13.9684
		10	-7.5473	-22.4245
S-band	2-4	0	-7.9029	-15.8256
		10	-16.2405	-26.5340
C-band	4-8	0	-13.3559	-37.0251
		10	-26.6215	-55.2752
X-band	8-12	0	-18.4081	-41.9475
		10	-20.2202	-45.8933

From the data shown in Table 2, there is a significant improvement in the performance of the pyramidal microwave absorber with the addition of 10% SiC compared to 0% SiC in all bands. The incorporation of 10% silicon SiC into the microwave absorber significantly enhances reflectivity performance. At L-band and S-band, the minimum reflectivity performance of the pyramidal microwave absorber with 10% SiC could not reach at least -20 dB, and the maximum value could not reach -30 dB, showing unsatisfactory performance. However, the pyramidal microwave absorber with 10% SiC provides good reflectivity performance at the C-band and X-band, where it manages to reach more than -20 dB for minimum reflectance with values of -26.6215 dB and -20.2202 dB, respectively. For the maximum reflectance value, the pyramidal microwave absorber with 10% SiC managed to achieve at least -45 dB at the C-band and X-band, with excellent values of -55.2752 dB and -45.8933 dB. This improvement is attributed to the unique characteristics of silicon carbide, such as heightened fire resistance, super-thermal properties, and overall increased efficiency, making it a valuable addition to the absorber's composition. Overall, it can be concluded that a pyramidal microwave absorber with the addition of 10% SiC performs well at C-band and X-band.

4. CONCLUSION

In conclusion, the developed pyramidal microwave absorbers, leveraging biomass and SiC, showcase enhanced performance in EMI reduction. The addition of SiC proves especially beneficial, leading to superior reflectivity. These absorbers, with commendable fire resistance, thermal properties, and eco-friendliness, hold promise for commercial applications. This study underscores the significance of incorporating sustainable materials in communication technology for advanced electromagnetic compatibility. Further research can explore the broader application of eco-friendly materials in achieving efficient EMI reduction.

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