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Investigation of microwave absorbing properties for magnetic nanofiber of polystyrene–polyvinylpyrrolidone

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ABSTRACT

Aligned magnetic blend of polystyrene–polyvinylpyrrolidone (PS–PVP) nanofibers were prepared by this method. First, polystyrene–polyvinylpyrrolidone (PS–PVP) blend solution in THF was synthesized. Then magnetic of PS–PVP–Fe_3O_4–polyethylene glycol (PEG) was prepared by masking method. Finally, magnetic nanofiber of PS–PVP–Fe_3O_4–PEG was prepared by electrospinning method, too. An electric potential difference of 25 kV was applied between the collector and a syringe tip, and the distance between the collector and the tip was 13 cm. Fe_3O_4 is exhibit various magnetic properties of which the complex permeability and the permittivity, in particular, are important in determining their high frequency characteristics. The magnetic oxide particles and nanofiber of nanometer size were characterized by TEM and SEM respectively. The thermal properties of nanofibers were determined by TGA and DSC. The magnetic characterization of the fibers was also performed by VSM and AFM techniques. On the other hand, nanofiber with diameters ranging from 30 to 40 nm, showing at room temperature, coercive field values of around 25 kV and saturation magnetization was 1.1 emu/g. Microwave reflection loss of the sample was tested at 8–12 GHz microwave frequencies and the results showed that magnetic nanofiber possessed the microwave absorbing properties.

1. Introduction

Many types of radar absorbing materials are commercially available and, at present, the most cost effective means of shielding radar radiation, controlling electromagnetic interference and dissipating electrostatic charge is to use either magnetic or dielectric fillers [1] or intrinsically conducting polymers [2].

Magnetic absorption materials made by dispersing magnetic fillers in an insulating matrix continue to play an important role in the investigation and application of microwave absorption materials [3]. As ferrites can avoid the skin effect at high frequency and make the electromagnetic wave enter effectively due to their high resistivity, they can attenuate electromagnetic wave efficiently. In addition, for its higher efficiency and lower cost than that of other materials, they have been among the most popular conventional magnetic fillers. However, for a long period of time, much attention about ferrites has been focused on researching microwave absorption properties of new types of ferrites [4,5]. We have reported synthesis of nanocomposites containing some of ferrites compounds and investigated their microwave absorption properties [6,7].

Nanofibers are fibers that have diameter equal to or less than 100 nm. Considering the potential opportunities provided by nanofibers there is an increasing interest in nanofiber technology. Amongst the technologies including the template method [8], vapor grown [9], phase separation [10] and electrospinning has attracted the most recent interest. Electrospinning is a simple and versatile method for generating ultrathin fibers from a rich variety of materials that include polymers, composites and ceramics [11].

In this paper, the main object is to develop a fiber compounds with microwave absorption properties. So we have synthesized magnetic nanofiber with polystyrene–polyvinylpyrrolidone–Fe_3O_4–polyethylene glycol, PS–PVP–Fe_3O_4–PEG.

2. Experimental

2.1. Material

Polystyrene (Merck chemical Co.) and polyvinylpyrrolidone (Merck chemical Co.) and ferrous sulfate heptahydrate and polyethylene glycol (Mw: 4000). Tetrahydrofuran (THF, 99.5%, Duksan

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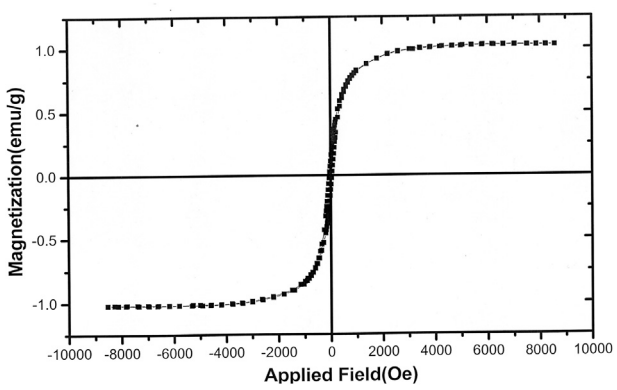

Fig. 1. Magnetization vs. applied field plot for PS–PVP–Fe_3O_4–PEG nanofibers at room temperature.

chemical Co.) and hydrogen peroxide and chloroform were used as solvent.

