Synthetic Metals 224 (2017) 18–26

Contents lists available at ScienceDirect

Synthetic Metals

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

Improving microwave absorption of the polyaniline by carbon nanotube and needle-like magnetic nanostructures

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ARTICLE INFO

Article history:
Received 22 August 2016
Received in revised form 24 November 2016
Accepted 25 November 2016
Available online 23 December 2016

Keywords:
Polyaniline
Magnetic nanostructures
CNT
Microwave absorption
Needle like

ABSTRACT

In this work, the microwave absorption of the polyaniline (PANI) was improved with various needle like magnetic nanomaterials. Several nanocomposites such as PANI–CNT, PANI–$CoFe_2O_4$, PANI–$NiFe_2O_4$, PANI–CNT–$CoFe_2O_4$, PANI–CNT–$NiFe_2O_4$ and PANI–graphene were successfully synthesized. The products were investigated by various analysis techniques such as X-ray diffraction pattern (XRD), energy dispersive X-ray spectroscopy (EDS), Fourier transform infrared spectroscopy (FT-IR), Raman spectroscopy, scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The results showed that the products were well crystallized. Also, in order to prove the synthesis of the nanocomposites, the products were analyzed with FT-IR and Raman spectroscopy. The morphology of the products was obtained by SEM and TEM images and it was found that CNT and magnetic nanostructures were well dispersed in the polymer matrix. Magnetic properties of the products were studied by alternating gradient force magnetometer (AGFM). Microwave absorption behavior of the products was investigated in detail and it was found that PANI–CNT–$NiFe_2O_4$ nanocomposite showed the best microwave absorption behavior. In fact, when both CNT and ferrite nanostructures are added to the polymer matrix, they improve the absorption value. Moreover, the results showed that the morphology of the magnetic nanomaterials has a significant effect on the microwave absorption value. In fact, due to high active surface of needle like magnetic nanostructures, they can absorb more microwave radiation.

1. Introduction

Until now, conducting polymers have gained much attention due to their unique applications in the second batteries [1] sensors [2], and diodes [3] and also improvement of corrosion inhibition [4], and electromagnetic shielding [5,6] by them. Microwave absorption properties of these polymers are due to electrical conductivity and presence of bound/localized charges leading to strong polarization and relaxation effects [7–9]. Magnetic materials have gained attention to use beside the conducting polymers to improve the microwave absorption. Until now, some works have done on the microwave absorption of the magnetic materials in the nanocomposite systems [10–13]. But their high density limited their applications [14]. So, beside the magnetic nanomaterials, other kinds of nanostructures such as carbon nanomaterials have used in this field. Wide absorption frequency range, strong absorption properties, low density, good thermal stability and antioxidant capability are ideal microwave absorbers features [14]. Because of a conducting polymer doesn't have all the features, nanomaterials can be a good candidate to aid the polymer for microwave absorption. For example, carbon nanomaterials, especially carbon nanotubes are a good choice to add the polymer due to their low density and high electron conductivity [15–24]. Thermal stability of the polyaniline is increased by adding ferrite and CNT in the polymer matrix. Gandhi and et al. [10] have studied the effect of adding $CoFe_2O_4$ to the polyaniline matrix on the polymer thermal stability. It was found by adding cobalt ferrite to the polymer matrix; its thermal stability was improved. This enhancement in the thermal stability can be accounted due to some ionic interaction of the $CoFe_2O_4$ with amine group of aniline ring and may form a coordinate bond between the Fe-N as the Fe has incomplete d-orbital to which ANH_2 group can donate his lone pair of electrons. In addition, adding CNT to the polymer matrix improve the thermal stability of the polymer. The retardation of degradation of the polymer is likely to be a result of absorption, by the activated carbon surface, of free-radicals generated during polymer decomposition [25]. Also, the increased thermal stability

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http://dx.doi.org/10.1016/j.synthmet.2016.11.034

of MWCNT/PANI over that of the pure PANI was explained by (i) the long conjugate π–π bond formed between PANI and MWCNT [11,12]. In this experimental work, we synthesized different polyaniline nanocomposites contained carbon nanotube, $CoFe_2O_4$, and $NiFe_2O_4$ and investigated the microwave absorption behavior. The main reason for choosing polyaniline as polymer matrix is that this polymer is an excellent conducting polymer and has an outstanding environmental stability and it can be easily doped [26]. The products were analyzed via various analysis. The results showed that by adding magnetic nanomaterials and carbon nanotube to the polymer, microwave absorption is improved significantly. Also, it was concluded that the morphology of the magnetic nanomaterials has a key role in the microwave absorption behavior. Based on our knowledge, there are few works related to the investigation the effect of magnetic nanomaterials morphology on the microwave absorption. In addition, in this work, two magnetic nanomaterials were used to increase the microwave absorption of the polymer matrix and the microwave absorption was improved by adding CNT into the polymer matrix.

