Physical and Optical Properties of Nickel Ferrite ($NiFe_2O_4$) Nanoparticles Based on Iron Sand

L. Mahmudin(✉), Y. Ndora, and M. S. Ullum

Department of Physics, Universitas Tadulako, Palu, Indonesia
lufsyim14@yahoo.co.id

Abstract. Research has been conducted on the analysis of nickel ferrite ($NiFe_2O_4$) nanoparticles based on iron sand. The purpose of this study was to produce nickel ferrite nanoparticles and to determine the physical and optical properties of nickel ferrite nanoparticles. In this study, the synthesis of nickel ferrite ($NiFe_2O_4$) nanoparticles was carried out using the coprecipitation method and characteristic using XRF, XRD, and UV-Vis to determine the composition, crystal structure, and optical properties (absorbance) of nickel ferrite ($NiFe_2O_4$) nanoparticles. The results of the synthesis by the coprecipitation method obtained a solid black precipitate which indicated that the iron content was present. The characteristic result of nickel ferrite ($NiFe_2O_4$) nanoparticles ranged from 0.29 to 5.16 nm with a cubic spinel crystal structure. For each 6 g and 10 g sample, maximum absorption occurred at a wavelength of 350 nm with absorption peaks of 1.046966 and 1.220268 and FWHM 53.4415 nm and 43.95231nm respectively.

Keywords: Nickel ferrite Nanoparticles · Iron Sand · Coprecipitation

1 Introduction

Along with the development of industrial science and technology, especially in Indonesia which has abundant natural resources such as iron sand, it encourages researchers to create and realize new works by exploring existing natural resources, for example iron sand. One of the results of technological developments is technology engaged in nanoparticles by utilizing natural materials as one of the basic ingredients for their manufacture. Nanoparticles are particles that have a smaller diameter of around 1–100 nm and are formed from organic and inorganic materials [1]. One of the many nanoparticles currently being developed is nickel ferrite ($NiFe_2O_4$) nanoparticles.

Nickel ferrite ($NiFe_2O_4$) nanoparticles are soft magnetic materials with low coercivity but high resistivity, making them very suitable for magnetic field and magneto-optical applications. $NiFe_2O_4$ nanoparticles display a narrow hysteresis curve and thus, this material is very good for use in power transformers and applications in telecommunications. $NiFe_2O_4$ can also be used in sensor technology, gas, and humidity, and as a catalyst [2].

Several studies on nickel ferrite ($NiFe_2O_4$) nanoparticles that have been carried out include [3] conducting research on synthesizing nickel ferrite ($NiFe_2O_4$) nanoparticles

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using the co-precipitation method and characterization of its magnetic properties with varying concentrations of NaOH 3 M, 5 M and 10 M as a precipitating agent. [4] conducted a study on the effect of NH_4OH concentration on the size of nickel ferrite ($NiFe_2O_4$) nanoparticles synthesized by the co-precipitation method made from iron sand with varying concentrations of 3 M, 5 M, and 10 M NH_4OH.

From the description above, this research will analyze the physical and optical properties of nickel ferrite ($NiFe_2O_4$) nanoparticles synthesized by the coprecipitation method using NH_4OH as a precipitating agent with a concentration of 10 M and iron sand as a base material.

2 Experimental Methods

The material used in this research is iron sand, HCL (12 M), NiCl2, NH_4OH (10 M), and Aquadest. The steps for making nickel ferrite ($NiFe_2O_4$) nanoparticles are as follows. Iron sand was washed clean and then extracted. After that, the iron sand containing magnetic is mashed using a mortar and then sieved. The sieve results are then washed, dried using a furnace, and then tested for XRF.

The iron sand that has been extracted is then synthesized by the coprecipitation method. 10 g of iron sand were used and mixed with 20 ml of HCL (12 M) while stirring and heating using a magnetic stirrer equipped with a hot plate for 60 min at 60 °C until a precipitate of $FeCl_3$ was formed and then filtered. The precipitate formed was reddish yellow. Then the resulting solution was coprecipitated by mixing 25 ml of ammonium hydroxide solution (NH_4OH) with a concentration of 10 M and 2.37 g of $NiCl_2$ while stirring using a magnetic stirrer at 60 °C for 60 min. Furthermore, the precipitate formed is then washed thoroughly using distilled water to remove impurities. The precipitate formed is black and will then be calcined using a furnace with a temperature of 200 °C for 2 h to produce nickel ferrite ($NiFe_2O_4$) nanoparticle powder. XRD characterization is then carried out. For UV-Vis characterization, nickel ferrite ($NiFe_2O_4$) nanoparticles were diluted using 1 M HCL until they were almost clear and tested with a wavelength of 200–600 nm.

