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Adjustable 3-D structure with enhanced interfaces and junctions towards microwave response using FeCo/C core-shell nanocomposites

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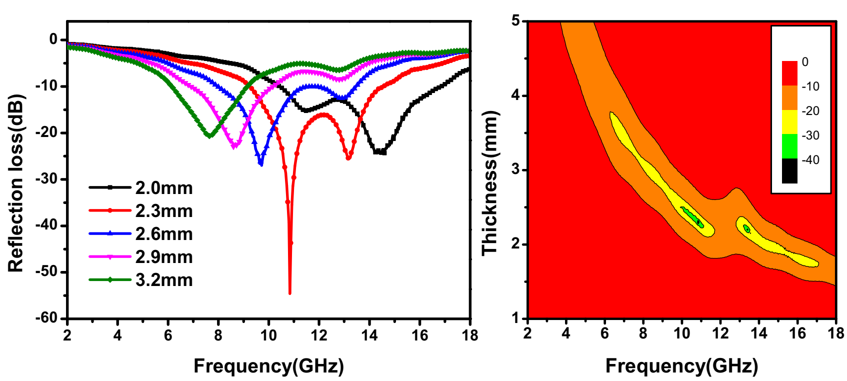
GRAPHICAL ABSTRACT

The FeCo/C core-shell nanocomposites have been synthesized by the carbon thermal reduction method and show an optimal microwave absorption performances with adjustable 3-D morphology and appropriate impedance matching.



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ABSTRACT

In this work, the 3-D honeycomb-like FeCo/C nanocomposites were synthesized through the carbon thermal reduction under an inert atmosphere. The enhanced microwave absorption properties of the composites were mainly attributed to the unique three dimensional structure of the FeCo/C nanocomposites, abundant interfaces and junctions, and the appropriate impedance matching. The Cole-Cole semicircles proved the sufficient dielectric relaxation process. The sample calcinated at 600 °C for 4 h showed the best microwave absorption properties. A maximum reflection loss of −54.6 dB was achieved at 10.8 GHz with a thickness of 2.3 mm and the frequency bandwidth was as large as 5.3 GHz. The results showed that the as-prepared FeCo/C nanocomposite could be a potential candidate for microwave absorption.

1. Introduction

The electromagnetic interference (EMI) is becoming a concerning problem because of the rapid developments of the electronic communication devices in military and civil fields [1,2]. Consequently, there is great demand to fabricate effective absorbent to eliminate the EMI or convert the unwanted electromagnetic energies into thermal energies [3]. To eliminate the EMI, the attenuation capabilities (magnetic loss and dielectric loss) and the appropriate impedance matching are mainly adopted. Thus, magnetic nanoparticles (ferrites, magnetic metals and alloys) have attracted much attention due to its large magnetic loss to

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attenuate the electromagnetic energy, which make them potential candidates for microwave absorption [4–6]. Generally, the application of the magnetic nanoparticles alone for microwave absorption has many disadvantages such as high weight and a relatively narrow bandwidth [7]. However, the excellent microwave absorbent should be equipped with the features of lightweight, strong absorption and corresponding broad frequency width for practice application [8].

As the FeCo alloy possesses high saturation magnetization and larger magnetic permeability, which endow it with efficient magnetic loss [9,10]. For example, Yan et al. synthesized $Fe_{1-x}Co_x$ alloy microparticles (x = 0.4, 0.5 and 0.6) by the low temperature reduction and the obtained the maximum reflection loss of −59 dB at the thickness of 3.6 mm [6]. Kim et al. plated the FeCo alloy film on ceramic microspheres and the reflection loss below −20 dB covered the X-band region [11]. So far, carbon materials (graphene, carbon nanotube and carbon fiber) are well known for the light weight and abundant resources. Recent progresses show that the absorbent with magnetic loss and the dielectric loss simultaneous are beneficial to attenuate the electromagnetic energies. For example, the FeCo/C hybrid with the morphology of nanofiber showed the maximum reflection loss of −47.5 dB at the thickness of 1.6 mm [12]. Liu et al. prepared the 2-D nanosheet Fe_3O_4/C composite and the maximum reflection loss reached −46 dB at the thickness of 2.9 mm [13]. Wu et al. synthesized the ring-like Fe_3O_4/C composites and the maximum reflection loss of −55.68 dB was achieved at 3.44 GHz [14]. Obviously, it is an effective way to improve the microwave absorption properties through combining the magnetic material and the dielectric material with different morphology.

