

ELECTROMAGNETIC SHIELDING PROPERTIES OF Al_2O_3 -SiC COMPOSITES

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Abstract

A work has been carried out on the electromagnetic shielding (EMS) properties of Al_2O_3 -SiC composites. The commercial alumina having 5 μm particle size was used as a matrix material and SiC was used as second phase in three different size fractions (40-80, 80-125 and 125-250 μm) and different content (30% and 40% by weight) to form ceramic particle reinforced ceramic matrix composite. The powders were shaped in hexagonal form (diagonal length of 25 mm). They were pressed uniaxially and sintered in N_2 atmosphere before measuring their electromagnetic shielding effectiveness (EMSE). EMSE was investigated using Agilent E5071C Network Analyzer in the frequency range of 12.4–18 GHz (Ku band). The thickness of all samples tested was kept constant. It was found that the shielding effectiveness of SiC-reinforced Al_2O_3 composite materials compared to pure alumina have a reasonable level. Increasing particle size of SiC has increased the shielding effectiveness of composite structure.

Key words: Composite materials, alumina, SiC, electromagnetic shielding (EMS), shielding effectiveness (SE)

INTRODUCTION

Ceramics and Ceramic Matrix Ceramic Composites

Ceramic materials are widely used in many applications due to their various chemical and physical properties as a monophase or as composites. Such as aluminum oxide (alumina, Al_2O_3), which is a well-known technological ceramic and used in variety of applications from bearings to refractory industries due to its high hardness and high melting point, respectively. Monolithic alumina or alumina with a little amount of additive for sintering aid used mainly refractory industry or electrical insulation applications for room and as well as for high temperature applications. However, using high amount of additives, like silicon carbide (SiC) into alumina, making ceramic matrix ceramic reinforced composites (CMC), is a common way to increase its mechanical properties, like wear resistance and toughness. Many of those CMC structures, a very fine grain size of secondary phases like whiskers (Sugiyama, 2007) and nanoparticles (Wu, 2009) were used and it was aimed to have a full density of the composites using pressurized sintering (Vincenzo, 2009). Alumina ceramics are good for electrical insulating, however it is not common to have them for electromagnetic interference (EMI) shielding applications.

Electromagnetic Shielding

Blocking or preventing electromagnetic field by using materials, which can be conductive or non-conductive is called electromagnetic shielding effectiveness (EMSE). Indeed, the metals and their

composites (with polymers) are favored for electromagnetic interference (EMI) shielding, but considering their high weight and low corrosion reliability and also for low stability at high temperatures, the new materials in this application areas needed to be investigated. Metals have been found to be effective filler used in polymer matrix composites (PMC) in order to have EMI shielding. Wu (2010) for example found that nickel powder of 0.3 to 0.5 μm size fraction (with 13 vol.%) in PES improved the EMI shielding of composites incredibly. Although EMI shielding of PMC materials are so effective, they are limited to be used in temperatures above their glass transition temperatures which are so low compared ceramics. Some other materials like carbon (Chung, 2001) were also used for effective EMI shielding. It is explicit that Al_2O_3 -based composites have been widely studied because of their outstanding properties such as good chemical stability, oxidation resistance, good wear resistance and low electrical conductivity. Because of their low conductivity behavior and when needed to be used at very high temperatures, ceramic materials can be used for EMI shielding and electromagnetic shielding (EMS) applications. In the present study, the dielectric properties and EMS properties of Al_2O_3 – SiC composites were investigated at Ku-band frequencies (in the range of 12.4–18 GHz frequency).

Shi et al (2008) added Ti_3SiC_2 particles into alumina and sintered using hot-pressing, measured EMI of the composite at the frequency range of 12.4 – 18 GHz (Ku band). They observed that the EMI shielding increased with an increase in addition of the Ti_3SiC_2 particles. There is more research needed to be carried out in this field using ceramics and ceramic matrix composites. In this respect present study concentrates on the EMS of alumina reinforced with coarse grains of SiC at Ku-band frequencies in the range of 12.4-18 GHz.

