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Electromagnetic Scattering Properties and Characterisation of Sintered SiC Composite–Based Microwave Spectrum

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Abstract

Silicon carbide (SiC) is one of the most promising structural ceramic materials because of its excellent thermal and electromechanical properties. These properties are beneficial for CMC that enhances the performance of composites, especially those containing integrated nanoadditives. In this research, SiC composites were fabricated from SiC at three concentrations, ZnO and Si. The magnetic properties of the mixtures were tested through vibratory sample monitoring. The green samples were sintered in a sintering furnace at 1600 °C in a nitrogen environment. The obtained composites have been tested and characterised using different techniques, including X-ray diffraction, surface morphology using FESEM and network analyser, and the dielectric properties of the samples were tested. On the basis of the sintering environment, silicon nitride was detected in the composite because of the nitriding process along the composite. Weak magnetic and absorbing properties were calculated for all the SiC composites. The dielectric properties of a composite were considered high when the composite tended to be a reflector at a low frequency range and a transmitter as the frequency increased along the frequency band. Therefore, the composite exerted a potential effect on the applications where shielding properties required in microwave range to prevent wave interference.

Keywords: *SiC nanocomposite: scattering parameter; vibratory sample monitoring of SiC*

1. Introduction

Ceramic materials are considered non-metallic and inorganic materials used in many industrial sectors. Nitride, carbide and oxide materials are classified as ceramics. possessing high densities and lightweight characteristics. Ceramic composites utilised in electromagnetic (EM) absorption applications are designed to serve two functions, withstanding harsh environments at rising temperatures and absorbing or transmitting the exposed EM waves [1].

One of the most promising structural ceramic materials is silicon carbide (SiC), which has excellent thermal and electromechanical properties and good mechanical characteristics [2]. Certain materials are combined with SiC to satisfy the dielectric properties of designated composites for structural composites. Typically, additives alter the EM properties of SiC and turn it into a transparent, absorber or EM-shielded structural composite [3]. Complex permittivity determines whether SiC composites have one of the scattering parameters. In theory, complex permittivity or relative permittivity (ε_r) is mainly divided into two parts: real (έ) and imaginary (ε'') [4].

Microwave-absorbing materials (MAMs) have been increasingly used in industrial applications because of worsening EM pollution and radiation [5, 6]. In addition, SiC ceramic composites are considered next-generation MAMs [7] and promising materials for stealth technologies and military applications [8]. These composites reduce radar signatures during interactions with aircraft, tanks, targets and ships [9]. Similarly, EM interference reduction by microstrip back-radiation is common in civilian applications. SiC composites in particular applications are required to be transparent rather than to have absorbing characteristics. This property is highly recommended for high EM frequency applications particularly in the microwave range (X-band range; from 8.2 to 12.4 GHz), such as radars, radome, Doppler, TV and telecommunication transmission [10].

The transparency of EM waves can occur at a weak RL by obtaining low complex permittivity [11]. The values of ε_r are frequency dependent, showing varied responses to EM. Some studies on SiC used silicon nitride as a start material to reduce EM wave reflection and enables EM waves to penetrate composites. Xiao Lin et al. [12] used SiC and silicon nitride as porous media for EM isolation; the composite was prepared by sintering at 1700 °C in a nitrogen atmosphere. Instead of the sintering temperature, an oxidation process was utilised by Zheng et al. [13] at 1100 °C to oxidise a Si_3N_4–SiC composite; the process reduced reflection when an interference action occurred between the EM waves and the front or rear surfaces of the composite. The microstructure of composites is affected by rising temperature, which is visible in prominent X-ray diffraction (XRD) peaks or crystallography changes from amorphous to crystalline structure [14, 15]. Wen et al. [6] observed changes in the SiC composite from amorphous to a crystalline structure at elevated temperatures. This conversion was directly reflected on the dielectric properties of the composite that showed a ladder behaviour and increased the absorption performance of the SiC composite. Likewise, Li et al. revealed that some fraction of the SiC was transformed into SiO_2 because of oxidation at 1100 °C and the decreased XRD peak of SiC. This decrease affected the behaviour of permittivity, increasing the value. Ma et al. [16] examined heat treatments at 900 °C, 1400 °C, 1600 °C and 1800 °C. At 1800 °C; the process caused the composite to exhibit the largest degree of crystallisation, that is, the narrowest diffraction peak at (002), and directly reduced the interplanar spacing of the composite. These changes in crystallinity improved the polarisation of the material 1.7 times at temperatures above 1400 °C. A similar concept has been used but with different additives [17,21].

In this study, a composite with weak absorption properties was obtained by enhancing the dielectric properties of a SiC-based nano reinforcement.

2. Materials and Method

SiC nanoparticles, silicon microparticles and ZnO nanoparticles with average particle size of 500, 1000–3000 and 10–30 nm, respectively, were used in the experiment. The preparation of powder and sampling of SiC composites were conducted and explained in our last publication [22]. All fabricated samples were sintered at 1600 °C in a nitrogen environment in a horizontal tube furnace. SiC and ZnO were pre-sintered at this temperature because the sintering temperatures of the two materials are higher than this temperature. Si was melted and directly influenced by N_2; however, this procedure nitrided the molten Si that bonded to the bulk composite and distributed the nitriding effect all over the composite. The sintering temperature profile can be seen in Fig. 1a. A low heating rate was adopted to reach the desired temperature. The dwell times for 800 °C and 1600 °C were 90 and 120 min, respectively [23], and the cooling rate was set according to the default of the furnace to reach the room temperature. The samples were characterised through VSM (Fig. 1b). An X-ray diffractometer was used. For PAN analysis, $\lambda = 1.5405$ nm, the Cu-Kα anode was used and the ratio between Kα1 and Kα2 radiation was 0.5. The angle of diffraction ranged from 10 to 90. The surface morphology was visualised using a Ziess Supra 55 VP scanning electron microscope, and the sintering of the samples and Si_3N_4 was ensured. The complex permittivity and S11 and S21 scattering parameters were measured using a network analyser (ENA, Keysight E5071C) in a range of 8.2–12.4 GHz.

