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RF Magnetic Shielding Effects of an Aggregated Plate Constructed from Carbon Tiles

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The contamination of the environment by electromagnetic pollution has increased with the increased employment of electronic instrumentation. The use of electromagnetic shielding in the radio frequency (RF) region has, therefore, increased in order to improve environmental conditions. It is known that the value of RF magnetic shielding degree SD_H for a superimposed plate, constructed from carbon and ferrite plates, does not equal the sum of the individual SD_H values of the carbon and ferrite plates. In the present paper, an aggregated carbon plate (46 mm squere) is formed, constructed from carbon tiles (9.2 mm length, 9.2 mm width, 2 mm thickness). A compound plate was constructed by the superimposing a ferrite plate over the aggregated carbon plate. It was found that the values of SD_H for the compound plate equaled the sum of the SD_H values of the aggregated carbon and ferrite plates. Experimental results revealed several characteristics of the compound plate, including for example, the dependence of SD_H on radio frequency, and the dependence of SD_H on the value of RF output power.
Key words: RF magnetic shielding, carbon plate, aggregated carbon plate, aggregated ferrite plate, compound plate

1. INTRODUCTION

Recently, with the rapid development in the field of information technology, there has been an increased need for electromagnetic shielding in the radio frequency (RF) region [1-8]. Electromagnetic shielding plates are used to reduce the influence of environmental electromagnetic waves, and to protect the environment from the leakage of generated electromagnetic waves [9-12]. As one of the basic areas of research for the improvement of the electromagnetic environment by the use of natural resources, the present research examines the RF magnetic shielding characteristics (SD_H) of an aggregated carbon plate, constructed from carbon tiles, in the frequency region of 1 MHz to 3 GHz. Furthermore, the present authors have improved the RF magnetic shielding effects of the aggregated carbon plate by the superposition of a ferrite plate over the aggregated carbon plate, termed the compound plate. The individual characteristics and those of the combined aggregated carbon and ferrite plates are also examined.

Experimental results reveal several characteristics of the aggregated carbon and the compound plates, including the RF magnetic shielding degrees SD_H as a function of radio frequency f, and the non-dependence of SD_H on the value of RF output power.

2. EXPERIMENTAL PROCEDURE

2.1 Fabrication of the aggregated carbon plate

Carbon tiles (9.2 mm square, 2 mm thickness) were cut from a commercial carbon plate (Toyo-Tanso, IG-110, 50 mm square, 2 mm thickness), by a diamond saw at low cutting speeds to inhibit thermal effects. The tiles were glued together using a commercial polymeric resin (Nichiban, AR-R30, Araldite), and then dried naturally at room temperature (300 K) for approximately 12 hours. The aggregated carbon plate (46 mm length, 46 mm width, 2 mm thickness) such as illustrated in Fig. 1, was then polished using sandpaper (Sankyo, No. 800).

For the shake of comparison, an aggregated ferrite plate (TDK, IB-015, 46 mm square, 6 mm thickness) was also constructed in a similar manner as the fabrication of the aggregated carbon plate.

As one of the basic research for demonstrating the RF magnetic shielding effect of aggregated carbon plate, the present authors have made two different compound plates. That is, the first compound plate was constructed by the superposition of a ferrite plate on an aggregated carbon plate, and also, the second compound plate was formed by using aggregated ferrite and aggregated carbon plates.

2.2 Definition of the RF magnetic shielding effect

The experimental system for measuring RF magnetic shielding effects is arranged for this study was shown in Ref. [13]. The RF output, in the frequency region from 1 MHz to 3 GHz, of the tracking generator (HP, 8594E)

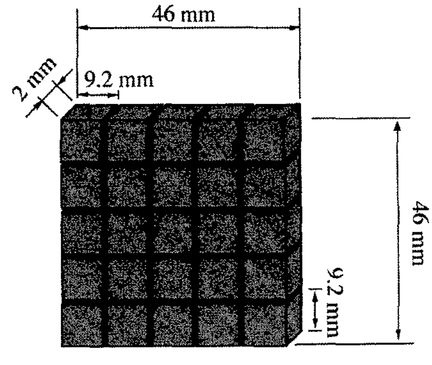

Fig. 1. Schematic illustration of a typical aggregated carbon plate.

