Ceramics International 42 (2016) 9636–9639

Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

Synthesis and electromagnetic wave reflectivity of Si_3N_4 ceramic with gradient Fe_3O_4 distribution

Xiangming Li [a,*], Mingjun Gao [a], Yun Jiang [b]

[a] School of Environment and Materials Engineering, Yantai University, Yantai, Shandong 264005, PR China
[b] Department of Foreign Languages, Northwest A&F University, Yangling, Shaanxi 712100, PR China

ARTICLE INFO

Article history:
Received 2 February 2016
Accepted 7 March 2016
Available online 8 March 2016

Keywords:
Si_3N_4
Fe_3O_4
Gradient distribution
Chemical precipitation
Electromagnetic properties

ABSTRACT

A Si_3N_4 ceramic with gradient distribution of tri–iron tetroxide (Gradient–Si_3N_4–Fe_3O_4) was fabricated with a combined technique of chemical precipitation and directional infiltration. Electromagnetic wave could enter Gradient–Si_3N_4–Fe_3O_4 with little reflection because of weak impedance mismatch at its surface. Also the electromagnetic wave entering the Gradient–Si_3N_4–Fe_3O_4 propagated with small reflection due to continuous and gradual change of impedance resulting from the gradient Fe_3O_4 distribution, and was absorbed completely by Fe_3O_4 of the gradient structure.
© 2016 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

1. Introduction

Many studies have demonstrated that absorption is more useful than reflection in shielding electromagnetic wave though absorption is more difficult to achieve than reflection [1–11]. In these studies, carbon and ferrite are two typical electromagnetic wave absorbers, which are usually added in a material to enhance its electromagnetic wave absorption. However, the surface impedance mismatch of the material worsens with carbon or ferrite inclusion, which presents a difficulty in absorbing electromagnetic wave. Therefore, the electromagnetic wave absorption of a material could hardly be enhanced simply by adding carbon or ferrite [1–3].

For example, Si_3N_4 ceramic with uniform distribution of pyrolytic carbon (PyC–Si_3N_4) demonstrates strong surface impedance mismatch, so there is a large part of incident electromagnetic wave reflected on the surface of PyC–Si_3N_4 [2]. However, due to absence of PyC at its surface, Si_3N_4 ceramic with gradient distribution of PyC (Gradient–PyC–Si_3N_4) not only shows strong attenuation of electromagnetic wave but also demonstrates weak surface impedance mismatch. Thus, most of incident electromagnetic wave could enter Gradient–PyC–Si_3N_4 and be absorbed [3]. As demonstrated by our previous work [3], the electromagnetic wave absorption of the material could be enhanced effectively by the introduction of the absorber with a gradient distribution.

Tri–iron tetroxide (Fe_3O_4) is one of the ferrite series electromagnetic wave absorbers, which is gaining interest for its high wave–absorbing strength. However, the narrow wave absorbing band of Fe_3O_4 limits its application as a good electromagnetic wave absorber [1,5–11]. Some studies have been carried out to fabricate Fe_3O_4 nanoparticles with different morphology [12–14], especially urchin–like [12], dendrite–like [13], hollow spherical [14], etc., to widen the wave absorbing band of Fe_3O_4. The electromagnetic wave absorption of Fe_3O_4 nanoparticles with special morphology is enhanced significantly because of large specific surface area of Fe_3O_4 nanoparticles. However, the material with uniform distribution of Fe_3O_4 nanoparticles also shows poor electromagnetic wave absorption due to its strong surface impedance mismatch.

In this work, a Si_3N_4 ceramic with gradient distribution of Fe_3O_4 (Gradient–Si_3N_4–Fe_3O_4) is fabricated with a combined technique of chemical precipitation and directional infiltration. Microstructure observation and phase identification of Fe_3O_4 are carried out. The effect of infiltration pressure on Fe_3O_4 distribution in Gradient–Si_3N_4–Fe_3O_4 is investigated. The electromagnetic wave reflectivity of Gradient–Si_3N_4–Fe_3O_4 with different patterns of Fe_3O_4 distribution is measured and discussed.