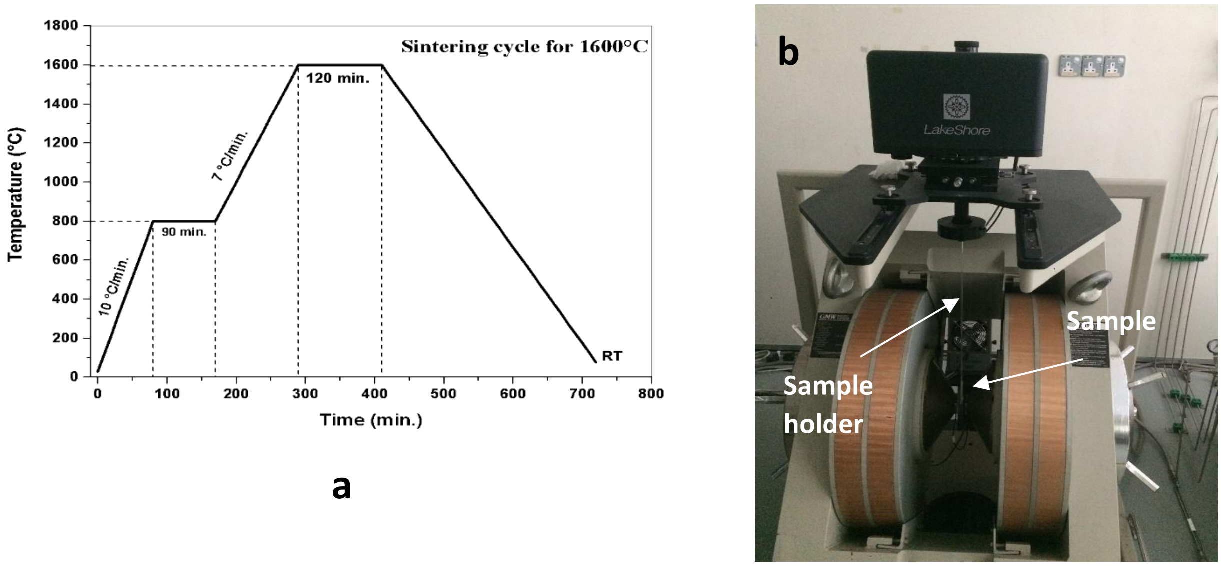

Fig. 1. a) Sintering temperature profile b) VSM testing machine

3. Results and Discussions

3.1.1. Magnetic properties of the mixture

The test is important to the examination of changes in the magnetic properties of SiC, such as magnetisation saturation, coercivity, retentivity of magnetisation and squareness. If additives can affect the absorption properties of composites by affecting real and imaginary permeability, high magnetic properties can result in high absorption ability. Thus, it was not used in this study. The lowest magnetic properties were used to ensure that no EM was stored.

Fig. 2 shows the magnetic properties of SiC composites at 70% SiC with different additive concentrations. The magnetisation saturation of SiC, which was 0.0047 emu/g, increased compared with that of the pure SiC (approximately 0.0172 emu/g) [24]. The increase in magnetic saturation (Ms) was due to the effects of ZnO and Si because they have higher magnetic properties than SiC. Therefore, the amount of ZnO tended to increase the Ms of SiC from 70/20/10 to 70/10/20. The increase in the magnetisation saturation of SiC can be attributed to the higher number of electrons in the electron shell of Zn as compared with that in Si. However, the increase in the Ms of the SiC composite was due to the effects of ZnO and Si.

The coercivity (Hc), as mentioned in Table 1, decreased gradually with increasing ZnO. This effect was due to the interaction of the dipole effect of the global composite. The interaction weakened when the amount of additives changed. The changes in the magnetic properties of SiC were due to the Jahn Teller effect distortion of ZnO ions in the SiC composite [25]. Similarly, the retentivity (Mr) and squareness values were extremely small and close to zero, indicating an extremely low magnetic property. This result can be attributed to the low magnetic characteristics of the composites that tend to lose the acquired magnetic field rapidly when it was reduced to zero. The value in Table 1 shows the effect of additive concentration variation on the magnetic characteristics of SiC even with little influence. The Ms was considered extremely low in general, but variation in its magnetic values was due to the effects of ZnO and Si.

Table 1
Magnetic properties of SiC composite at different additives concentration

Composite name	Ms (emu/g)	Hc (Oe)	Mr (emu/g)	Squareness
70/10/20	0.0172	56.823	659.6×10^{-6}	0.0383
70/15/15	0.0245	60.42	450.36×10^{-6}	0.0192
70/20/10	0.0238	20.49	175.19×10^{-6}	0.0072

The mixture did not attain magnetisation saturation even when the magnetic field increased to the maximum value. This pattern of the hysteresis loop was due to the absence of dipole occurrence of the electron and indicates that the electron’s shell has completely filled and saturated the 1s, 2s and 2p orbits and tend to cancel any applied magnetic field [26].

