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Rationally regulating complex dielectric parameters of mesoporous carbon hollow spheres to carry out efficient microwave absorption

Yan Cheng [a], Zhaoyong Li [a], Yong Li [a], Sisi Dai [a], Guangbin Ji [a,*], Huanqin Zhao [a], Jieming Cao [a], Youwei Du [b]

[a] College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 211100, PR China
[b] National Laboratory of Solid State Microstructures, Nanjing University, Nanjing 210093, PR China

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ABSTRACT

In this study, the mesoporous carbon hollow spheres (MCHS) have been prepared through a facile hard-template etching strategy. It is confirmed that the tetrapropoxysilane (TPOS) has distinct influence on the dispersity, hollow cavity and shell thickness of MCHS. Furthermore, MCHS with different construction can regulate dielectric and microwave absorption effectively. We also proved that the generated hollow void and mesporous lay in carbon spheres could boost dielectric loss ability and impedance match behavior. When the addition of TPOS is 1.73 mL, the high specific surface area of MCHS can be achieved, in addition, the maximum reflection loss value of −50.9 dB at 11.1 GHz with a thickness of 3.2 mm can be gained. Moreover, corresponding effective bandwidth can be reached to 5.4 GHz ranging from 9.1 to 14.5 GHz. Besides, MCHS prepared by 3.46 mL TPOS can achieve broad bandwidth of 6.5 GHz (from 11.2 to 17.7 GHz) under 2.0 mm. The excellent microwave absorption capability of MCHS can be ascribed to the strong dielectric loss, hollow void and mesoporous in carbon shell, which were beneficial to the reflection and absorption of the microwave. Such light and efficient absorbers may be as predominant candidate for the applied in microwave absorption territory.

1. Introduction

Recently, the fast development of electronic equipment and wireless communication has caused intense electromagnetic interference (EMI) problems that not only harm the health of human being but also disturb the operation of precise electric instrument. Moreover, the electromagnetic wave located in gigahertz is widely used in military domain to detect action targets. Therefore, the development of efficient microwave absorbing materials possesses significant sense to make equipment stealth and solve EMI problem [1–6]. Over past decade years, metal sulfide and/or oxide, *e.g.*, CuS, Bi_2S_3, MoS_2, PbS, ZnO, etc., have demonstrated remarkable strength in dielectric properties and microwave attenuation because of their great chemical properties [7–11]. So far, combining efficient absorbing properties with lightweight feature is the current development trend for advanced microwave absorption. In this context, carbon materials like carbon nanotubes (CNTs), carbon fibers (CNFs), carbon foams, carbon spheres and graphene have been attracted considerable attention on solving EMI issues [12–16].

Lately, a mass of carbon-based composites were investigated acting as robust microwave absorbers. On one hand, carbon materials are frequently used to construct core/yolk-shell structure composites to reduce integral density and enhance dielectric loss ability. For instance, carbon encapsulated magnetite nanospindles, yolk-shell C@C microspheres and porous C@Fe_3O_4 hybrid nanotube were well fabricated and achieved excellent microwave absorbing performance with assistance of carbon component [17–19]. On the other hand, regarding as one of the most significant member in carbon family, graphene and its composites are intensively explored such as decorating with metal oxides, metal sulfides, perovskites and magnetic species to tune impedance matching behavior and microwave absorbing capacity [20–25]. In addition, our group designed hollow carbon sphere@Fe@Fe_3O_4 nanocomposites and confirmed the superior attenuation ability of carbon constituent [26]. These achievements give much inspiration that carbon materials could be great candidate for microwave absorption field if the synthesized process could be toward facilitation

* Corresponding author.
E-mail address: gbji@nuaa.edu.cn (G. Ji).

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and low cost. In view of this, single carbon material such as carbon sphere may be an effective strategy taking into account both sides of simplicity and efficiency.

On this basis, conducting microstructure designation could further promote absorption properties. Che et al. prepared excellent microwave absorber of CoNi@air@TiO_2 and demonstrated the air in the composite is helpful for microwave penetrating and dissipating [27]. Zhao and co-workers declared the void space in yolk-shell Ni@void@SnO_2 led to high surface areas and large porosities, which is beneficial for impedance matching and microwave scattering [28]. Furthermore, mesoporous in Fe_3O_4/carbon could not only alleviate the density of products, but also facilitate to consume microwave [29]. Accordingly, we can conclude that hollow voids and pores are effective to improve microwave absorption.