2. Experimental

All the materials were of the analytical grade and used without further purification. Product physicochemical properties were investigated by the X-ray diffraction pattern (XRD) recorded via a Rigaku D-max C III, X-ray diffractometer using Ni-filtered Cu $K\alpha$ radiation. Scanning electron microscopy (SEM) images were taken by Philips XL-30ESEM equipped with an energy dispersive X-ray (EDX). Fourier transform infrared (FT-IR) spectra were recorded on Shimadzu Varian 4300 spectrophotometer in KBr pellets. Transmission electron microscopy (TEM) images were obtained on a Philips EM208 transmission electron microscope with an accelerating voltage of 200 kV. Room temperature magnetic properties

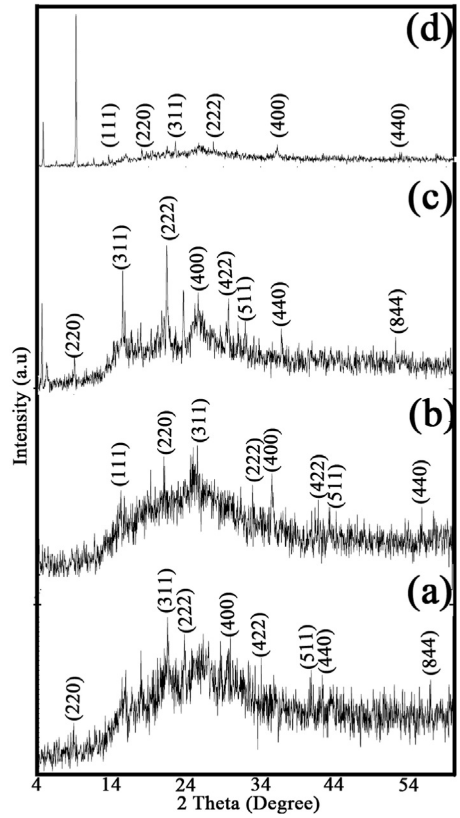

Fig. 1. XRD pattern of (a) $PANI/CoFe_2O_4$ and (b) $PANI/NiFe_2O_4$, (c) $PANI/CNT/CoFe_2O_4$ and (d) $PANI/CNT/NiFe_2O_4$.

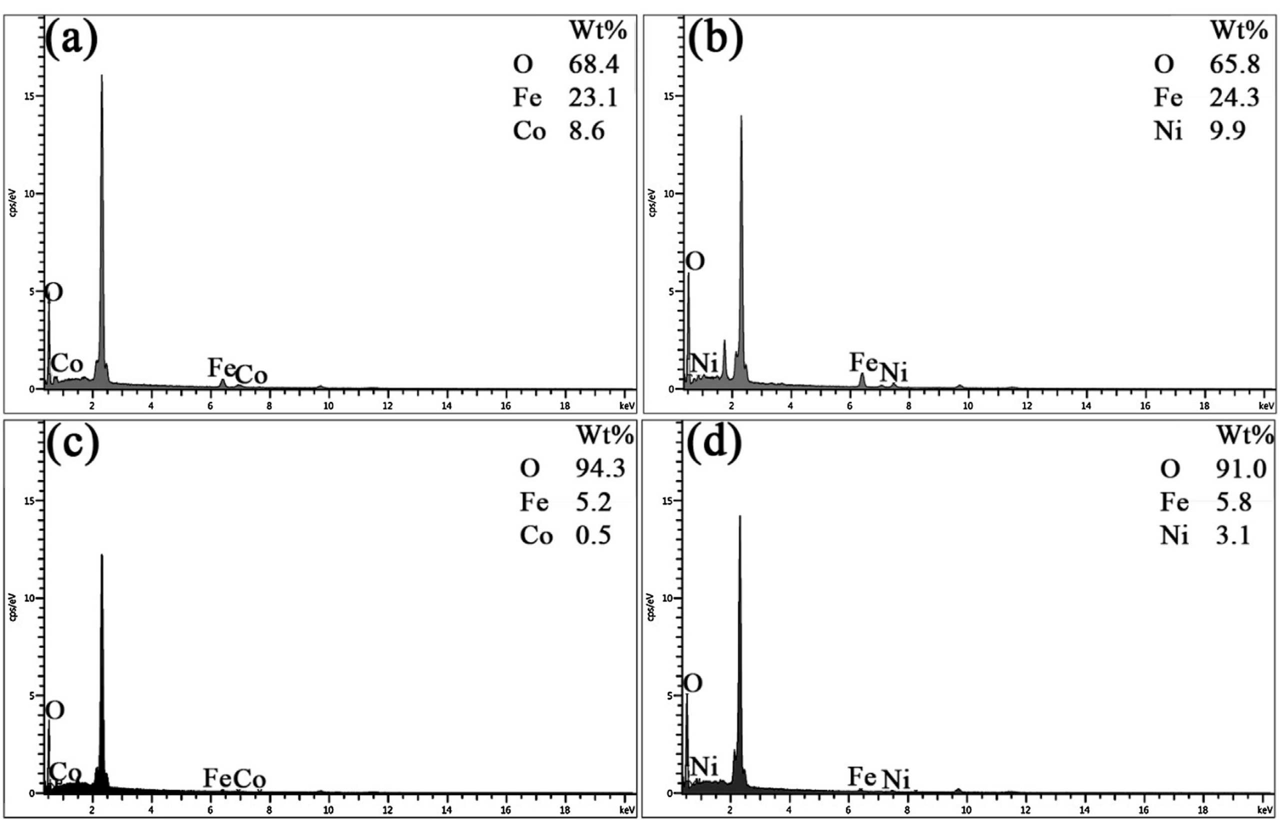

Fig. 2. EDS spectra of (a) PANI–$CoFe_2O_4$, (b) PANI–$NiFe_2O_4$, (c) PANI–CNT–$CoFe_2O_4$, and (d) PANI–CNT–$NiFe_2O_4$.