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Iron-based nanomaterial sheets for electromechanical applications

Indradeep Kumar *, C. Dhanasekaran

Department of Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies (VISTAS), Chennai 600117, India

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ABSTRACT

Now a day's Single-Walled Carbon nanotubes (SWCNTs) having the greatest attention on the earth. This area favors a 2-D graphene sheet configurationally which is rolled up into a hollow cylindrical structure. Having just one surface or wall of the cylinder, the cylindrical formation is named as Single-Walled Carbon Nanotubes. The structure appears sort of a set of cylinders having the same center with a continuing layer separation of 0.34 Å termed as multi-walled carbon nanotubes. A mixture of Nanopowder of iron oxide and a blend of Single-Walled Carbon Nanotubes provides great promising properties towards the Electromechanical applications by enhancing their electrical and mechanical properties. In this paper, we will discuss the characteristics and behavior of the newly synthesized nanoparticle sheet whose major constituent is iron. This paper will also explore the advantages and disadvantages of the conventional Iron sheets used in electromechanical applications. for synthesizing the nano iron sheets, among different methods we used the nano-emulsion method in which we mixed two nanoparticles in a different phase to get the desired result.

Selection and Peer-review under responsibility of the scientific committee of the 2nd International Conference on Nanoscience and Nanotechnology.

1. Introduction

In the domain of nanoscale, the properties exhibited by the nanoparticle cannot be observed in bulk or counterpart of atoms. Therefore it is a great deal to prepare nanomaterials that provide desired characteristics. Because of synthesizing simplicity in the laboratory and their elegant characteristics, Iron Oxide Nanostructures (IONs) gains a unique position in between the other metal oxides of nano size. Iron oxide nanostructure-based material, exploited for different purposes in various research because of their magnetic, optical, electrical, and catalytic behaviors. Despite that, in some cases, it is necessary to combine IONs with other nanostructured materials to forms enhanced properties nanocomposites. Concerning this Single-Walled Carbon Nanotubes (SWCNTs), a valuable option having great potential for synthesizing the nanocomposites. This hybridized nanocomposites can be used for developing a new class of electrical and mechanical components or in other words in electromechanical applications like transformers, inductor, bobbins and other electromechanical components, to increase the life span of the components and to prevents from the hazard because of malfunctioning, like overheating causes fire, etc. This paper describes Fe_3O_4(IONs)-SWCNTs nanocomposite for electromechanical applications and stared with the introductory information and preparation of IONs and SWCNTs separately. Various types of iron oxides are available in nature amongst them mostly hematite, maghemite and magnetite are found in nature. By reducing or oxidizing annealing process all forms of iron oxide can be converted in other forms.

1.1. Iron oxides nanostructures

Many researchers used earlier hematite, maghemite, and magnetite iron oxides for their research to form nanocomposite Therefore in this paper we are mainly focusing on Magnetite (Fe_3O_4).

1.1.1. Magnetite (Fe_3O_4)

Magnetite ($Fe^{II}Fe^{III}_3O_4$) is also named as iron (II, III) oxide or ferrous ferrite. Magnetite molecular formula Fe_3O_4 can be depicted as FeO_Fe_2O_3. Magnetite having the strongest magnetism among all the natural minerals. It differs from all other iron oxides because this having Fe^{++} and Fe^{+++} ions both at the same time. Fe_3O_4 having CCP structure forming cubic inverse spinal structure.

1.1.2. Single-walled carbon nanotubes (SWCNTs)

Graphene sheets rolled in the cylindrical formed are known as carbon nanotubes. Generally, two types are depending upon the number of graphene sheets used. If one graphene sheet is rolled

* Corresponding author.
E-mail address: indradeep1989@gmail.com (I. Kumar).

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Fig. 1. Experimental setup.

in the cylindrical form then it is known as Single-walled carbon nanotube and if more number of the sheet is rolled concentrically then it is known as multi-wall carbon nanotubes. The Young's Modulus of SWCNTs having greater than 1 TPa and the Tensile strength is around 200Gpa. The thermal conductivity can be higher up to 2500 W/mK. With a perfect mass to weight ratio, a very small radius of the tip of the curvature, and sensible heat emitting properties, SWCNTs have proven that it is a wonderful candidate for emission.

