Anealling dependence of structural and magnetic properties in aluminum substituted cobalt-ferrite nano particle

Budi Purnama, Suharyana
Physics Department Sebelas Maret University,
Jl. Ir. Sutami 36A Kendingan Jebres Surakarta 57126, INDONESIA
E-mail:bpurnama@mipa.uns.ac.id

Abstract. Anealling dependence of structural and magnetic properties in aluminum substituted cobalt ferrite nano particle are presented here. The composition is defined by the mole-

stociometry calculation. The co-precipitation method is performed to produce the aluminum substituted cobalt ferrite. The anealling temperature are selected to be 600°C, 800°C and 1000°C for 5 hours at atmosphere condition. The XRD results show that the XRD-peak increase with the increase of the anelling temperature. It mean that the fine crystalline structure realize at the higher temperature. The The VSM results indicate that the saturated magnetisation increase with increasing anealling temperature. This is can be explained that the refine of crystalline structure is also promote re-distribution cation at crystalline cites which the final of the magnetic moment become large at a higher temperature anealling.

1. Introduction
Within the last decade, magnetic nanoparticles have become one of the interesting research topic considering superior physical characteristics compared to the bulk phase [1,2]. Of the many nanoparticles of magnetic, cobalt ferrite becomes the main material. One important property of the magnetic nanoparticles are not lost the magnetic property when nano particles are less than 100 nm. The presence of a single magnetic domain on a nanoparticle is a target for researchers considering being able to open up opportunities in the medical application. Especially as contrast agents on MRI as well as drug carriers in cancer treatment systems [3].

Cobalt ferrite is classified as inverse spinel oxide. With Co²⁺ cations occupying at the octahedral site and Fe³⁺ cations occupy the tetrahedral site and octahedral sites [4]. Conventionally, the nano magnetic properties in cobalt ferrite modify by the redistribution of cations such as post annealing treatment, and also by the substitution of transition metal ions (Ni, Al) and rare earth metals (Sr, Gd). Currently, the various cobalt ferrite syntheses that have been developed include coprecipitation [5], sol-gel, micro-emulsion, autocombution [6] and reverse coprecipitation [7]. Among the various methods, the coprecipitation method is one of the most widely used methods of synthesis of ferric cobalt nanoparticles [8].

In this paper, a study of the synthesis in aluminum substituted cobalt ferrite nanoparticles is presented. The samples were synthesized using coprecipitation method followed by post annealing treatment. The crystalline structure of the obtained nano particle samples were characterized by XRD. Where as the magnetic property are characterized by a vibrating sample magnetometer (VSM) at room temperature.
2. Experimental
The synthesis of cobalt ferrite nanoparticles is carried out by co-precipitated method as in the previous study [10]. In order to modify the magnetic characteristic of cobalt ferrite nanoparticles, 0.001 mole Al(NO$_3$)$_3$.9H$_2$O add to precursor solution. The synthesis is performed at temperatures of 95°C. After cool to room temperature, the product wash with ethanol and deionised water. The washing procedure is repeated for several time so that the clean product is obtained. Then the obtained product are dried overnight at 100°C. The following post annealing has been done at 600°C, 800°C and 1000°C for 5 hours. The X-ray diffraction (XRD) patterns of the samples are evaluated by Bruker D8 Advanced system X-ray powder diffractometer using Cu Kα source (1.54 Å) radiation. The scans of the selected diffraction peaks are selected in the step mode 0.02° from 15° to 70°. Finally the magnetic properties are characterized by vibrating samples of magneto meters at room temperature using magnetic field scan range from -20 kOe to 20 kOe.

3. Results and Discussion
Figure 1 presents the FTIR result of aluminium substituted cobalt ferrite which vary in the annealing temperature i.e 600°C, 800°C dan 1000°C for 5 hours. The absorption band around 3400 cm$^{-1}$ and 1600 cm$^{-1}$ are ascribed to the stretching mode of O-H and H-O-H bending vibration, respectively [11]. It is clearly observed from the graph that the characteristic absorption peaks disappear by increasing the annealing temperature. This means that the heat energy from the annealing treatment is used to break the O-H bonds in both stretching and bending modes. Whereas the characteristic of absorption peak at wave number $k = 596.99$ cm$^{-1}$, $590.24$ cm$^{-1}$, $586.39$ cm$^{-1}$, which correspond to temperature annealing 600°C, 800°C and 1000°C is the stretching vibration of aluminum substituted cobalt ferrite [11].

![Figure 1. FTIR spectra of the cobalt ferrite nanoparticles synthesized at 95°C and annealed at temperature of 600°C, 800°C and 1000°C](image-url)
Figure 2. XRD patterns for aluminum substituted cobalt ferrite synthesized at temperature of 95°C and annealed at 600°C, 800°C and 1000°C for 5 h.

Figure 3. Hysteresis curve of aluminum substituted cobalt ferrite synthesized at temperature of 95°C measure for samples with annealing temperature of 600°C, 800°C and 1000°C for 5 h.
Figure 2 shows the increase in the intensity of x-ray diffraction with the increase of the annealing temperature. It mean that the fine crystalline structure realize at the higher temperature. Furthermore, the increase of the peak XRD pattern also indicate the change of crystallite size. Calculation of the crystallite size at the strongest peak in XRD pattern using by Scherer formula is obtained 32.6 nm for annealing temperature of 600°C. The crystallite size change to become 34.9 nm and 37.5 nm when annealed at 800°C and 1000°C respectively. It seem to be the higher annealing temperature owing is enough two or more nano particles merge realize a larger particles size. These result consistent to study published by Huixia et al [12] and Swatsitang et al [13]. Magnetic properties of aluminum cobalt ferrite nano particle is depicted as Fig 3. The application of magnetic field from -20 kOe to 20 kOe appears to be enough to cause the magnetization of the nano particle sample to be saturated. It is clearly observed that saturated magnetization increases with the increase of the annealing temperature. The saturated magnetization $M_s$ slightly change from 32.37 emu/g to 38.71 emu/g when annealing temperature increase from 600°C to 800°C. The increase of annealing temperature 1000°C, the $M_s$ significantly increase of 48.88 emu/g. This is can be explained that the refine of crystalline structure is also promote re-distribution cation at crystalline cites which the final of the magnetic moment become large at high temperature annealing.

4. Conclusion
The annealing dependence of structural and magnetic properties in aluminum substituted cobalt ferrite nano particle are presented here. The composition is defined by the mole-stoichiometry calculation. The co-precipitation method is performed to produce of the aluminum substituted cobalt ferrite. The annealing temperature are selected to be 600°C, 800°C and 1000°C for 5 hours at atmospheric condition. The XRD results show that the aluminum is not significant change characteristic peak of the cobalt ferrite pattern. It should be expected that the aluminum ion may substituted in original crystalline structure of the cobalt ferrite. The whole of the XRD-peak increase with the increase of the annealing temperature. It mean that the fine crystalline structure realize at the higher temperature. The VSM results indicate that the saturated magnetisation increase with increasing annealing temperature. This is can be explained that the refine of crystalline structure is also promote re-distribution cation at crystalline cites which the final of the magnetic moment become large at high temperature annealing.

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