PROCEEDINGS OF THE INTERNATIONAL CONFERENCE NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. **2** No 2, 02PCN46(3pp) (2013)

The Effects of Fuel Type Above Magnetic Properties of the Nickel Ferrite Nanoparticles Synthesized with Microwave Method

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(Received 16 July 2013; published online 03 September 2013)

The synthesis of nickel ferrite nanoparticles was used various fuel substances such as glycine, urea and citric acid. The mixture prepared in stoichiometric rates was put in to the kitchen type microwave oven. In the end of reaction time was obtained a brown-black solid. The obtained solid was characterized with X-Ray Powder Diffraction and Scanning Electron Microscopy. The results of this analysis showed that all of the obtained particles have got nano-size particle size distribution. To determine the magnetic properties of the nanoparticles were analyzed by using a vibrating sample magnetometer. Fuel type used in synthesis is quite effective on the magnetic properties of $NiFe_2O_4$ nanoparticles.

Keywords: $NiFe_2O_4$, Nanoparticles, Magnetization

PACS numbers: 61.46.Df, 07.55.Ge

1. INTRODUCTION

Nanotechnology is area of intense scientific research, due to a wide variety of potential applications in biomedical, optical, and electronic fields. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures.

The properties of materials change as their size approaches the nanoscale and as the percentage of atoms at the surface of a material becomes significant. For bulk materials larger than one micrometre the percentage of atoms at the surface is minuscule relative to the total number of atoms of the material.

Synthesis and applications of nanoparticles of spinel ferrite structured is one of the most important research subjects due to their remarkable chemical and physical possessions like magnetic properties in recent years. The nanoparticles have been used in many applications, including ferrofluids, catalysts, microwave devices, gas sensors, and magnetic materials. The type of nickel ferrite with spinel structure is an essential composite material for the production of electronic and magnetic components that are extensively used in advanced technological applications to some remarkable of them are magnetic ferrofluids, dense information storage system and high frequency systems. [1,2].

Various chemical and physical techniques have been developed for the synthesis of NiFe2O4 nanoparticles such as sol-gel, hydrothermal, co-precipitation, aerosol, microwave, etc. that have the advantages for instance the low cost, low reaction time, large scale production. Common problems for many of these techniques are factors such as complex processes, expensive precursors and low production rates. [3,4].

Alike the techniques, the combustion method is a promising chemical method for preparation of various nano-sized ferrites in laboratory and semi-pilot scale that is fast and safe furthermore enables the formation of nano-sized metal oxide particles and allows to produce the ferrites without need of sophisticated equipments. Organic compounds like glycine, urea, citric acid, alanine etc. are used as fuels in the combustion method, suitable that they can be mixed directly with the metal salts to enhance the efficiency of the synthesis. Among the organic compounds, urea seems to be the most commonly used compound that it appropriately is cheap, readily available, non toxic and safe. In the present study, synthesis of nickel ferrite ($NiFe_2O_4$) nanoparticles via microwave-assisted combustion is investigated using urea, citric acid, glycine as fuel. [5,6].

2. EXPERIMENTAL

2.1 Synthesis

Analytical grade nickel nitrate hexahydrate ($Ni(NO_3)_2.6H_2O$), ferric nitrate nonahydrate ($Fe(NO_3)_3.9H_2O$) and fuel substances were purchased from Sigma- Aldrich. Nickel nitrate, ferric nitrate and fuel substances were mixed in stoichiometric ratios, instantly the mixture was formed due to hygroscopicity of metal nitrates which absorbs the moist from the air therefore this method does not require use of water or any solvent. The composition of the synthesis mixture was given in Table 1.

Table 1 – The composition of the synthesis mixture

The Sample	Composition of the synthesis mixture
NFU	($Ni(NO_3)_2.6H_2O$, ($Fe(NO_3)_3.9H_2O$), Urea
NFC	($Ni(NO_3)_2.6H_2O$, ($Fe(NO_3)_3.9H_2O$), Citric Acid
NFG	($Ni(NO_3)_2.6H_2O$, ($Fe(NO_3)_3.9H_2O$), Glycine

Then, the mixture was placed in a laboratory-type microwave oven at a maximum power of 800 W for 10 min. When the solution reached the point of spontaneous combustion, it started burning by releasing a very dense gas and heat, than the sample instantaneously becomes a solid.

3. RESULTS

The $NiFe_2O_4$ nanoparticles were prepared with microwave assisted combustion method. In this method, three different chemical substances were used as fuel. The used fuels are urea, glycine and citric acid. The prepared nanoparticles were characterized with SEM and XRD analysis. X-Ray diffraction patterns of the obtained particles were given in Fig 1.

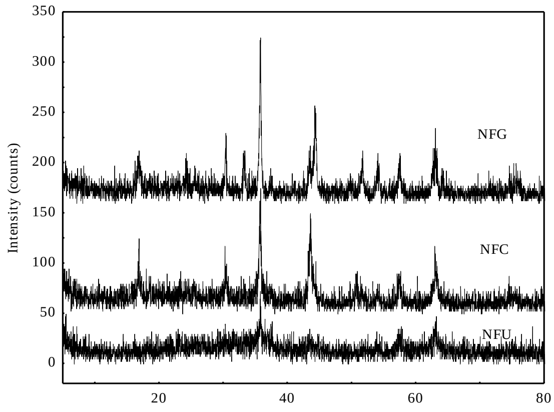

Fig. 1 – X-Ray diffraction patterns of the nanoparticles

The SEM images of the $NiFe_2O_4$ synthesized by using urea as fuel were given in Fig. 2.