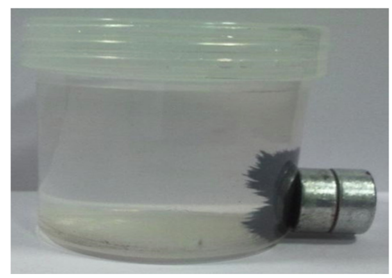

Fig. 2. Fe_3O_4 blend.

Fig. 3. SWCNTs Blend (1) 30PPM, (2) 60PPM.

2. Materials and methodology

The research objectives achieved through three hypothesis-driven tasks. Task 1 focuses on the synthesis of highly dispersed and stable nanoparticles like Iron oxide nanopowder and blends of Single-Walled Carbon nanotubes. The optimal stabilizers will be determined by Single-Walled Carbon Nanotubes (SWCNTs) based on effectiveness, environmental friendliness, and cost [3]. Then Iron oxide nanoparticles will be synthesized with the aid of selected low-cost and "green" stabilizers [1]. Task 2 was characterized and tested the particle size, surface area, and long-term stability of the stabilized nanoparticles and was measured with state-of-the-art microscopic, spectroscopic techniques. Task 3 was validated with the bench-scale experimental results through pilot-scale testing and test the feasibility of formed material.

3. Synthesizing of Fe_3O_4-SWCNTs composites

3.1. Nano-emulsion method

Nano-emulsion can be defined as the isotropic dispersion of relatively two immiscible liquids which is thermodynamically stable and that is stabilized by anionic, cationic and/or non-ionic surfactants, generally along with a co-surfactant which is widely used to obtain IONs. Depending upon the relative concentrations, molecules of surfactants self-assembled in various structures in the mixture (experimental set up is shown in Fig. 1). Much different technique can be used to synthesized nanoparticles using the nano-emulsion method. For example, Fe_3O_4 IONs can be mixed with SWCNTs (30 PPM and 60 PPM) (shown in Fig. 2) in blend form to produce nanoparticles in the form of precipitate using nano-emulsion method shown in Fig. 3. Based on the molecule of surfactant, relative concentration, and in vesicles, micelles, and bi-layer self-assembly of the molecule of surfactant. However, commonly used structures are micelles in the synthesis of nanoparticles either as reverse or normal micelles. The produced size of the droplets which are monodispersed varies from 5 to 100 nm in both cases. for synthesizing particles in nanoscale confined environments are provided by these dispersed phases only. During the formation of nanoparticles, nano-environments produced by the surfactant-covered alcohol pools, and at the same time, it's limiting the growth of nanoparticles. The droplet size of the nano-emulsion is directly proportional to the surfactant to alcohol ratio, although due to other factors like reactants concentration and surfactant film flexibility the nanoparticle's final size may also be changed. For synthesizing the composites various ways can be used in the nano-emulsion method. For example, precursor A and Precursor B are mixed in the alcoholic phase of two similar nano-emulsion to produce a precipitate of AB. The interior of the droplets determines the shape and size of the particles of precipitate AB (Fig 4).

4. Results and discussion

The magnetic properties of the synthesized pure Fe_3O_4 IONs and Fe_3O_4 IONs-SWCNTs nanocomposites are shown by the M–H curve in Fig. 5. The phase purity morphology and microstructure of the