Based on previous researches, there are various strategies to construct hollow micro-/nano-structured spheres [30–32]. In this work, we adopted a facile and novel hard-template etching process fabricating hollow carbon spheres as well as mesoprous in the shell. The carbon sphere size, shell thickness and hollow cavity of MCHS

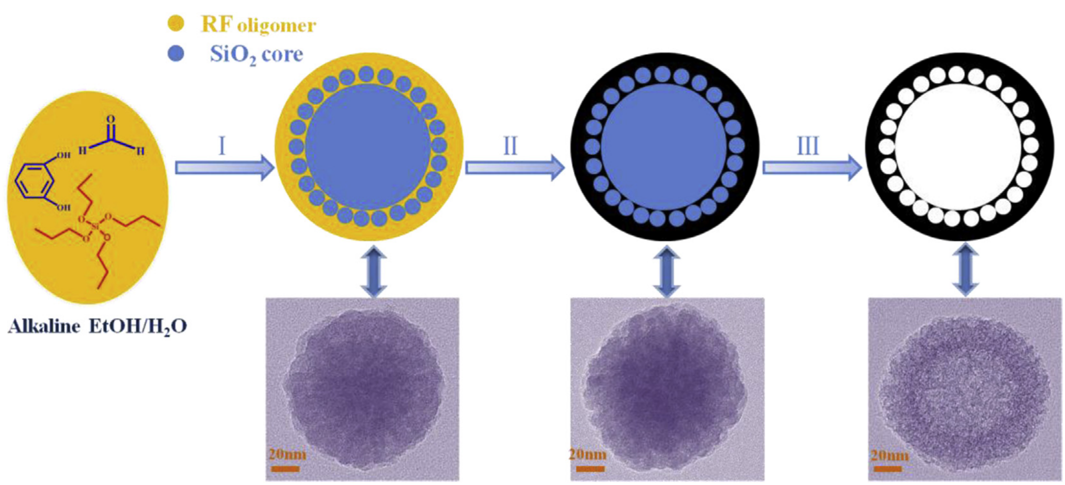

Fig. 1. The schematic diagram of the synthesis process for MCHS. (A colour version of this figure can be viewed online.)

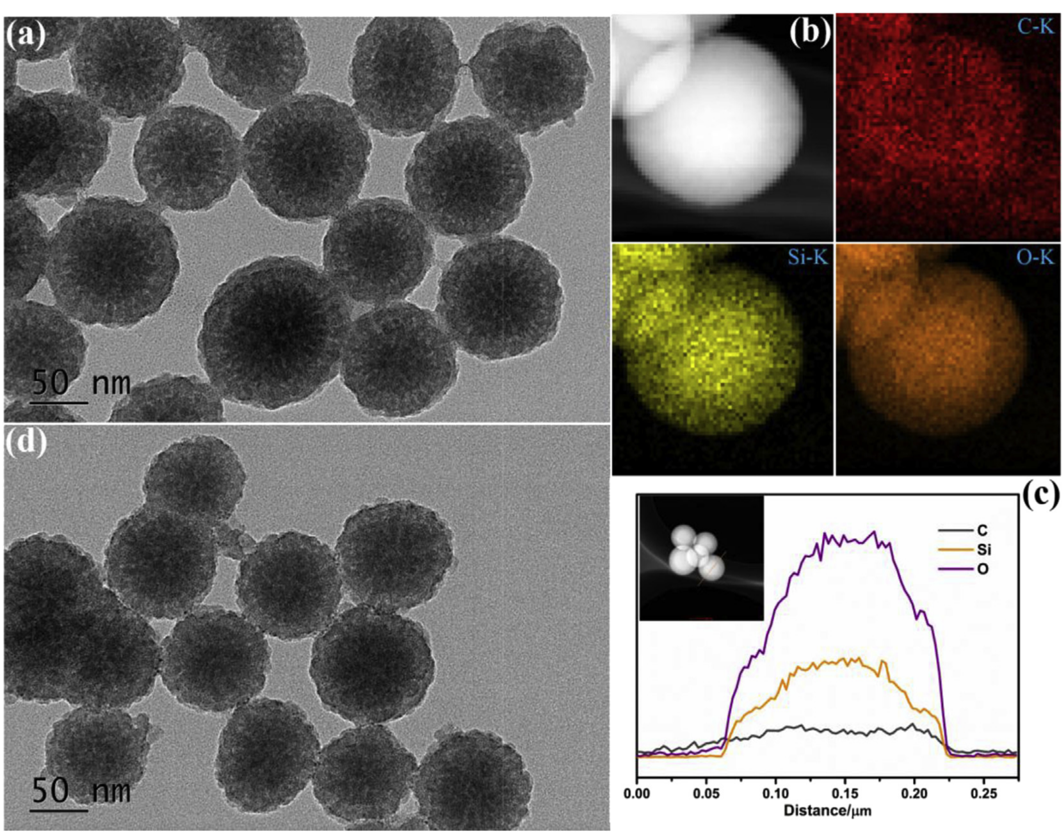

Fig. 2. TEM images (a), elemantal mapping (b), line scanning of precursor SiO_2@SiO_2/resin (c); and SiO_2@SiO_2/carbon after carbonization of precursor(d). (A colour version of this figure can be viewed online.)