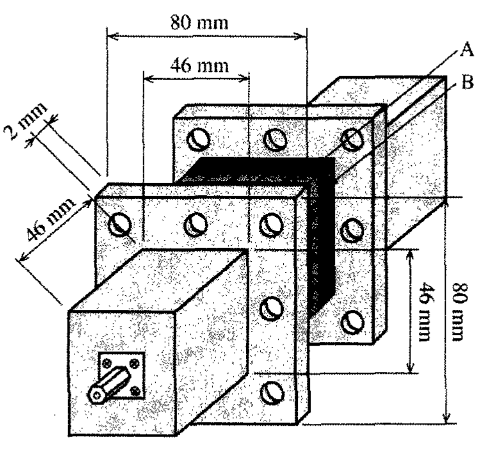

Fig. 2. Schematic diagram of the two metal cells used to measure the RF magnetic shielding effects. In this figure, A and B represent aggregated carbon and ferrite plates, respectively.

which incorporates a spectrum analyzer, is amplified by 50 dB by the use of a broadband amplifier (Kalmus, 210LC-CE). The amplified output is then guided to a transmitting antenna in a metal cell. The signal from the receiving antenna is amplified by 38 dB by a preamplifier (Sonoma, 317), and then guided to the inputterminal of the spectrum analyzer. The results from spectrum analyzer are then transferred through a GPIB cable to a laptop computer. Figure 2 illustrates a schematic diagram of the two metal cells. In the present research, the input power of the transmitting antenna and the distance between both cells are held constant (17 mm).

The RF magnetic shielding degree SD_H can be specified in terms of the reduction in the magnetic field strength, which was reported in Ref. [14]. In general, the value of RF magnetic shielding degree SD_H is defined as follows:

$$SD_H = 10\log_{10}(P_{H0}/P_{H1}). \qquad (1)$$

Here, P_{H0} and P_{H1} are the strength of the incident magnetic field power of the transmitting wave, and magnetic field power as it emerges from the shielding plate, respectively.

3. RESULTS AND DISCUSSION

3.1 RF magnetic shielding effects of the carbon and aggregated carbon plates

Figure 3 shows the RF magnetic shielding degree SD_H for the carbon and aggregated carbon plates as functions of frequency f over the radio frequency region from 1 MHz to 3 GHz, under constant RF output power P_H of 30 dBm of the transmitting antenna, at room temperature (300 K). In this figure, the curves formed by the solid and open squares represent the individual shielding characteristics for the carbon and aggregated carbon plates, respectively. It can be seen that the characteristics for both the carbon and aggregated carbon plates increase with the increase in frequency f from 1 MHz to 3 GHz.

3.2 RF magnetic shielding effects of the ferrite and aggregated ferrite plates

The plotted points in Fig. 4 denote the values of SD_H as functions of frequency f for the individual ferrite and aggregated ferrite plates, under constant RF output

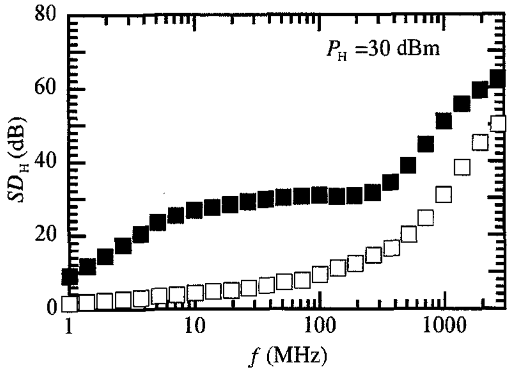

Fig. 3. The characteristics of SD_H for the carbon and aggregated carbon plates as a function of frequency f, under a constant RF output power P_H of 30 dBm of the transmitting antenna. The solid and open squares represent the results for the carbon and aggregated carbon plates, respectively.

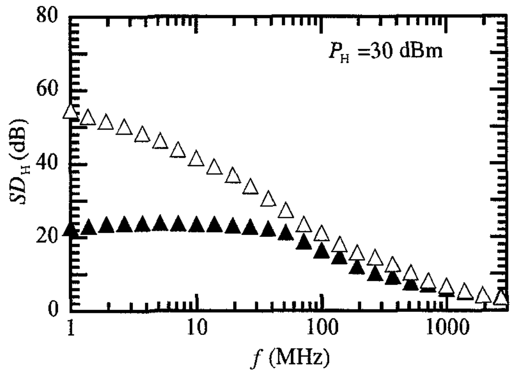

Fig. 4. Typical characteristics of the RF magnetic shielding degree SD_H as a function of frequency f, under a constant RF magnetic field power P_H of 30 dBm of the transmitting antenna. The open and solid triangles represent the results for the ferrite and aggregated ferrite plates, respectively.

power P_H of 30 dBm, at room temperature. In this figure, the curves formed by the open and solid triangles represent the ferrite and aggregated ferrite plates, respectively. As can be seen in this figure, the values of SD_H for the ferrite plate decrease with the increase in frequency f. It can also be seen that the values of SD_H for the aggregated ferrite plate are clearly independent of the value of f in the range from 1 MHz to 50 MHz, while they decrease with increasing f in the region from 50 MHz to 3 GHz.