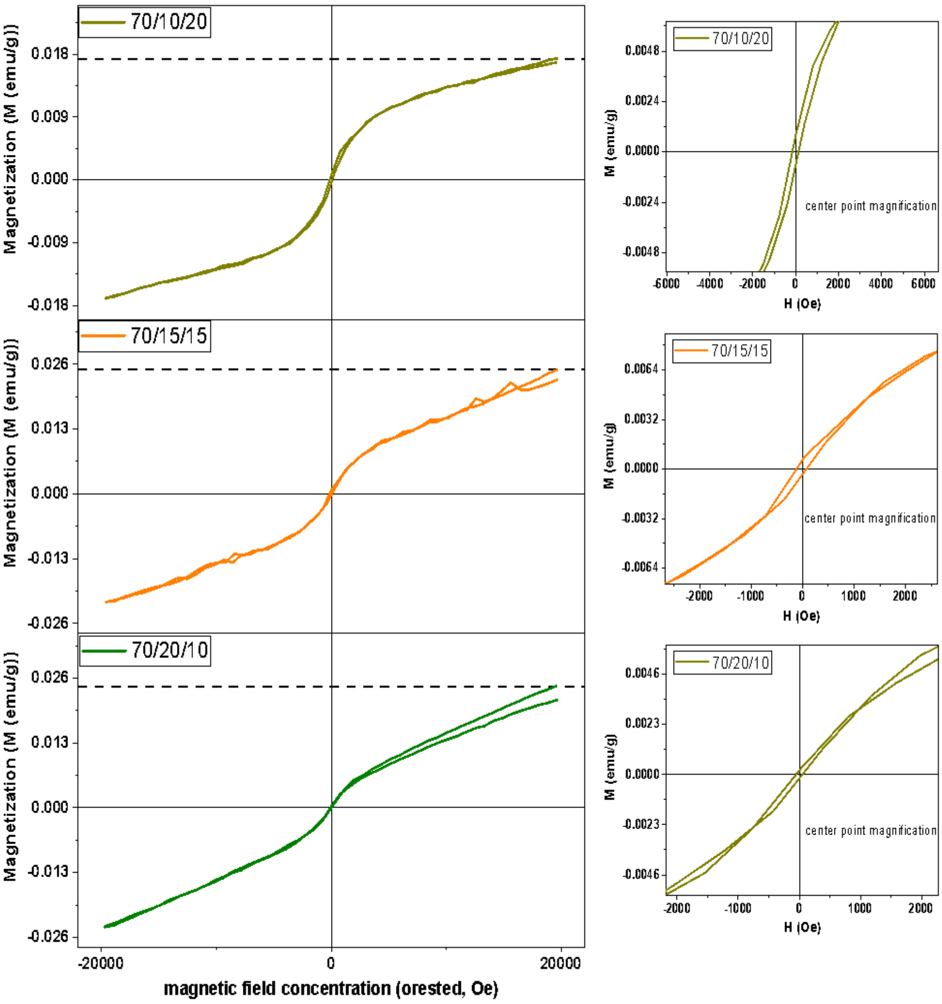

Fig. 2. Magnetic properties of SiC composites at 70% SiC

Fig. 3 shows the effects of additive concentrations on the magnetic properties of SiC. The soft magnetic was observed for all composites at 80% concentration, and maximum saturation magnetisation was observed at 0.0249 emu/g (Table 2). This result was associated with the 80/10/10 composite when both additives were equal in concentration. This trend was similar to that of the previous SiC concentration of the 70% SiC sample. However, when the amount of the additive varied, the value of Ms changed, indicating only a small difference between the maximum and minimum values. This result indicated that variations in EM properties among additives were small, revealing weak magnetic properties that led to poor EM absorption performance. Coercivity was varied, gradually decreasing with increasing ZnO, and retentivity fluctuated as the amount of additives changed. However, owing to coercive force, SiC can be classified as a soft magnetic material.

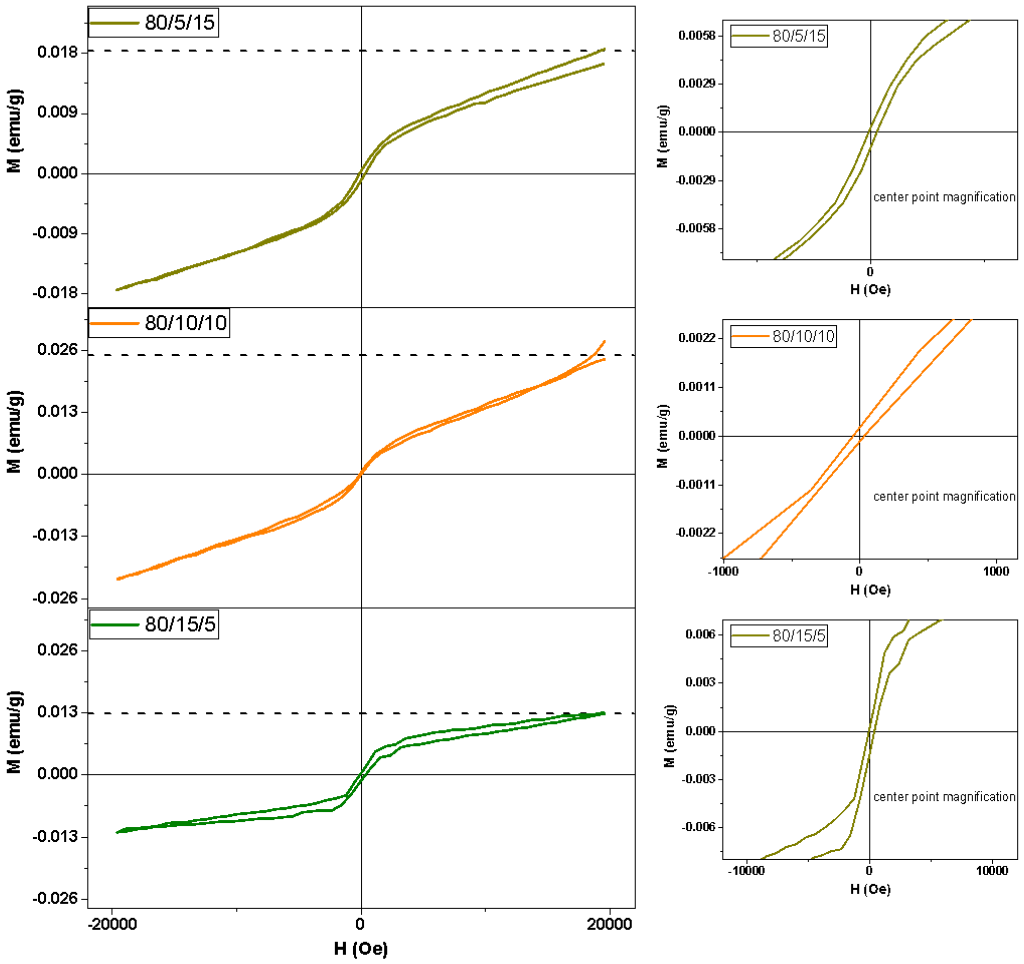

Fig. 3. Magnetic properties of SiC composites at 80% SiC

Table 2
Magnetic properties of SiC composite at different additive concentration

Composite name	Ms (emu/g)	Hc (Oe)	Mr (emu/g)	Squareness
80/5/15	0.018	295.76	617.04×10^{-6}	0.00342
80/10/10	0.0249	106.38	252.8×10^{-6}	0.00102
80/15/5	0.0128	91.35	175.19×10^{-6}	0.0072

In 90% SiC, which had a large SiC content, difference in Ms was marginal (Fig. 4 and Table 3). The maximum value was found in the 90/2.5/7.5 composite and was close to the maximum values of 70% and 80% SiC. The reduction in Ms was due to the increase in SiC content. The formation of S-shape in Fig. 4 gradually disappeared when the Si value decreased and plateaued, as in the 90/7.5/2.5 composite. However, the effect of additive on SiC afforded SiC magnetic properties, especially when the concentration of SiC was low, as in 70% SiC. Consequently, the diamagnetic behaviour of SiC was extremely strong because of its bond, forcing the composite to remain in its insulation area.

Many parameters, such as shape anisotropy, structure and crystallinity, can influence the magnetic properties of nanostructured materials [27]. This kind of influence is related to electron density in the orbital and how it is saturated with energy to accept addition energy. This influence was implied by variations in Ms and coercivity for all tested mixtures. The unpaired electron resulted in diamagnetic properties represented by the extremely low Ms. Low magnetisation led to low permeability, reducing the ability of a material to interact with the magnetic part of the EM wave. Reduction in permeability greatly influenced the absorption of the total composite, which showed increased transmission because of low magnetic conductivity.

Table 3
Magnetic properties of SiC composite at different additives concentrations

Composite name	Ms (emu/g)	Hc (Oe)	Mr (emu/g)	Squareness
90/2.5/7.5	0.0183	202.02	499.03×10^{-6}	0.0272
90/5/5	0.0168	291.74	68.06×10^{-6}	0.00404
90/7.5/2.5	0.0119	181.35	453.77×10^{-6}	0.0379

The VSM results of the selected SiC composites explained the strong diamagnetic properties of SiC, especially when the concentration reached the maximum value in the composite. Secondly, Si had a stronger effect than ZnO as an additive enhancing the magnetic properties of SiC. Furthermore, all composites showed extremely low magnetic behaviour and can be classified as soft magnetic materials [28]. The low degree of magnetisation, retentivity and squareness indicated that the composite gained a diamagnetic property that affected its interactions and the formation of the magnetic field of the EM wave. The VSM results indicated that the powder mixture resulted in a weak absorption property of the EMw spectrum.