2. Experimental procedure

The porous Si_3N_4 ceramic fabricated in our previous work [15] was machined into preform with a dimension of 180 mm × 180 mm × 5 mm, and then was assembled in a device (Fig. 1) to infiltrate Fe_3O_4 nanoparticles directionally. Before infiltration process, a solution of $FeCl_3$ (0.024 mol/L) and $FeCl_2$ (0.012 mol/L)

* Corresponding author.
E-mail address: li_xiangming@yahoo.com (X. Li).

http://dx.doi.org/10.1016/j.ceramint.2016.03.049
0272-8842/© 2016 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

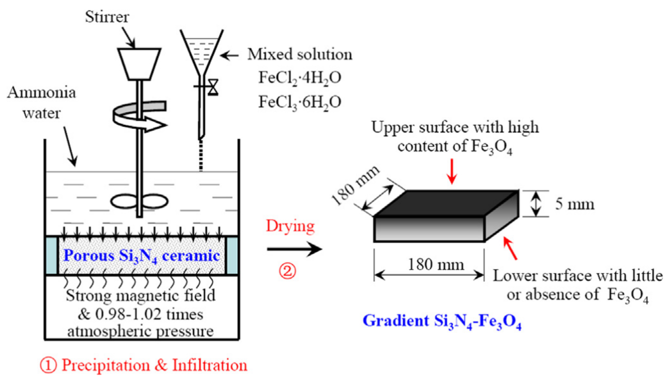

Fig. 1. Schematic of the process of Gradient–Si_3N_4–Fe_3O_4 fabrication.

was prepared by mixing $FeCl_3 \cdot 6H_2O$ and $FeCl_2 \cdot 4H_2O$ with distilled water. As shown in Fig. 1, an ammonia water with concentration of 5–6 mol/L was poured into the chamber above the preform, and then the mixed solution dripped slowly into the ammonia water. During the addition process, the ammonia water was stirred rapidly and a big powerful magnet was placed beneath the preform to speed the infiltration of reaction–derived Fe_3O_4 nanoparticles into the preform. When there was no liquid seeping out from the lower surface, the preform was taken out and dried at 90 °C for 5 h in air. The distribution of Fe_3O_4 in the preform could be controlled and adjusted by changing the pressure in the chamber at the bottom of the device (Fig. 1). The suitable pressure range was 0.9–1.05 times atmospheric pressure. For the convenience of the following discussion, the Gradient–Si_3N_4–Fe_3O_4 prepared with m times atmospheric pressure was denoted as Gradient–Si_3N_4–Fe_3O_4–m.

The microstructure was observed with a scanning electron microscopy (SEM, S–4800, Hitachi, Japan). Phase analyses were conducted by X–ray diffraction (XRD, X'Pert Pro, Philips, Netherlands). The Fe_3O_4 distribution was analyzed with an energy dispersive X–ray spectrometer (EDS, Genesis XM2, EDAX, USA) during SEM analysis. The electromagnetic wave reflectivity was measured with a Naval Research Laboratory (NRL) testing system [16,17].

3. Results and discussion

During infiltration, as the mixed solution dripped slowly into ammonia water, more and more Fe^{2+} and Fe^{3+} ions in ammonia water react with OH^- to produce Fe_3O_4 according to the following reaction equation.

$$Fe^{2+} + 2Fe^{3+} + 8OH^- \rightarrow Fe_3O_4 + 4H_2O \quad (1)$$

As known from our previous work [15], there are lots of well–connected pores formed by bonding the rod–like Si_3N_4 particles with each other in porous Si_3N_4 ceramic. At the beginning of infiltration process, with the help of powerful magnet beneath the preform, the reaction–derived Fe_3O_4 nanoparticles in ammonia water enter the preform along the well–connected pores and deposit in the pores gradually. As infiltration process goes on, the pores in the preform get smaller and smaller due to continuous deposition of Fe_3O_4 nanoparticles. The Fe_3O_4 nanoparticles could hardly arrive at deeper place in the preform but deposit in the pores near the upper side of the preform. Finally, Fe_3O_4 nanoparticles could only deposit on the upper surface of the preform when the pores near the upper side of the preform are stuffed.