EXPERIMENTAL WORK

Raw powders used in the present work were commercially available Al_2O_3 and SiC with the grain size of 5 μm (for alumina) and with a mean particle size of 40-80, 80-125, 125-250 μm for SiC, respectively. SiC powders were mixed either 30 or 40 wt.% in a planetary mill for 1 h to obtain a homogeneous mixing. Al_2O_3 /SiC mixed powders were shaped in hexagonal form (in the size of diagonal length of 25 mm) by pressing uniaxially at 400 MPa pressure (Figure 1). It is not obligate to shape in this gauge, however, it is important that the samples must fully cover the gap of the flange having rectangle gap of 7.80×15.80 mm². The composite samples were sintered at 1650 °C in N₂ atmosphere. Surface of the samples touching the instrument were polished after they sintered. The thickness of all samples tested was kept constant (2mm).

Electromagnetic shielding effectiveness of a material is determined by measuring transmitted power (P_T) and incident power (P_I). The EMSE is defined logarithmic ratio of these two parameters and it measured unit in decibels as given in (1).

$$EMSE = 10 \log \left(\frac{P_T}{P_I} \right) \quad (1)$$

Electromagnetic shielding (EMS) of test materials was measured on an Agilent E5071C ENA Series Network Analyzer in the frequency range of 12.4–18 GHz (Ku band). The codes for the samples which used in this study are given in Table 1 according to composition and grain size of SiC.



Figure 1. Hexagonal form of the compacts of Al_2O_3 / SiC composites for EMS testing

Table 1. The codes of the samples in respect to the composition of Al_2O_3 and SiC

Composition (wt. %)		Grain Size of SiC (μm)	Code of Samples
Al_2O_3	SiC		
100	0	-	Al_2O_3
70	30	40-80	30S_40-80
70	30	80-125	30S_80-125
70	30	125-250	30S_125-250
60	40	40-80	40S_40-80
60	40	80-125	40S_80-125
60	40	125-250	40S_125-250

The microstructural examinations were carried out using optical microscopy. Shimadzu XRD-6000 X-ray diffraction analyzer attached with an IXRF 5000 EDX instrument was used to analyze the crystalline phases. Densities of the sintered samples were calculated following the geometrical calculation using precision balance (sensitive to measure 0.0001g) and micrometer 1/20.

RESULTS AND DISCUSSION

After successfully mixing of Al_2O_3 and SiC particles, they were compacted and sintered. After sintering, bulk specimens were subjected to testing of electromagnetic shielding effectiveness (EMSE). Before EMS testing, flanges without using samples were fixed and test run carried out in order to have the background data, which were subtracted from the tests of the results obtained with Al_2O_3 / SiC composite samples. The results of EMSE of the samples tested were given in Figure 2-4. It was observed that the addition of SiC has increased the shielding effectiveness (SE) of the composites regardless of the particle size of SiC used compared to pure alumina used (Figure 2-4 & Figure 5-7).