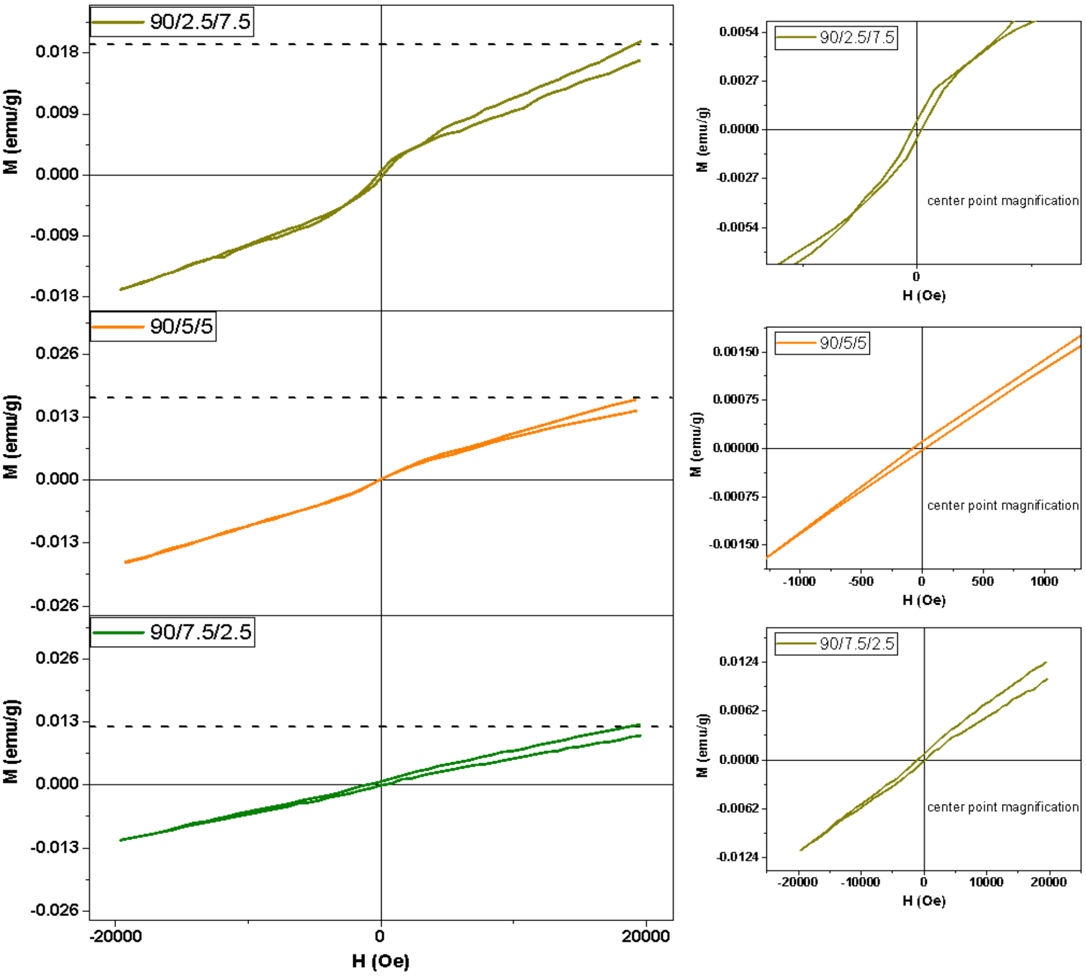

Fig. 4. Magnetic properties of SiC composites at 90% SiC

3.2. XRD analysis of sintered composites

The XRD peaks of composite sintered at 1600° are shown in Fig. 5. Notably, all the SiC composites were affected by the surrounding inert N_2 gas. The sharp peaks observed for SiC, ZnO and Si_3N_4 confirmed that the composite had a crystalline structure without any amorphous molecules. Owing to sintering environment, silicon nitride Si_3N_4 was detected along the diffraction angles in which all the Si_3N_4 peaks were matched with the reference no. ICSD (98-064-4683) and (98-016-4619) as a hexagonal crystalline structure. The peaks were in good agreement with the findings in the literature [12, 29-31].

Owing to high temperatures, Si and ZnO reacted individually. However, Si was more influenced because the temperature exceeded its melting point (1440 °C) and it reacted with the inert gas (N_2). Thus, the composition of Si_3N_4 did not influence ZnO or SiC. ZnO has a hexagonal structure (Wurtzite structure) with stable microstructural properties at high temperatures [32, 33]. Variation in the amount of Si in the original composites was observed, and the low intensity of Si_3N_4 was detected in the 90/7.5/2.5 composite. The good distribution of Si_3N_4 in the composite was indicated by the detected peaks along the diffraction angles. EM properties can be enhanced by varying the distribution of Si_3N_4 and attenuating the microwave energy. Moreover, enhancement can be achieved by increasing the permittivity value determining the shielding effect. The effect of shielding decreased with Si concentration in the 90/7.5/2.5 composite when a low amount of Si was added to the SiC composite.

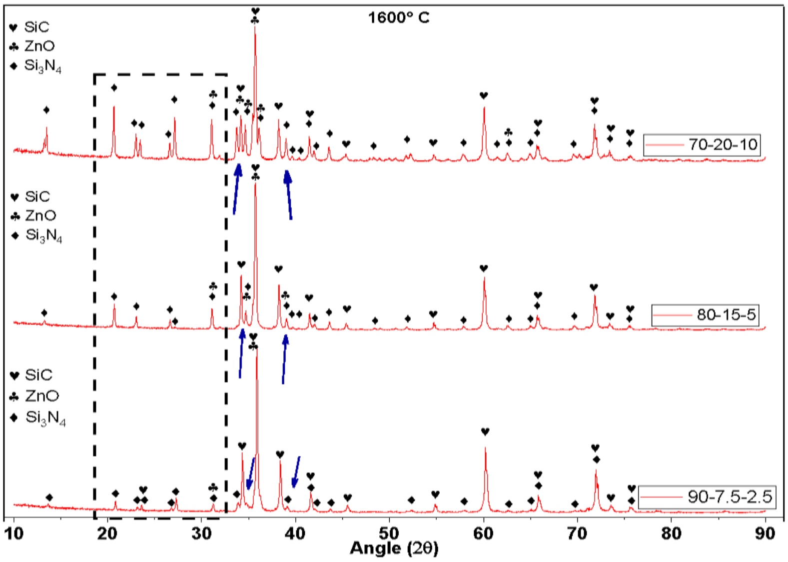

Fig. 5. XRD of the SiC composites at 1600°C

3.3. Morphology of the sintered samples

Fig. 6 shows the sample morphology of the SiC composite. The distribution of the molten Si in all particles exposed to high temperatures was uniform. Thus, the liquid-phase silicon that formed Si_3N_4 interconnected SiC and ZnO particles [34]. This behaviour was due to continuous network formation during sintering, producing a solid SiC composite structure and increasing the densification of the particles.