2.2. Measurement of properties

An ultrasonic reactor (Bandelin Sonorex Digitec) was used to provide the ultrasonic field. The physical properties of nanofibers and topographic pictures of nanofibers were studied by Atomic Force Microscopy (AFM). Transition electron microscopy (TEM) measurements were performed using PHILIPS EM 208. One drop of the sample solution was deposited on to a copper grid and the excess of the droplet was blotted off the grids with a filter paper. The sample was dried under ambient conditions. The nanoparticles size & morphology were observed by TEM images. The magnetic properties of fibers and magnetic nanoparticles were measured by a Vibrating Sample Magnetometer (VSM), The morphology of fibers was examined by Scanning Electron Microscopy (SEM, PHILIPS XL30). Microwave absorbing properties were measured by a Vector Network Analyzers (Agilent Technologies Inc. 8722) in the 8–12 GHz range at room temperature.

2.3. Synthesis of Fe_3O_4 nanoparticles

Fe_3O_4 Nanoparticles were prepared by Core–Shell system. First, 70 g of PEG (Mw: 4000) and 3 g of $FeSO_4 \cdot 7H_2O$ were solved in 140 ml of distilled water. This solution was transferred to a three-neck flask equipped with a condenser and nitrogen gas inlet and outlet with vigorous stirring for 30 min. Then 20 ml of H_2O_2 20% was added to the solution. This reaction was performed at 50 °C for 6 h at pH: 13. The pH of the reaction was set with NaOH 3 M. Then the solution was centrifuged. The Fe_3O_4 magnetic nanoparticles were prepared.

2.4. Preparation of the blend solution

The polystyrene–polyvinylpyrrolidone (PS–PVP) blend solution was prepared. A 4:1 mole ratio of PS and PVP were dissolved in THF to a final concentration of 11 wt%. The solution was then stirred at room temperature at 1000 rpm for a period of 7 h using a mechanical stirrer, and then filtered through a filter paper to remove any particulate matter. Finally, by adding Fe_3O_4-PEG to the filtered solution, magnetic PS–PVP–Fe_3O_4–PEG solution was prepared, which was then stirred for a period of 2 h. This solution was made using the following procedure.

2.5. Electrospinning

Electrospinning, have only 6 or 7 molecules across. The PS–PVP blend and PS–PVP–Fe_3O_4–PEG nanofibers were synthesized on an aluminum electrode (10 cm × 10 cm). An electric potential difference of 25 kV was applied between the collector and a syringe tip, and the distance between the collector and the tip was 13 cm. Although we tried to fabricate the same number of blend nanofibers as composite nanofibers on the electrode, a slightly different number of both fibers were generated and collected.

3. Results and discussion

The electrospinning process has been documented using a variety of fiber forming polymers. By choosing a suitable polymer and solvent system, nanofibers with diameters in the range of 40–2000 nm be made. Magnetization studies have shown that the magnetic PS–PVP–Fe_3O_4–PEG nanofibers exhibit superparamagnetic behavior and shows no hysteresis. The magnetic characterization of the fibers was performed by Vibrating Sample Magnetometer (VSM) and Atomic Force Microscopy techniques. The magnetization curve of PS–PVP–Fe_3O_4–PEG nanofibers is presented in Fig. 1. An electric potential difference of 10 kV was applied between the collector and a syringe tip, and the distance between the collector and the tip was 13 cm. On the other hand, nanofiber with diameters ranging from 30 to 40 nm, showing at room temperature, coercive field values was around 25 kV and saturation magnetization was (M_r = 1.1 emu/g).

In our study, the physical properties of PS–PVP–Fe_3O_4–PEG nanofibers were exhibit by Atomic Force Microscopy (AFM) with different size. The dark spots that were shown like tops are

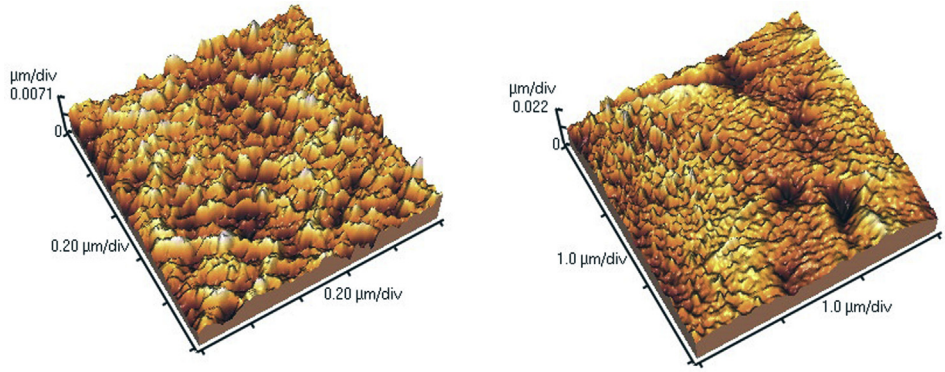

Fig. 2. AFM images of electrospun nanofibers of PS–PVP–Fe_3O_4–PEG.