3.3 RF magnetic shielding effect for the superposition of the ferrite plate over the carbon plate

Figure 5 denotes the RF magnetic shielding degree SD_H of the superimposed plate, that is the superposition of the ferrite plate over the carbon plate, as a function of

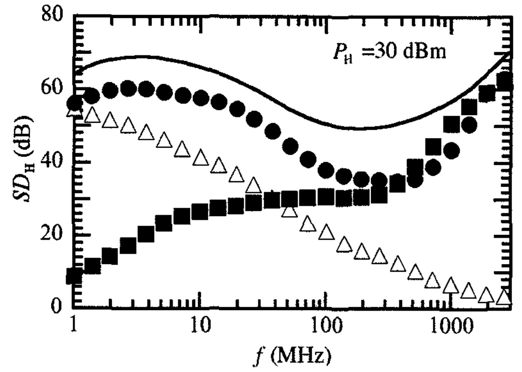

Fig. 5. The RF magnetic shielding degree SD_H of the superimposed plate (ferrite plate over the carbon plate, solid circles), the ferrite plate (open triangles) and the carbon plate (solid squares), as a function of frequency f, under a constant RF output power P_H of 30 dBm of the transmitting antenna. The solid line represents the sum of the values of SD_H for the individual carbon and ferrite plates.

frequency f, under constant RF output power P_H of 30 dBm of the transmitting antenna, at room temperature. In this figure, the curves formed by the solid circles, solid squares, and open triangles represent the shielding characteristics for the superimposed, carbon, and ferrite plates, respectively. Furthermore, the solid line represents the sum of the individual values of SD_H for the carbon and ferrite plates. It is found that the values of SD_H for the superimposed plate do not agree well with the sum of the individual SD_H values for the plates.

3.4 RF magnetic shielding effect for the compound plate

Figure 6 displays the RF magnetic shielding effects for the first compound plate constructed from the aggregated carbon and ferrite plates, as a function of frequency f, under constant RF output power P_H of 30 dBm of the transmitting antenna. In this figure, the curves formed by solid circles, open squares, and open triangles represent the compound plate, the aggregated

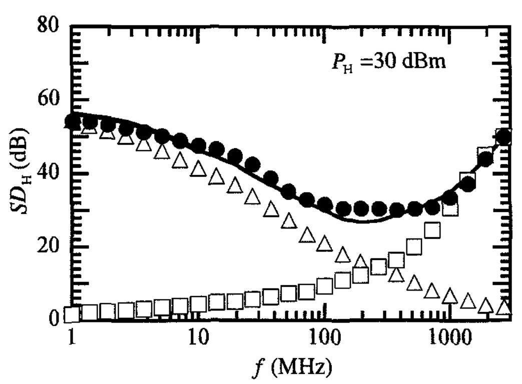

Fig. 6. The RF magnetic shielding degree SD_H for the first compound plate (solid circle), aggregated carbon plate (open squares), and ferrite plate (open triangles), as a function of frequency f, under a constant RF output power P_H of 30 dBm of the transmitting antenna. The solid line represents the sum of the values of SD_H for the aggregated carbon plate and the ferrite plate.

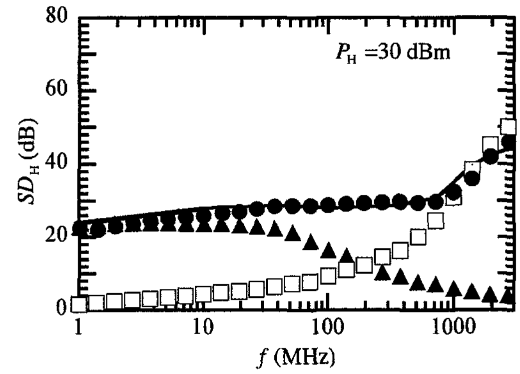

Fig. 7. Typical characteristics of RF magnetic shielding degree for the second compound plate (solid circles) constructed from aggregated carbon (open squares) and aggregated ferrite (solid triangles) plates, as functions of frequency f, under a constant RF output power P_H of 30 dBm of the transmitting antenna. The solid line represents the sum of the values of SD_H for the aggregated carbon and aggregated ferrite plates.

carbon plate, and the ferrite plate, respectively. Furthermore, the solid line represents the sum of the values of SD_H for the aggregated carbon plate and ferrite plate. It is found that the measured SD_H values for the compound plate agree well with the sum of the individual values. That is, the value of SD_H for the compound plate can be shown as the addition of two values for aggregated carbon plate and the ferrite plate. These results represent important fundamental criteria in the design of practical RF shielding systems.