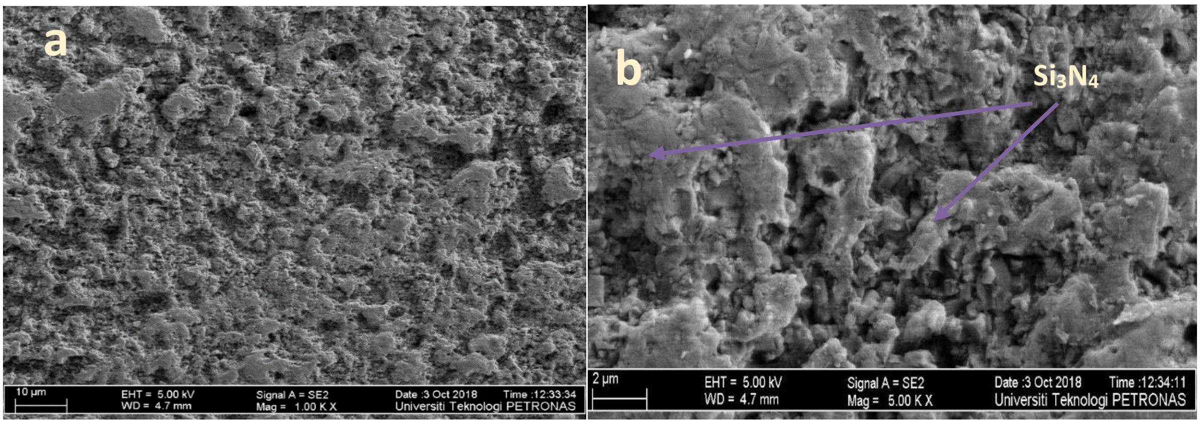

Fig. 6. a) FESEM of the sintered SiC composites at 1600°C, b) magnification of (a) showing the silicon nitride.

3.4. EM Responses properties of the sintered samples

EM properties determine how much a composite respond to exposed EMw. A response can have different shapes (absorption, reflection or shielding and transparent properties). All these characteristics are influenced dramatically by the fabrication process, types and number of additives and the number of phases facing the incident EMw. Therefore, the sintering environment (inert gas N_2) was dispersed in the molten particles, thereby generating a combination that proportionally influenced the wave propagation inside the composite. This reaction generated a compound considered transparent to microwave and increased the electron charge mobility of the composite particles [29, 35].

3.4.1. Dielectric properties

When EM waves, especially microwave, are incident on a material, three mechanisms may occur and cause the polarisation of composite particles: electronic, ionic and orientation and space charge polarisation. However, these mechanisms enhance the charge mobility of an electron and increase the real part of permittivity or conductivity. Therefore, three different phases resulted in a specific transparent property because of the existence of oxide and nitride in the composite. These compounds altered the dielectric properties of SiC and turned it into a conductive material to a material with microwave properties.

The complex permittivity of the samples with 70%, 80% and 90% SiC concentration are shown in Fig. 7. SiC plays a major role in the reduction of permittivity because it is considered a dielectric material when it is pure. This effect comes from the orientation of its crystalline structure after exposure to a high temperature. However, even at a high temperature, it did not change the inherent EM properties of SiC because no major conversion turning SiC into a different phase occurred. Meanwhile, variation in EM response between composites in each individual group was attributed to the additives. The molten silicon formed Si_3N_4, and the sintered ZnO added additional bond force to the composite, considerably influencing increment in polarisation. This added force resulted in a maximum value of 16.21, which corresponded to 12.4 GHz for the 70/10/20 composite, as observed in Fig. 7a. This modification corresponded to the high Si_3N_4 content. The permittivity gradually decreased to 8.99 at 9.43 GHz in the 70/20/10 composite, where the maximum value of ZnO existed, which allowed for microwave propagation. Fig. 7b shows the imaginary part of permittivity, and the largest value was obtained from the 70/10/20 composite. This result indicated that the electrical conductivity of the composite was at its maximum value, and the broad peaks shown in the figure were related to large polarisation relaxation. Hence, the dissipated energy at this level was extremely weak compared with that of the 70/20/10 composite, where no obvious resonance peaks appeared. This increment in ε'' value was associated with an increase in the temperature, enhancing the mobility charge of the electron by accelerating response.

Fig. 7c shows the 80% SiC composites. The low amount of ZnO was associated with increase in permittivity. Thus, 80/5/15 had the highest permittivity values, which gradually decreased to a minimum at 80/15/5. When ZnO concentration was low, the composites showed abundant broad resonance peaks, compared with 80/15/5. The width of these resonance peaks increased with frequency, as in the 80/15/15 composite, where both additives had similar percentage, but then disappeared in the 80/15/5 composite. The decrease in the number of peaks was attributed to the low concentration of Si_3N_4, which reduced polarisation. This behavioural change in resonance positions did not match when the composites contained 90% SiC, as shown in Fig. 7e. The mixing ratios shared similar resonance peaks at 10.12 GHz.

In principle, high-value permittivity is typically associated with low impedance values [36]. Therefore, sintering at 1600 °C caused Si to melt, ZnO to sinter and SiC particles to pre-sinter. Consequently, the incident wave faced a new phase of polarisation because of change in the crystalline structure, especially in Si, which resulted in phase change because of phase sintering. The imaginary permittivity of all the composites sintered at 1600 °C tended to be frequency dependent, and the energy storage increased with frequency. This behaviour demonstrated that the internal structure was stable and contained a conductive network [3, 19]. The imaginary permittivity part and electrical conductivity increased because of ZnO.

As a result, the nitriding samples increased the conductivity of the composite through the phase transformation of Si from a solid form to a liquid form after Si combined with nitrogen. However, the results were close to that in a previous study. [29].