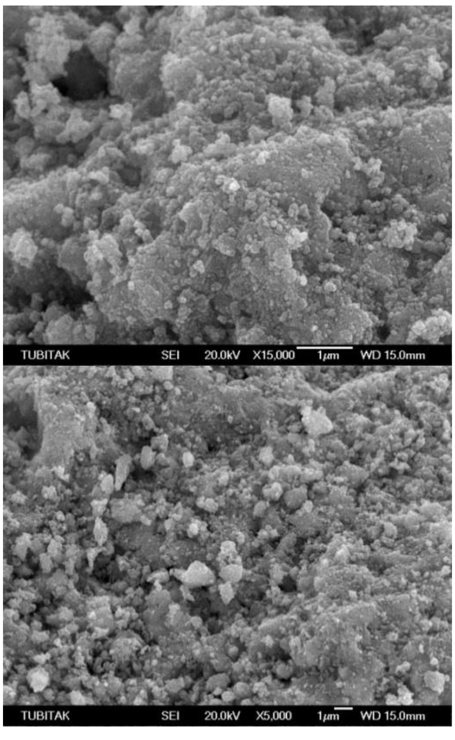

Fig. 2 – The SEM images of the $NiFe_2O_4$ synthesized by using urea as fuel

The aim of this study is to investigate the effect of fuel type above magnetic properties of $NiFe_2O_4$ nanoparticles synthesized with microwave assisted combustion method. Accordingly; the nanoparticles synthesized by using three different fuels. This fuels are glycine, urea and citric acid. The fuel type used in synthesis of nanoparticles with microwave assisted combustion method is quite effective above the cyristal structure of nanoparticles. The cyristal structure is the most important parameter on the magnetic properties of the nanoparticles. The magnetic properties of nanoparticles were measured by using a vibrating sample magnetometer system (VSM). Finally, a Cryogenic Limited PPMS was used to probe the dc (extraction method) and ac magnetization at room temperature, for fields up to 3 T.

The hysteresis loop curves of the samples were formed with the measured experimental datas. The obtained results were given ghrapically in Fig.3.

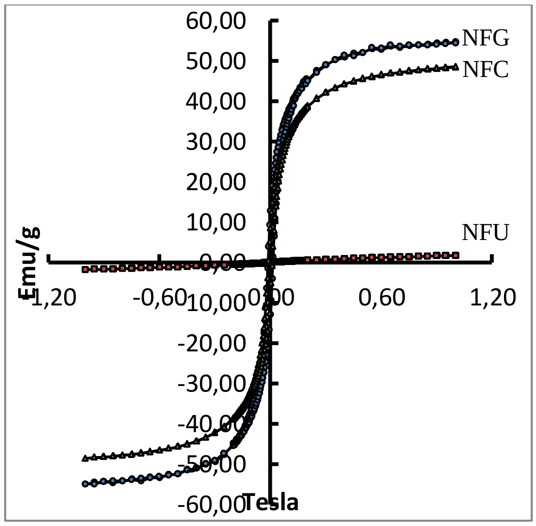

Fig. 3 – The hysteresis loop curves of the nanoparticles prepared with various fuels

The observed increase or decrease can be due to many factors. Cation redistribution, the existence of surface spins or the formation of spin glass structure can all influence the magnetic properties at the submicron sizes. The presence of a dead layer has also been thought to be one of the reasons for the reduced magnetization in the ultrafine regime [8].

The magnetic properties of materials are dependent on the sample shape, crystallinity, magnetization direction, etc. [7]. The various magnetic properties like saturation magnetization, remanent magnetization and coercivity are estimated from the hysteresis curve. Magnetic characterization of the nickel ferrite nanoparticles is performed using vibrating sample magnometer (VSM) at room temperature with a maximum upto 10 kOe. Magnetic hysteresis loops of the nanoparticles produced at the different temperatures are shown in Fig. 8. All of the nanoparticles exhibit a ferromagnetic behavior at room temperature.

The saturation magnetization values of the nickel ferrite nanoparticles are observed to decrease with decreasing grain size. The linear decrease in saturation magnetization values is associated with the heat treatment temperature applied.

The saturation magnetization values (Ms), remnant magnetization (Mr) values and coercivity (Hc) values of the nanoparticles produced at the high temperatures were calculated from the hysteresis curve given in Fig. 8.

4. CONCLUSION

$NiFe_2O_4$ nanoparticles can synthesis with various methods such as combustion, sol gel, hydrothermal etc… In this study, $NiFe_2O_4$ nanoparticles were synthesized with microwave assisted combustion method. In this method; the some substances have to be used as fuel. The aim of this work was to investigate the effect of fuel type above magnetic properties of $NiFe_2O_4$ nanoparticles synthesized with microwave method. We observed that fuel type is quite effective on magnetic properties of the particles.

According to the hysteresis loop curves of the samples, the magnetic properties of the $NiFe_2O_4$ nanoparticles changed with fuel type. The all of the samples showed ferromagnetic behavior. But, the nanoparticles prepared by using glycine as fuel have got the more better saturation magnetization than the others.

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