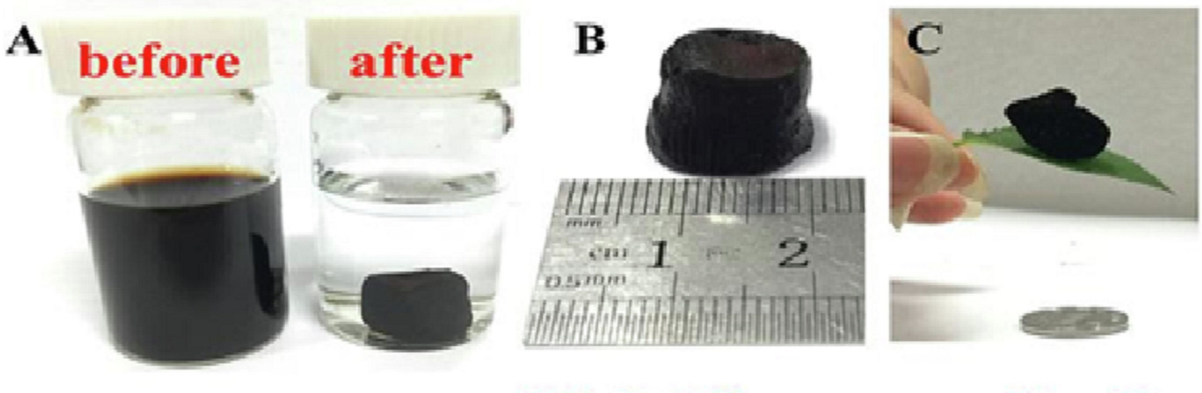

Fig. 4. Formation of composite.

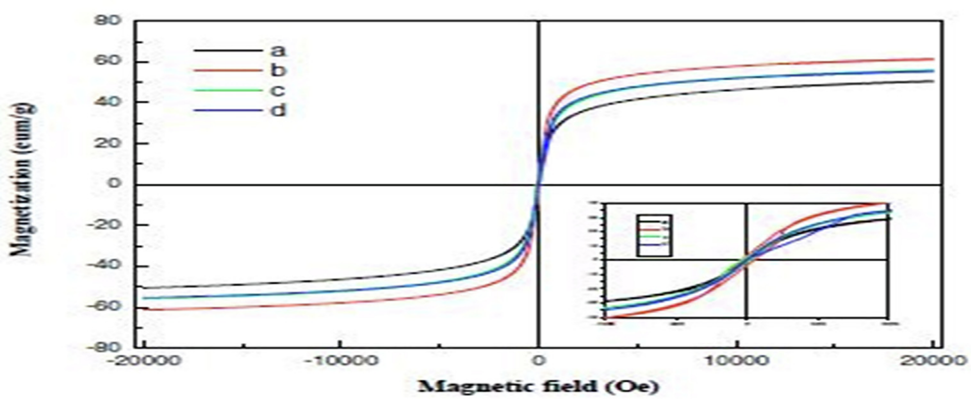

Fig. 5. Hysteresis curve of the samples.

samples were investigated by Transmission Electron Microscopy (TEM), Electron Diffraction, and Scanning Electron Microscope (SEM) [2]. Magnetic Properties were investigated at 25 °C with the help of a Vibrating sample magnetometer in the presence of applied magnetic field [2,4–6].

4.1. Characterization

The crystal phase and structure of the specimen were investigated by X-Ray Diffraction (XRD) method. Fig. 6 demonstrates the patterns of XRD of bare Fe_3O_4 IONs and Fe_3O_4 IONs-SWCNTs nanocomposites. The diffraction peak shown in both the specimen is similar which are 012, 104, 110, 113, 024, 116, 018, 214, and 300.

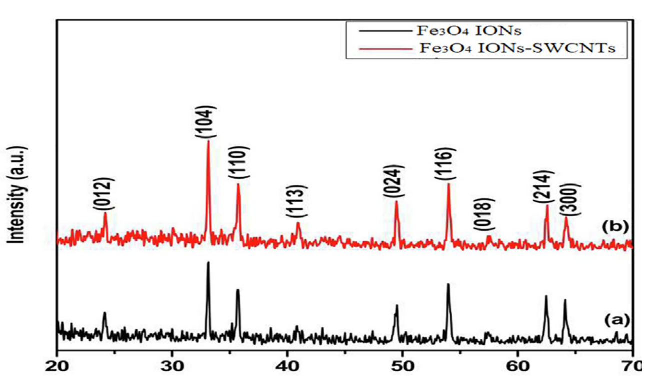

Fig. 6. XRD pattern of the samples.