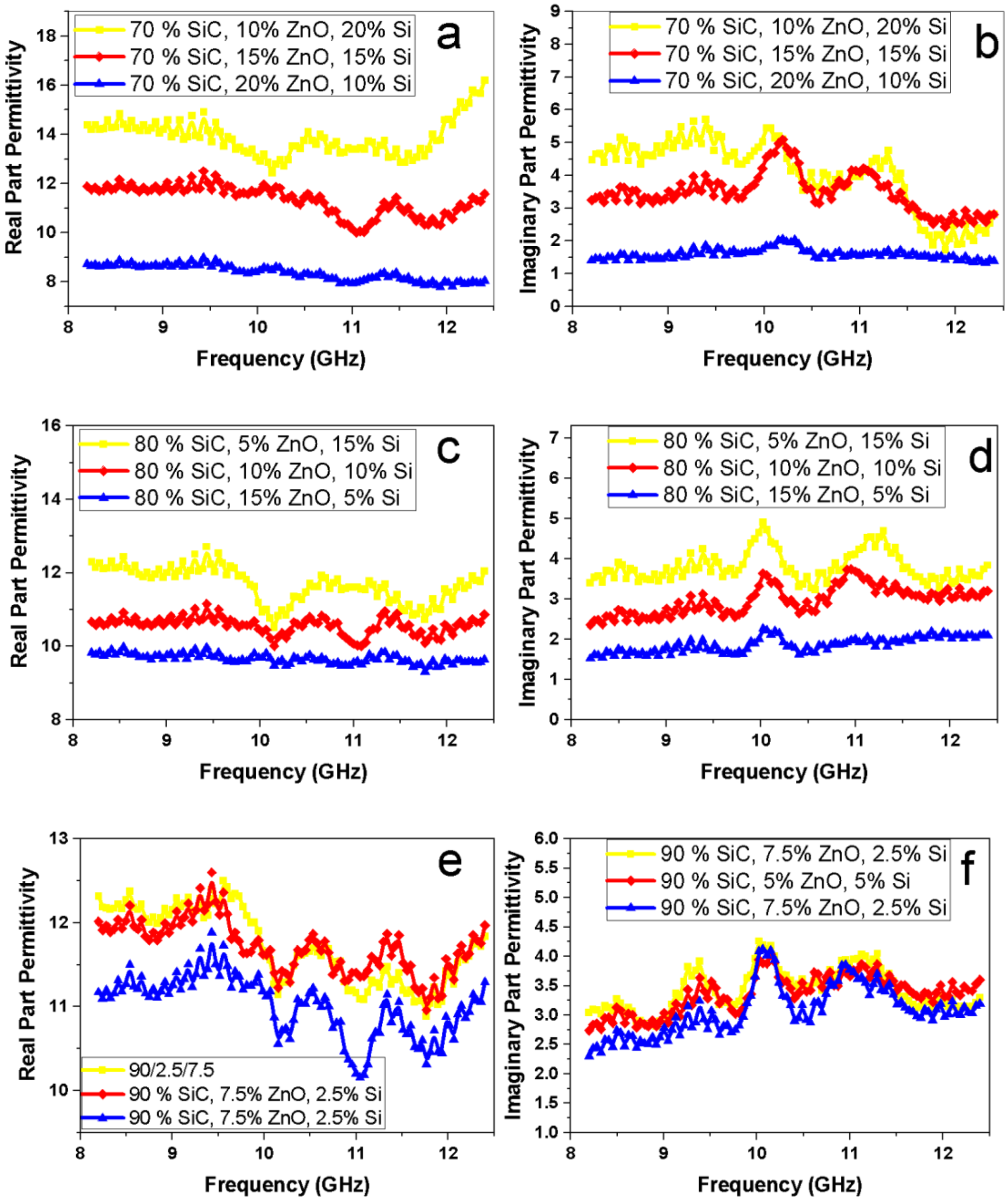

Fig. 7. Complex permittivity of 90% SiC composites at 1600°C a, c, e) real part permittivity, b, d, f) imaginary part permittivity.

3.4.2. Scattering performance

EM wave scattering can be explained in three parts: reflection, transmission and absorption. Reflection occurred at the two surfaces of the bulk material, the external and other surface oppose to the exposure surface (internal). Meanwhile, the transmitted and absorbed waves can propagate throughout a material. Some waves penetrate the internal surface, whereas some are reflected inside the composite, dissipate gradually and are converted into thermal energy.

Fig. 8 shows the reflection (S11) performance of all the samples sintered at 1600 °C. The effect of additives varied the S11 value, especially at high concentration ratios. ZnO and Si_3N_4 exhibited good response to EM waves in terms of reflection (0.71–0.26). Their effect was clearly differentiated by their different concentration ratios in the SiC composites. In the 90% SiC (Fig. c), no considerable differences were observed between the different additive concentrations because of the high amount of SiC. This trend demonstrated that a low concentration of additives results in low variations. Thus, charge mobility is considered approximately equal in 90% SiC. At a high frequency, the composite was unable to store microwave energy and tended to transmit from the other side.

The transmission coefficients were computed from S21 (Fig. 9) for the 1600 °C samples. Transparency increased with frequency for all cases [37, 38]. This increment showed that the composites were frequency dependent. The introduction of ZnO and Si to the composite played a crucial rule in wave propagation.

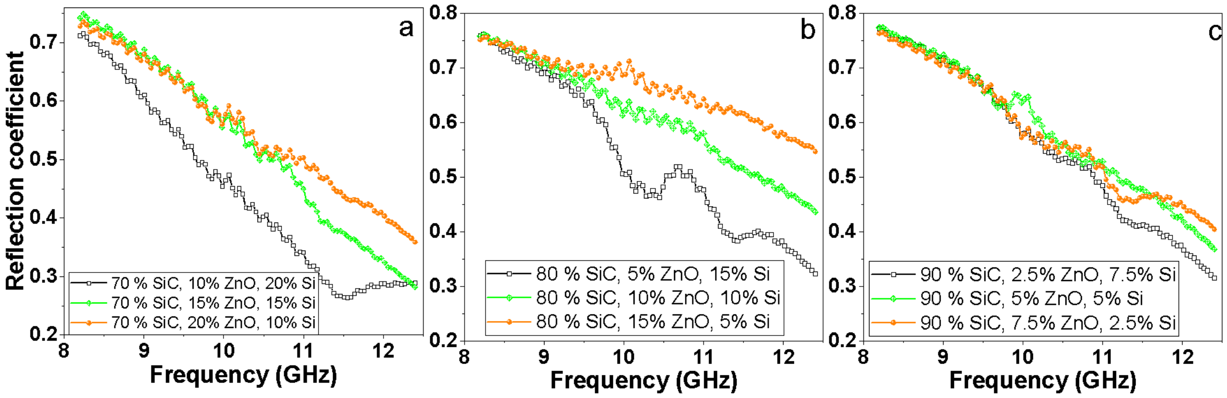

Fig. 8. Reflection coefficient of the sintered samples a) 70% SiC, b) 80% SiC and c) 90% SiC