3 Results and Discussion

In this study, before carrying out the synthesis process, an initial characterization using XRF will be carried out to determine the composition of the iron sand sample and ensure that the sample contains magnetic. The characterization results can be seen in Fig. 1. Figure 1 shows that iron sand contains iron (Fe) compounds of 91.42%, titanium compounds (Ti) of 5.44%, and other compounds of 2.50%. The percentage yield is a relative calculation of the overall peak area that appears in the absorption pattern, meaning that the area of a certain peak is to be compared with the overall area of the peak that appears.

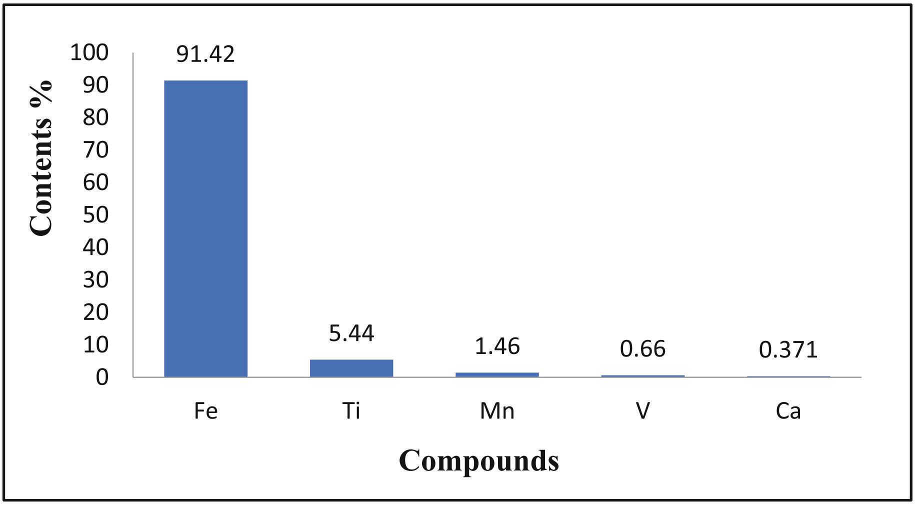

Fig. 1. Presentation results of iron sand content using XRF

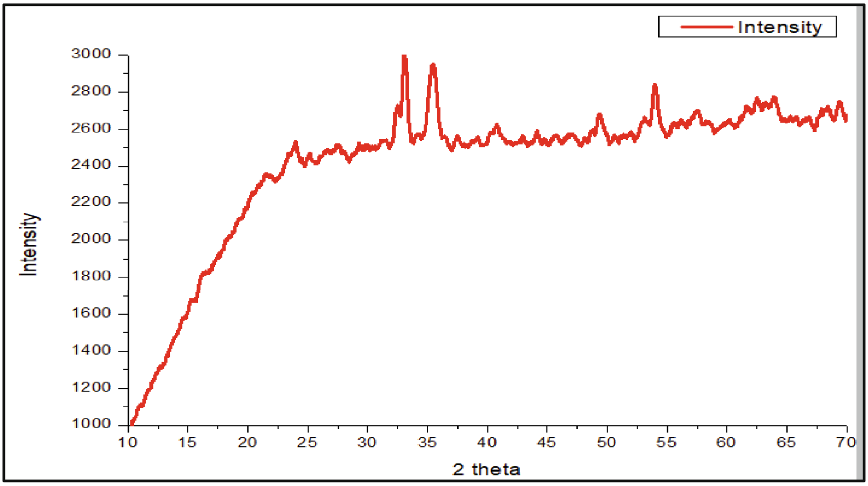

Fig. 2. X-ray diffraction of $NiFe_2O_4$ with a calcination temperature of 200 °C