Higher crystallinity can be predicted by the intense and sharp peaks of diffraction. Peaks also indicate sample purity. The composition of the element and the surface morphology of the nanocomposites were examined by TEM, SEM, and HRTEM also. TEM images of the samples are shown in Fig. 7. From the TEM images, it is clear that the SWCNTs are dispersed over the Fe_3O_4 IONs. TEM images also show two-dimensional plates of SWCNTs having a size of about 30 to 50 nm and 3 to 5 nm in thickness. A larger plate of Fe_3O_4 IONs which can be seen clearly in grey color particle in Fig. 3a. After the reduction, the SWCNTs particle having dark in color became covered by Fe_3O_4-IONs which has a light grey color. Hence the composite of Fe_3O_4-IONS and SWCNTs forms under annealing at 900 °C [7,8].

The SEM image which is shown in Fig. 8 shows the tubular morphology of the Fe_3O_4 IONs-SWCNTs nanocomposites. The length of the formed nanotubes is around 120–370 nm, the inner diameter of 30–50 nm, and an outer diameter of 70–100 nm. The presence of Fe_3O_4 IONs and SWCNTs confirms by HRTEM shown in Fig. 9.

5. Applications

5.1. Biomedical

Synthesized composites can be used for contrast agents in MRI, labeling of the cell, handling and separation of cells, drug released in a controlled way, magnetofection, cell purifying, magnetic separation, and in severe inflammation.

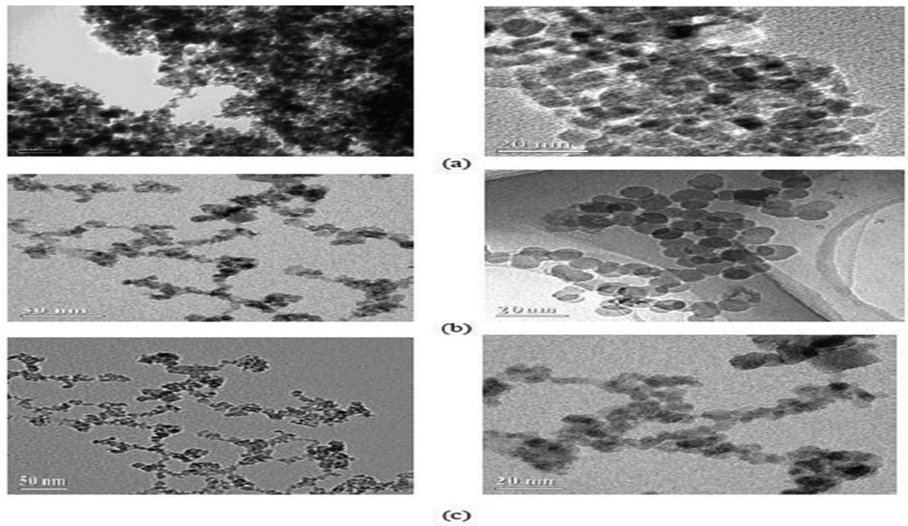

Fig. 7. TEM image of Fe_3O_4-SWCNTs various samples.