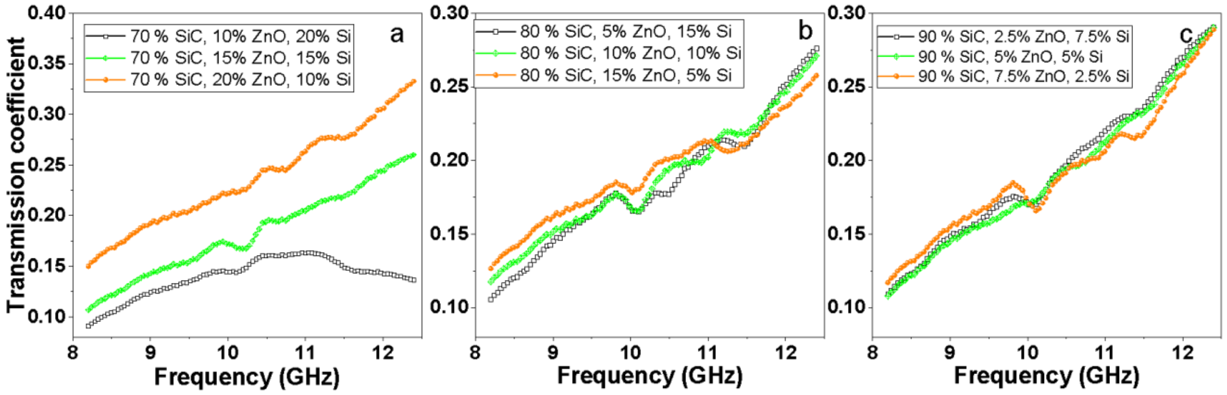

Fig. 9. Transmission coefficient of the sintered samples a) 70% SiC, b) 80% SiC and c) 90% SiC

3.4.3. Absorption evaluation

The values of reflection loss (RL) are shown in Fig. 10. The composite had an extremely weak absorption properties for all mixing ratios. Furthermore, slight difference in the frequency of the absorption was observed at different frequency bands. A composite can be considered to have good absorption properties when the RL exceeds −10 dB, in which 90% of energy is stored inside the composite and reflected until it is converted into heat and dissipates to the environment. A composite associated with this property is called a microwave-shielding material. In this study, shielding was not achieved because of the nature of silicon nitride, which tends to transmit most of the energy. By contrast, ZnO has an oxide element that enables wave energy to pass through particles without storing it.

The lowest RL obtained for the 70/20/10, 80/15/5 and 90/2.5/7.5 composites were −6.699 dB at 12.06 GHz, −5.76 dB at 10.9 GHz and −5.36 at 11.7 GHz, respectively, which are in good agreement with those obtained in a previous study [39]. The high ε′ values of the composites at this level showed that the material is a reflector and transmitter rather than an absorber, and the microwave energy hardly infiltrated the material.

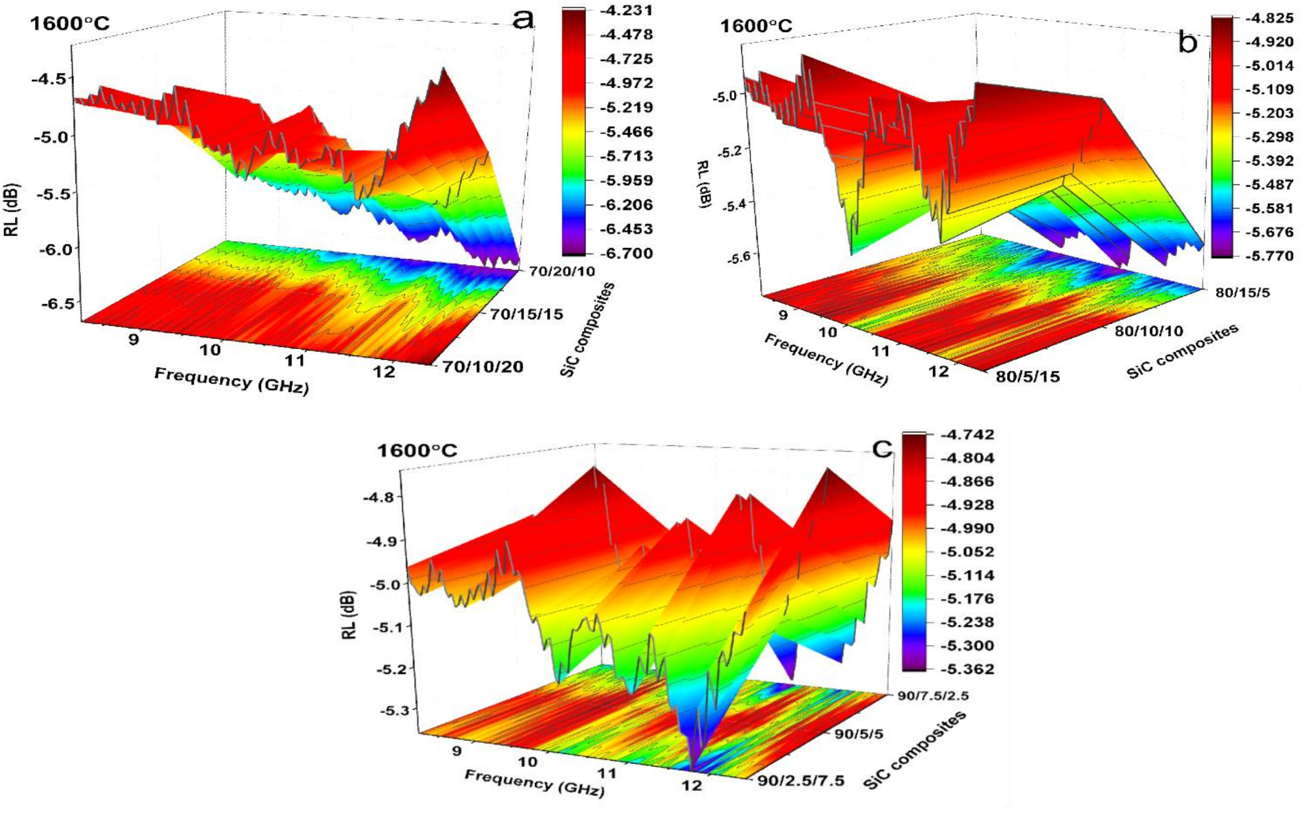

Fig. 10. RL of composites sintered at 1600°C a) 70% SiC, b) 80% SiC and c) 90% SiC

Furthermore, Si_3N_4 affected the absorption coefficient by promoting the propagation of the transmitted wave and minimising internal scattering due to porosity. The large gap between the ε′ and ε″ lowered the impedance mismatch along the frequency band. This observation was ascribed to a balance between the two values and enabled the composite to absorb energy. This balance was not associated with a specific material and mainly depended on the orientation of the dielectric properties, enhancing the particles and increasing the ε″ value as permeability increased.

3.4.4. Variable thickness measurement (VT)

The scattering parameters of the 70/20/10 composite with varying thickness are shown in Fig. 11. The selected composite was based on the increased transmission response. The thickness increased the shielding effect and reflection. However, the responses of the SiC composites varied as reflection gradually decreased with increasing thickness.

The highest reflection factor was obtained in the 2 mm-thick sample, which had the lowest transmission rate. Conversely, a rapid decrease in reflection was observed along the X-band at 4 mm thickness, which was sufficient for the minimum reflation of 0.1 at 12.4 GHz. Low reflection led to high transmission or absorption properties. The 4 mm-thick composite exhibited rapid increase in transmission coefficient because of the large effect of porosity associated with composites fabricated at 1600 °C. Porosity increased with thickness, which can be generated in the global composite because of the introduction of silicon nitride.