Fig. 2(a) and (b) show the microstructures at the upper and lower surfaces of Gradient–Si_3N_4–Fe_3O_4 respectively. As predicted, the pores among Si_3N_4 particles at the upper surface of Gradient–Si_3N_4–Fe_3O_4 are filled with Fe_3O_4 nanoparticles, while the lower surface of Gradient–Si_3N_4–Fe_3O_4 is still porous with no Fe_3O_4 nanoparticles detected. Accordingly, it is inferred that there is a gradient distribution of Fe_3O_4 in Gradient–Si_3N_4–Fe_3O_4. In addition, Fig. 3 shows the high–magnification micrograph of the Fe_3O_4 nanoparticles in the pores at the upper surface of Gradient–Si_3N_4–Fe_3O_4. The Fe_3O_4 nanoparticles stack closely with each other and have uniform diameters of about 15–20 nm.

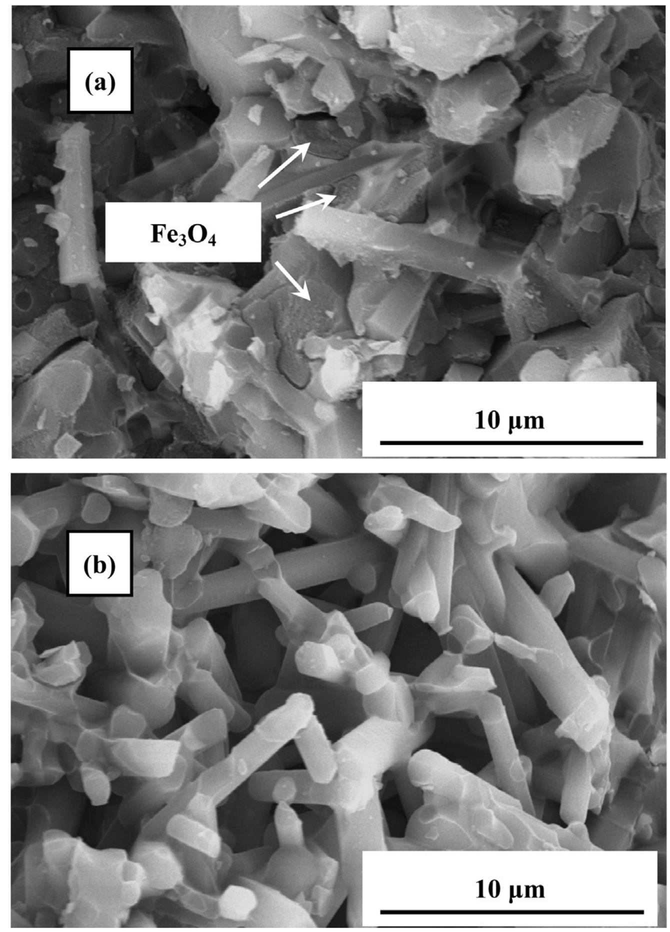

Fig. 2. Microstructures at the (a) upper and (b) lower surfaces of Gradient–Si_3N_4–Fe_3O_4.

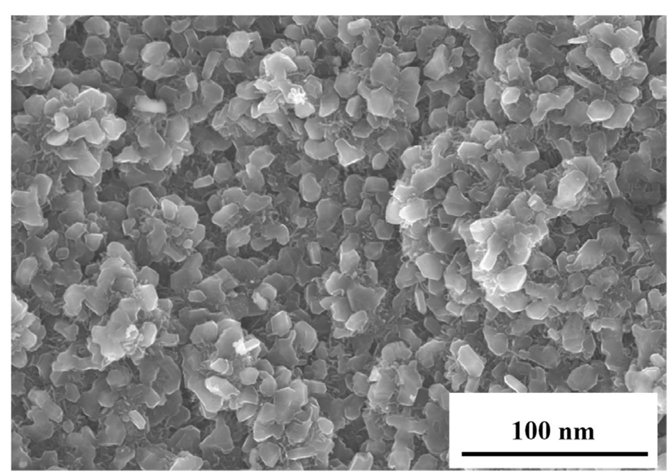

Fig. 3. High–magnification micrograph of the Fe_3O_4 nanoparticles.

After infiltration, there is a number of Fe_3O_4 nanoparticles deposited on the upper surface of Gradient–Si_3N_4–Fe_3O_4. Fig. 4

Download English Version:

https://daneshyari.com/en/article/1459036

Download Persian Version:

https://daneshyari.com/article/1459036

Daneshyari.com