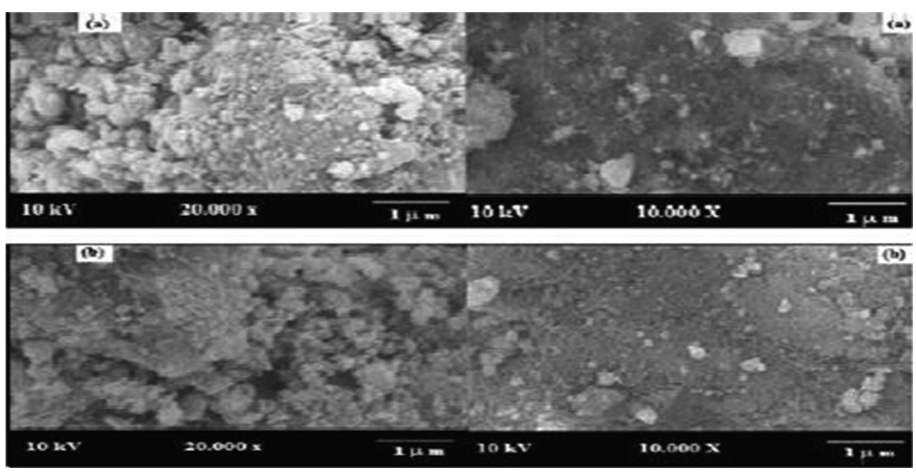

Fig. 8. SEM micrographs showing the morphology of iron oxide and SWCNTs Mixture, (a) 30 min, and (b) 90 min [3].

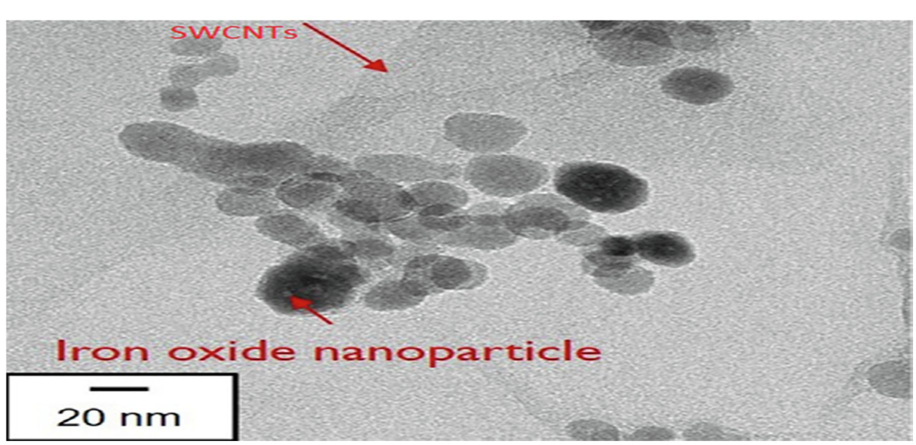

Fig. 9. HRTEM image of Fe_3O_4-SWCNTs composite.

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5.2. Food and agriculture

This can be used as a crop boosting product. Before sowing seeds the seed can be treated with the composites. This can also be used in the packaging of food, encapsulations, remote sensing devices, etc.

5.3. Health care

Imaging and nanoscale biosensor, therapeutic targets in tumor or cancer, antigen deliver system, in pulse laser for treatment, and water treatment.

5.4. Energy

Coating of photovoltaic film, to increase fuel efficiency, as a catalyst in Biofuels, in batteries and fuel cells as the electrode, in solar panels, homes, automobiles, power plants, etc.

5.5. Defense

Electronics and sensors, nanocomposites, nanowires, and smart materials in the structure.

6. Conclusion

This research directly addresses the priority need for research "concerning the applications of nanotechnology in electromechanical components". New class nanosheets which were synthesized by combining of Nanopowder of Iron Oxide and Single Walls Carbon Nanotubes (SWCNTs), having physically stable, thermally powerful, and environmental friendly nanosheets and characterized, and a cost-effective, higher strength to weight technology based on the new materials was developed for electrical components like transformers, inductor, bobbins and other electromechanical components, to increase the life span of the components and to prevents from the hazard because of malfunctioning, like overheating causes fire, etc.

By the use of the Nano Emulsion method in which thermodynamically stable two immiscible substances which were stabilized by non-ionic, anionic, or cationic surfactants, can obtain the nano clay of mixture of nanopowder of Iron oxide and SWCNTs. The formed nanosheets from the nano clay having improved electromechanical properties like high strength to weight ratio, almost negligible rusting ability, Damage-tolerance, and thermal protection and control was achieved.

This research was carried out with two different quantity of SWCNTs namely 30 PPM and 60 PPM so the researcher may investigate with a higher proportion like 100 PPM or more to get the different and desired results.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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