However, differences among the 2.5, 3.0 and 3.5 mm-thick samples were small. The 3 mm-thick samples had the same thickness as the standard samples used in the previous measurement and showed a compatible response of reflection and transmission, as stated previously. The thickness of the composite had a direct proportional relationship with complex permittivity and permeability. Thus, a small thickness can negatively affect transmission because of reduced attenuation, which occurred because of the small distance between the external and internal surfaces. Thus, internal scattering was reduced because of the lag in electron charge motion.

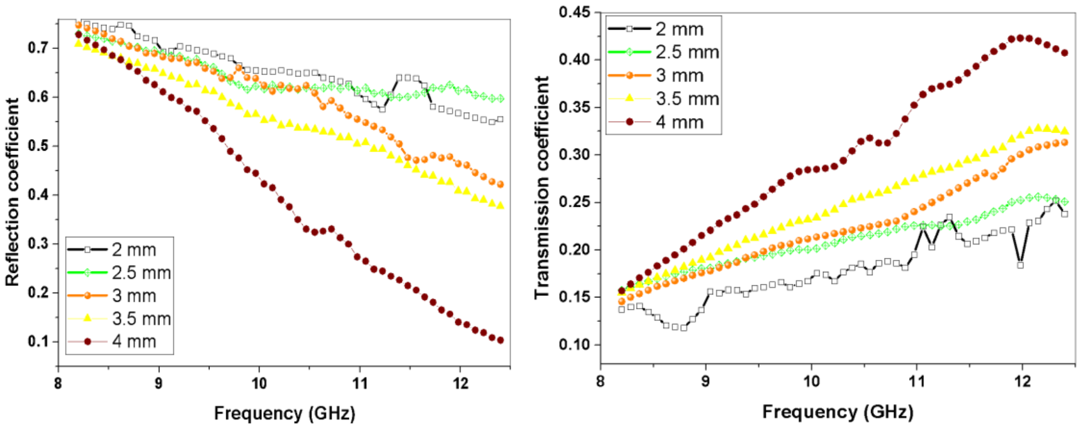

Fig. 11. Transmission and reflection coefficients of VT samples

The exposed microwave on the surface has to attenuate inside a material, particularly in dielectric materials. This form of attenuation is mainly determined using destructive interference.

$$f_m = \frac{c}{4d}\sqrt{|\mu_r \varepsilon_r|}, \qquad \ldots(1)$$

where f_m is the peak frequency and d is the absorber thickness. The peak frequency is proportionally attributed to complex permittivity and permeability, and thickness has an inverse relationship with f_m. Hence, the calculation of RL shown in Fig. 12 for all samples had no considerable absorption properties and was compatible with the scattering parameter. The minimum value of RL was associated with the 2 mm thickness and had a value of −6.49 at 9.8 GHz. Poor absorption properties were observed in the samples with other thickness.

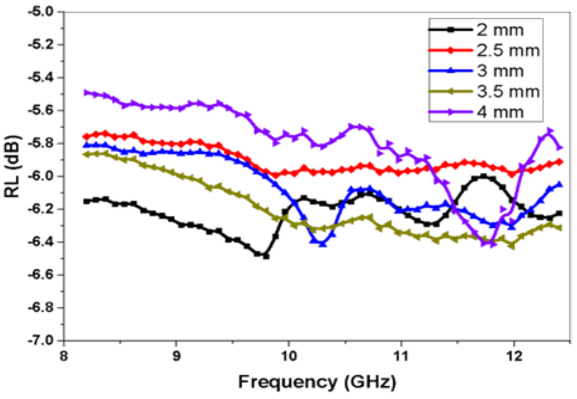

Fig. 12. RL of the VT samples

4. Conclusion

SiC composites were fabricated with different additive concentrations through sintering. All the sintered samples produced silicon nitride, which was detected along the XRD diffraction angles and confirmed the reaction between the fused Si and N_2. Hence, the reaction between nitrogen and the molten silicon showed good correlation. Si_3N_4 exerted a considerable effect on the interfacial polarisation of microwave. The dielectric coefficient increased to a maximum value (16.21) at a mixing ratio 70/10/20, in which the maximum Si content was found in the composite. The 70/20/10 composite had the lowest permittivity (7.8) because of the effect of ZnO on the bulk composite and low concentration of Si. In terms of scattering parameters, the maximum value of reflection of the 70% SiC was higher than the maximum values of the 80% and 90% SiC.

The calculation of the transmission line theory indicated poor absorption in all the sintered samples.

Variation in the thickness of the highest transparency coefficient samples showed deviations in transmission and reflection. Thickness of 2 mm produced the highest reflection factor in all materials. Meanwhile, the lowest reflection (0.10 at 12.4 GHz) was observed at a thickness of 4 mm. The VT results indicated that the composite exhibited high response to microwaves in terms of variable thickness. Notably, the designated composite had moderate transparent properties suitable for random application, allowed high microwave frequencies to penetrate the composites and protected the microwave instrument safe from the effects of harsh environments.

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خصائص التشتت الكهرومغناطيسي وتوصيف طيف الميكروويف القائم على مركب SiC الملبد

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المستخلص

واحدة من أكثر مواد السيراميك الهيكلية الواعدة هي كربيد السيليكون (SiC)، فهي تتمتع بخصائص حرارية وكهروميكانيكية ممتازة. هذه الخصائص مفيدة ل CMC لتعزيز أداء المركب خاصة عند إضافات النانو المدمجة. في هذا البحث، تم تصنيع مركب SiC من ثلاثة تركيزات مع ZnO و Si. تم اختبار الخواص المغناطيسية لجميع المخاليط باستخدام مراقبة العينة الاهتزازية (VSM). تم تلبيد العينات الخضراء في فرن التلبيد عند 1600 درجة مئوية في بيئة النيتروجين. تم اختبار جميع المركبات التي تم الحصول عليها وتوصيفها باستخدام تقنيات وتوصيفات مختلفة مثل حيود الأشعة السينية، ومورفولوجيا السطح تمت باستخدام FESEM، ومحلل الشبكة لاختبار الخصائص العازلة للعينات. بناء على بيئة التلبيد، تم اكتشاف نيتريد السيليكون في المركب بسبب عملية النترجة على طول المركب. من ناحية أخرى، تم حساب الخصائص المغناطيسية والامتصاصية لجميع مركبات SiC. تعتبر الخصائص العازلة عالية حيث يميل المركب إلى أن يكون عاكسا في نطاق التردد المنخفض ونافذ كلما زاد التردد على طول نطاق التردد. ولذلك، فإن المركب له تأثير محتمل على التطبيقات التي تتطلب خصائص التدريع في نطاق الموجات الدقيقة لمنع تداخل الموجات