To identify the crystal structure of the formed nanoparticles, characterization was carried out using XRD. The results of the measurements using the XRD characterization can be seen in Fig. 2. The results of the XRD characterization in Fig. 2 show that there are diffraction patterns of $NiFe_2O_4$ which are indicated by the presence of Miller index peaks. The location of the peaks of the diffraction patterns from each other has the same pattern tendency. The Miller index peaks obtained were 8 data, namely 202, 311, 222, 400, 313, 511, 404, 600 with an angle of 2 respectively (18,28°), (19,20°), (20, 22°), (24.08°), (26.54°), (32.46°), (33.10°) and (35.54°) which are diffraction peaks in the form of a cubic spinel. These results are in accordance with the results obtained [3]. The

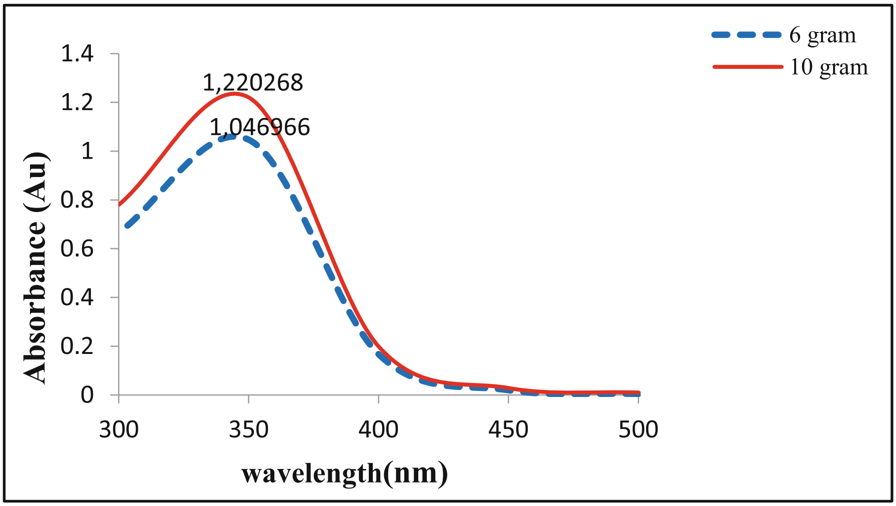

Fig. 3. Result of UV-Vis characterization

grain size of the NiFe2O4 nanoparticle crystals obtained from hkl 202, 311,222, 400, 313, 511, 404 and 600 were respectively 1.57 nm; 2.34 nm; 0.29 nm; 4.43 nm; 2.22 nm; 5.15 nm; 5.16 nm; 3.03 nm with a cubic spinel-shaped crystal structure.

Measurement of optical properties was carried out using a UV-Vis instrument with a wavelength of 200–600 nm. This is because the formation of nanoparticles can be identified by the formation of absorbance peaks in the wavelength range of 200–800 nm [5].

Based on Fig. 3, for each sample of 6 gr and 10 gr, maximum absorption occurred at a wavelength of 350 nm with absorption peaks for each sample of 1.046966 and 1.220268. The highest peak wavelength corresponds to one of the results obtained [6] which obtained two $NiFe_2O_4$ wavelength peaks, namely 323 and 350 nm. From these results, it can be seen that the mass of the sample has no significant effect on the wavelength. The peak value of absorption (absorbance) increased which was not much different between samples. This is due to differences in energy levels. The greater the concentration of $NiFe_2O_4$ solution, the greater the absorbed absorbance. The FWHM values obtained from processing using originlab software for UV-Vis data in each sample are 53.4415 nm and 43.95231 nm.

Based on the results obtained, the maximum absorption peak occurs at a wavelength of 350 nm with a nanoparticle size of around 0.29–5.15 nm and a cubic spinel-shaped crystal structure. The smaller the size of the nanoparticles, the faster the interaction and magnetic response between the particles increases so that the sample is super paramagnetic which can be used as a catalyst.

4 Conclusion

From the research results obtained nanoparticles of nickel ferrite (NiFe2O4) with nanoparticle sizes ranging from 0.29 to 5.16 nm with a cubic crystal structure. From the UV-Vis results of nickel ferrite ($NiFe_2O_4$) nanoparticles, it can be seen that the optical properties with the emergence of absorption peaks of light energy that occur at a wavelength of 350 nm can be used as a catalyst material.

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