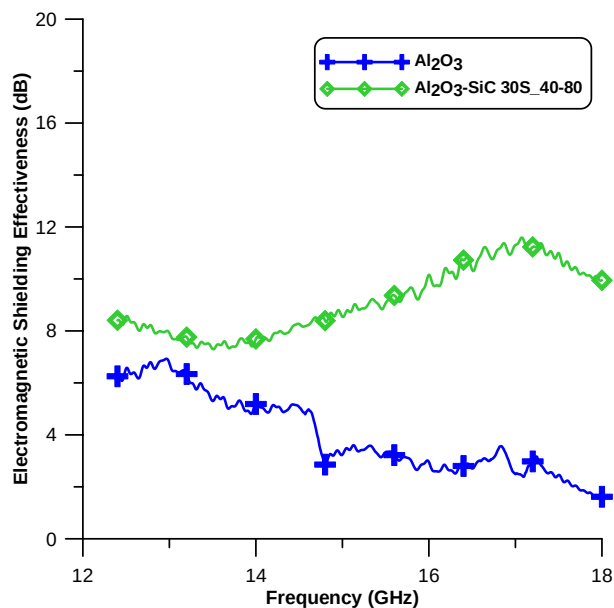


Figure 2. EMSE of Al₂O₃ / SiC composites with using 30wt.% 40-80µm SiC content

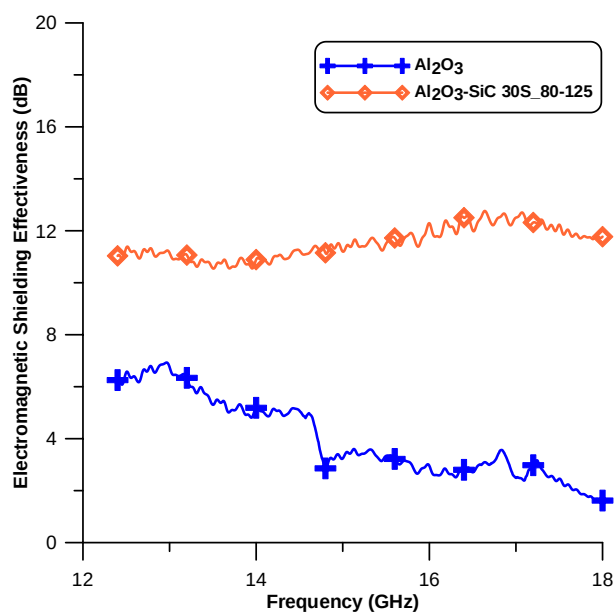


Figure 3. EMSE of Al₂O₃ / SiC composites with using 30wt.% 80-125µm SiC content

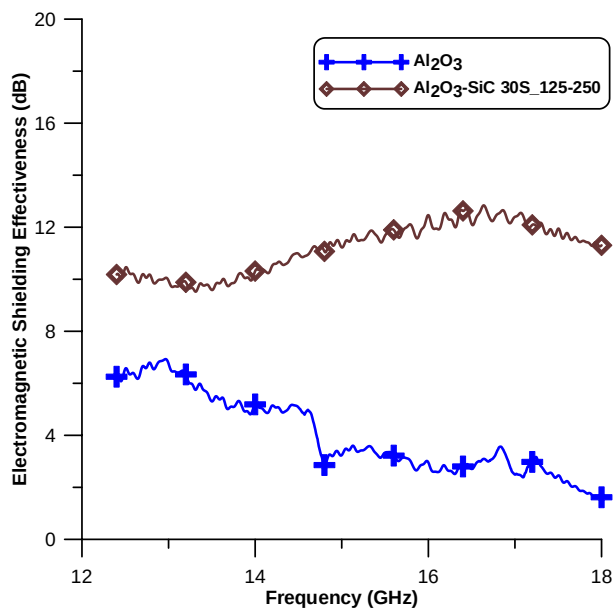


Figure 4. EMSE of Al₂O₃ / SiC composites with using 30wt.% 125-250µm SiC content

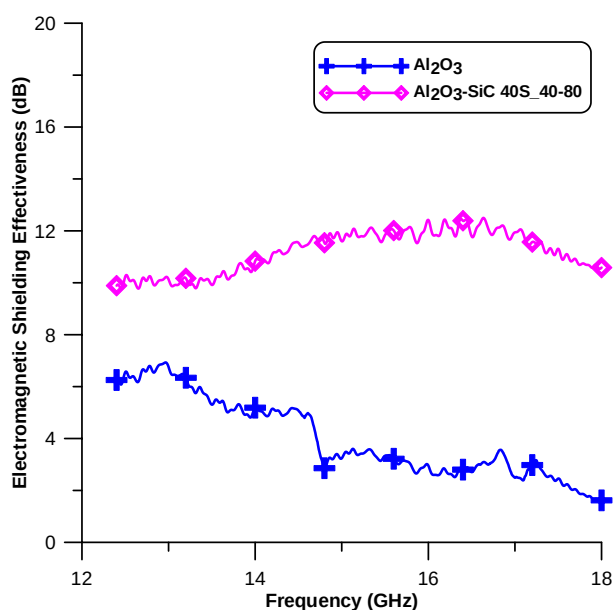


Figure 5. EMSE of Al₂O₃ / SiC composites with using 40wt.% 40-80µm SiC content

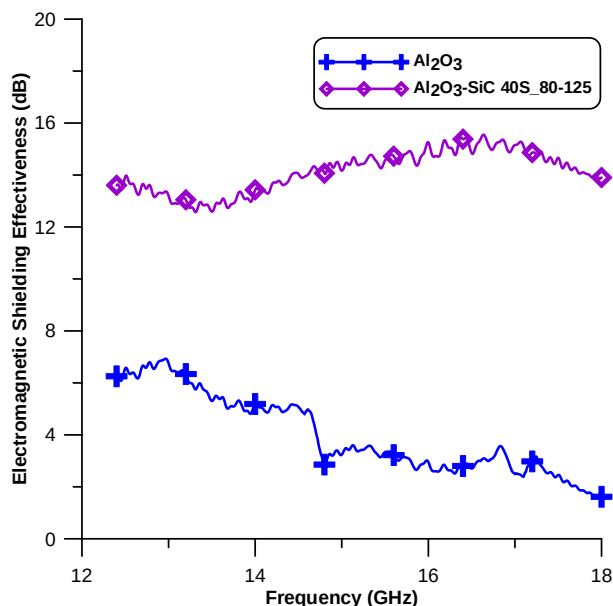


Figure 6. EMSE of Al₂O₃ / SiC composites with using 40wt.% 80-125µm SiC content

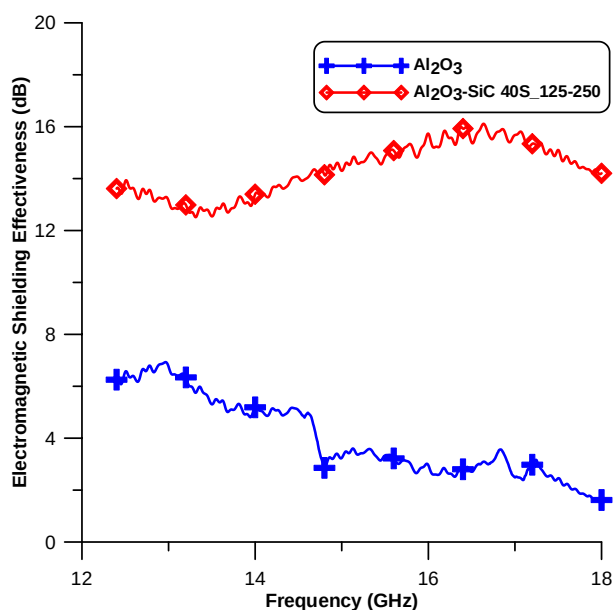


Figure 7. EMSE of Al₂O₃ / SiC composites with using 40wt.% 125-250µm SiC content

However, it tends to be coarser grain (SiC powder) size fractions of the samples have slightly higher shielding effectiveness than the fine grain (powder) size samples. The effect of increasing shielding effectiveness with an increase in SiC grain size might be due to rough patterning of SiC phases (Figure 8-c & 8-f).

The effect of SiC content on the EMSE of the composite is given in Figure 5-7. The results of shielding effectiveness (SE) for Al₂O₃ – SiC composites having 40wt.% SiC content show a noticeable

increase in EMSE compared to samples given in Figure 2-4. The maximum shielding effectiveness observed for a given compositions were in the range of 10 dB and 17 dB when SiC content increased from 30 wt. % (Figure 2-4) to 40 wt. % (Figure 5-8). Highest value was obtained with sample of 40S_125-250.

Sample coded 40S_125-250 has coarsest grains of SiC as shown in Figure 8 (f). It is possible to claim that, the higher particle size to have the higher the shielding effectiveness of the composites that used in this work. As it can be seen in Figure 8, reinforcing SiC particles having cornered shapes are dispersed uniformly in alumina matrix. Grey regions imply alumina matrix and dark grey and cornered particles imply the reinforcement component of SiC. Pure alumina, however, shows a little shielding effectiveness behavior especially at high frequencies above 14 GHz (Figure 2-4 & Figure 5-7).

There is a relationship between electrical conductivity of material and shielding effectiveness. Therefore, the addition of SiC into alumina increased the material's electrical conductivity. SiC electrically conductive compared to alumina, which is a good electrical insulator. Consequently, addition of SiC reducing the composites' electrical resistance and hence increasing EMSE effect of the composite system.