Thus, we present a simple carbon thermal reduction method for preparing the FeCo/C nanocomposites. As the appropriate impedance matching and morphology of the hybrid are necessary to attenuate the electromagnetic wave, we adjust the morphology of the FeCo/C composites with matched impedance to investigate the effect on electromagnetic loss capabilities. Also, the maximum reflection loss of the sample reaches −54.6 dB at 2.3 mm and the frequency bandwidth covers from 9.2 GHz to 14.5 GHz corresponding to a thickness of 2.3 mm. The results highlight that the adjustment of the morphology with matched impedance can be an efficient application in designing microwave absorbent.

2. Experimental

2.1. Preparation of FeCo/C composite

The FeCo/C nanocomposites were synthesized through a simple carbon thermal reduction method. Firstly, 2.5 mmol cobalt acetate tetrahydrate ($C_4H_{14}CoO_8$) was added into a 50 mL beaker containing 20 mL ethanol. After a sonication treatment of the mixture for 20 min, 2.5 mmol iron chloride hexahydrate ($FeCl_3{\cdot}6H_2O$) and 2 g

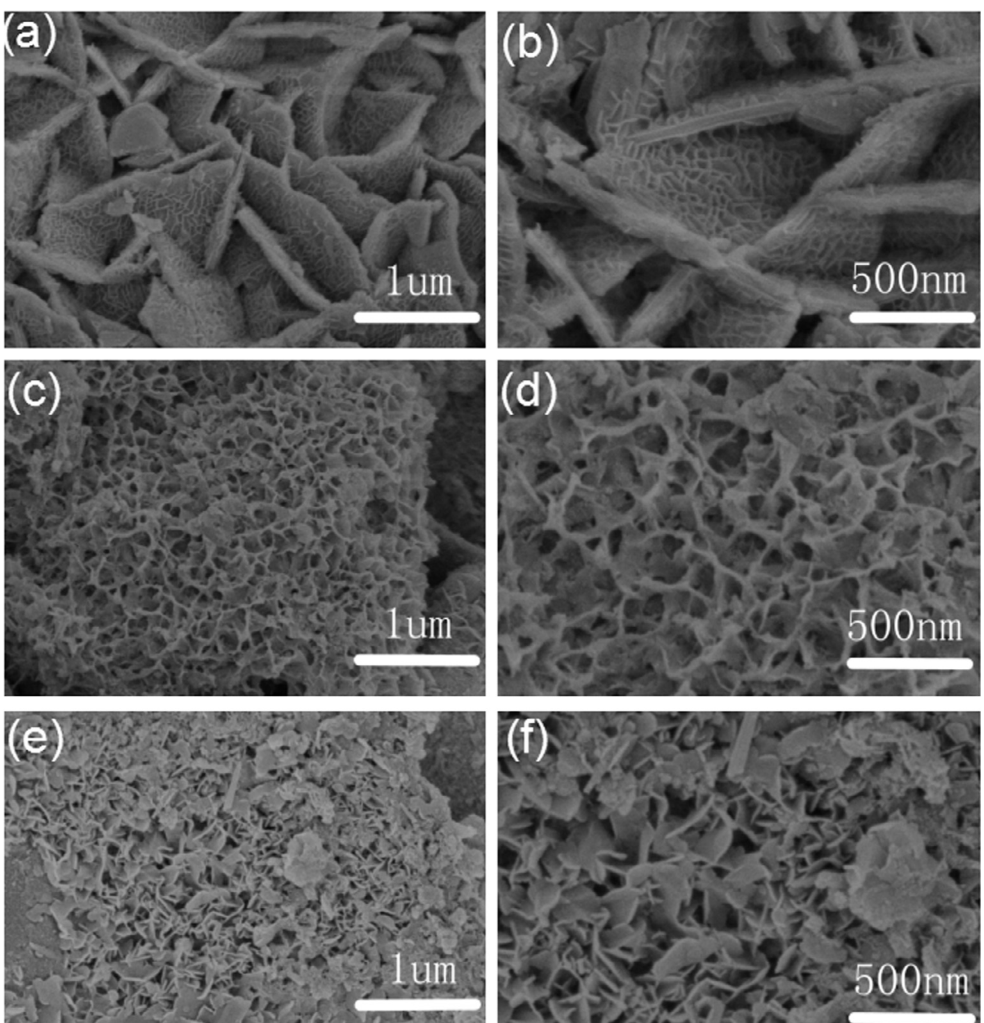

Fig. 1. Low-magnification and high-magnification SEM images of FeCo/C-3 (a, b); FeCo/C-4 (c, d); FeCo/C-5 (e, f).