Figure 7 shows the RF magnetic shielding effects for the second compound plate constructed from aggregated carbon and aggregated ferrite plates, as a function of frequency f, at room temperature, under a constant RF output power P_H of 30 dBm of the transmitting antenna. In this figure, the curves formed by solid circles, open squares, and solid triangles represent the compound, aggregated carbon, and aggregated ferrite plates, respectively. Furthermore, the solid line represents the sum of the individual values of SD_H for the aggregated

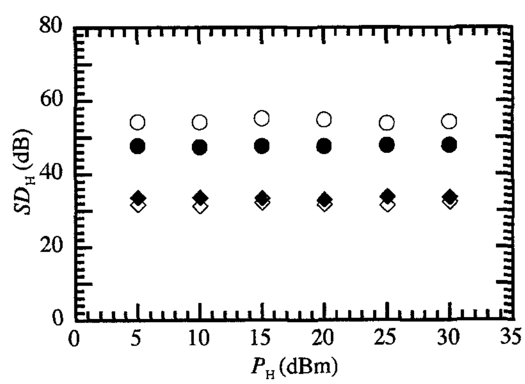

Fig. 8. Typical characteristics of SD_H for the first compound plate constructed from aggregated carbon and ferrite plates, as a function of RF output power P_H of the transmitting antenna. The open circles, solid circles, open diamonds, and solid diamonds represent the results for 1 MHz, 10 MHz, 100 MHz, and 1 GHz, respectively.

carbon and aggregated ferrite plates. It is found that the characteristics of SD_H for superposition of the aggregated ferrite plate over the aggregated carbon plate remain constant over a wide frequency region from 1 MHz to 1 GHz. In addition, it is found that the measured values for the second compound plate agree well with the sum of the individual aggregated plates. That is, the value of SD_H for the second compound plate can be represented by the sum of the two values for aggregated carbon and aggregated ferrite plates.

The characteristics of SD_H for the values of RF output power P_H of the transmitting antenna for the first compound plate constructed from aggregated carbon and ferrite plates are displayed in Fig. 8. The open circles, solid circles, open diamonds, and solid diamonds represent the results for 1 MHz, 10 MHz, 100 MHz, and 1 GHz, at a temperature of 300 K, respectively. It can be seen that the characteristics of SD_H for the compound plate display no dependence on the values of P_H in the region from 5 dBm to 30 dBm. Similar results for the carbon, ferrite, aggregated carbon, aggregated ferrite, and superimposed plates were also obtained (not shown). It can be concluded that the values of SD_H remain constant and are not dependent on the values of P_H over this power region.

4. CONCLUSIONS AND SUMMARY

The contamination of the environment by electromagnetic pollution has been increasing with the employment of more electronic instruments. The use of effective electromagnetic shielding has, therefore, been required to improve the electromagnetic environment. As one of the basic areas of research for the improvement of the electromagnetic environment, with use of natural resources, the present research has demonstrated the RF magnetic shielding characteristics SD_H of an aggregated carbon plate constructed from carbon tiles in the frequency region of 1 MHz to 3 GHz. In addition, an attempt was made to improve the characteristics of the RF magnetic shielding degree SD_H for the aggregated carbon plate by the superposition of a ferrite plate over the aggregated plate. The results for the present research can be summarized as follows:

(1) The values of SD_H for the superimposed plate, that is, the superposition of a ferrite plate over a carbon plate, did not agree with the sum of the individual values of SD_H for the carbon and ferrite plates in the frequency region from 1 MHz to 3 GHz, which was shown in Fig. 5. However, the superimposed plate displayed good characteristics for RF magnetic shielding.

(2) The values of SD_H for the first compound plate, that is, the superposition of the ferrite plate over the aggregated carbon plate, were shown to agree well with the sum of the individual values for the aggregated carbon plate and ferrite plate in the frequency region from 1 MHz to 3 GHz, which was shown in Fig. 6. These results represent important fundamental criteria in the design of practical RF shielding systems.

(3) The characteristics of SD_H for the second compound plate, that is, the superposition of the aggregated ferrite plate over the aggregated carbon plate, were shown to remain constant over the wide frequency region from 1 MHz to 1 GHz. The values of SD_H for the second compound plate were also shown to agree with the sum of the two values for the aggregated carbon and aggregated ferrite plates, which was shown in Fig. 7.

(4) The characteristics of SD_H for the first compound plate displayed no evidence of dependence on the values of P_H in the region from 5 dBm to 30 dBm, as shown in Fig. 8. Similar results for the carbon, ferrite, aggregated carbon, aggregated ferrite, and superimposed plates were obtained.

During the present research, the results indicated that the RF magnetic shielding characteristics for the compound plate were found to agree well with the sum of the two values for the aggregated carbon and ferrite plates. As a result, the present authors are now investigating the physical meaning behind the fact that the values of SD_H for compound plates equal the sum of the individual SD_H values for the aggregated carbon and ferrite plates, or the aggregated carbon and aggregated ferrite plates.

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