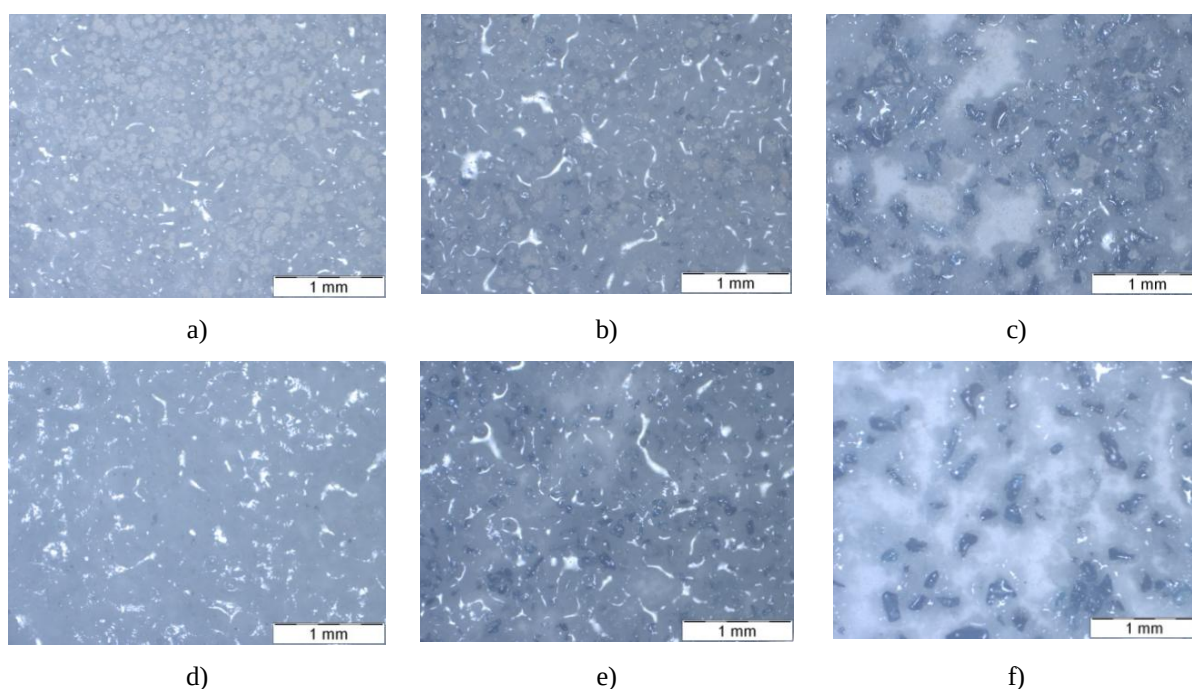


Figure 8. Optical micrograph of the sample coded a) 30S_40-80, b) 30S_80-125, c) 30S_125-250 and samples coded d) 40S_40-80, e) 40S_80-125, f) 40S_125-250

For samples of pure Al_2O_3 , it is interesting to note that an increasing in frequency results in decreasing shielding effectiveness. On the other hand, the addition of SiC, regardless of the amount of secondary phases, results in an increase in shielding effectiveness especially in higher frequency range tested (14.5 – 17.2 GHz). Although the values of EMSE obtained with Al_2O_3 / SiC composites were quite low compared to the absorber and some metallic materials, nonetheless that is reasonably good and could be of some use especially under very high temperatures and/or corrosive environments.

CONCLUSION

It was found that the electromagnetic shielding effectiveness (EMSE) of SiC particulate reinforced Al_2O_3 composite materials has been in admissible level and it varies between 9 – 17 dB at frequency of 12.4 – 18 GHz compared this to monophase Al_2O_3 which shows only 2 – 7 dB shielding. It was found that increasing in SiC content has an increase in the shielding effectiveness of composite structure. It was also observed that increasing in particle size of SiC has increased the shielding effectiveness of composite structure.

In conclusion, although Al_2O_3 – SiC ceramic composites have lower shielding effectiveness than shielding materials and metals however, they have a potential of use when electromagnetic shielding is necessary in special environments such as high temperature, corrosive conditions etc. where other materials cannot be used.

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