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支援課題名（日本語）　：酸化鉄磁性ナノ粒子の作製と評価：GMR 薄膜の作製
Program　Title（English）　：Fabrication and Characterization of Iron Oxides-based Magnetic Nanostructures; Fabrication of GMR thin films

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1. 概要（Summary ）

Magnetic nanoparticles (MNPs) have become great subject of research interest because of their unique physical and magnetic properties as compared to their bulk counterpart. One of the examples of widely studied MNPs is iron oxides and which has higher magnetic anisotropic due to the enhancement of superparamagnetism in this system. Material with superparamagnetic behavior possesses a high magnetization value under the influence of external magnetic field, but when there is no external magnetic field applied, the magnetization is zero. The nature of the superparamagnetic generally emerges from small size ferromagnetic material (in nanometer order). With these extraordinary magnetic properties, iron oxide has been used as spin filter, heterostructure devices, and biomedical applications. Metal ferrite is one example of iron oxide-based materials. Metal Ferrite belongs to the inverse spinel ferrite class materials which have a chemical formula AB_2O_4 (where A = Mn, Zn, Mg, Ni, Co, and B = Fe) in which A^{2+} [Ni^{2+} ($3d^8$) and Co^{2+} ($3d^7$)] ions reside on octahedral sites and Fe^{3+} ($3d^5$) ions reside equally among tetrahedral (A-sites) and octahedral sites (B sites). Oxygen ions are found in FCC closepacked structures. The unit cell contains 32 O-atoms in a cubic lattice with 8 T*d* (FeO_4) and 16 O*h* (AO_6 and FeO_6) occupied sites. In this research, magnetic nanoparticles (MNPs) of cobalt ferrite ($CoFe_2O_4$), manganese ferrite ($MnFe_2O_4$), magnesium ferrite ($MgFe_2O_4$) and magnetite (Fe_3O_4) with various particle sizes have been successfully synthesized by co-precipitation method. The magnetic properties of MNPs have been also investigated in order to study the potency as an active material on Surface Plasmon Resonance (SPR)-based biosensor application and as absorbents for purification of water waste. On the other hand, giant magnetoresistance (GMR) thin films with structure CoFeB/Cu/CoFe/MnIr have been also fabricated.
The films had been used for analyzing magneto-resistance effect of MNPs by adding the MNPs coloid into the surface of thin films.

2. 実験（Experimental）

AFe_2O_4 nanoparticles were synthesized from A chloride and $FeCl_3.6H_2O$ by co-precipitation method by varying the synthesis temperature, concentration of co-precipitant (NaOH), and duration of centrifugation. However Fe_3O_4 have been synthesized chemically by $FeSO_4.7H_2O$ and $FeCl_3.6H_2O$ with ratio 1:2. CoFeB/Cu/CoFe/MnIr t hin films have been fabricated by RF magnetron sputtering. Properties of ferrite-based and magnetite (Fe_3O_4) nanoparticles have been analyzed by scanning electron microscope (SEM), vibrating sample magnetometer (VSM) and magnetic force microscopy (MFM).

3. 結果と考察（Results and Discussion）

The XRD results showed that the peaks were identified as characteristic of AFe_2O_4 with the main peaks for all samples at approximately 2θ=35.2^o region, which is the top main peak (311) of the c cubic spinel. This analysis is confirmed by the appearance of other peaks are also characteristic of the peak areas of AFe_2O_4 (220), (400), (511) and (440). Lattice parameter values of $CoFe_2O_4$ obtained by profile refinement of XRD data for the samples varied in 60°C temperature synthesis, 80^{o}C and 120^{o}C is 8.379; 8.371 and 8.353 Å, respectively. This indicates that the particle size increases with increase of temperature synthesis. It can be concluded that the temperature parameter plays a role in determining the grain size of nanoparticles. Furthermore, the nanoparticles were synthesized by varying the concentration of NaOH also showed peaks in the same region with samples synthesized by varying the temperature.

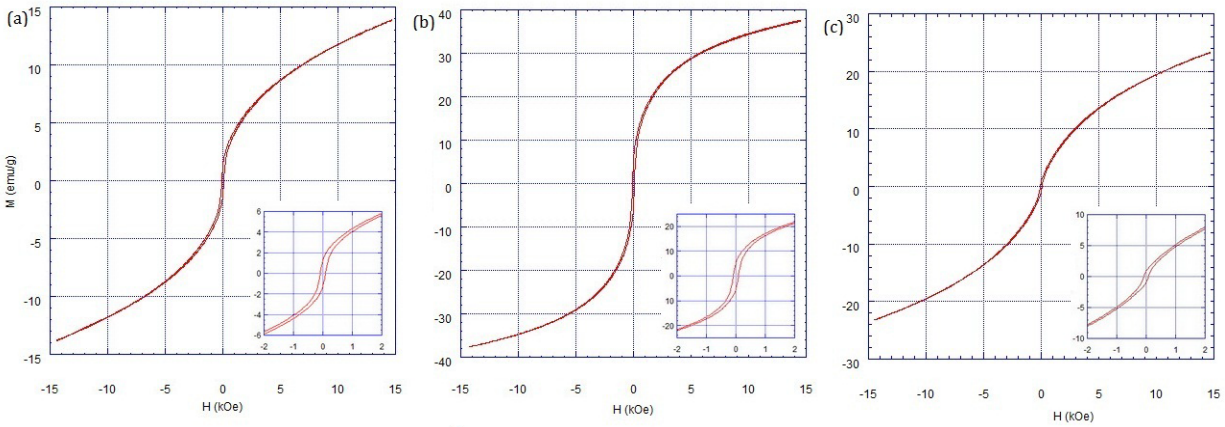

Fig.1. *M-H* loop for samples with various NaOH concentrations: (a) 1.5 M, (b) 5 M and (c) 15M

This indicates that the sample was synthesized with NaOH concentration variations have also crystallized well.

These magnetic properties investigation indicate that the magnitude of the external magnetic field required by the magnetized of nanoparticles to return to the zero position will be smaller due to the small size of the grain. This suggests that the grain size of of nanoparticles affect the magnetic properties of nanoparticles in which the coercivity of nanoparticles decreases with the smaller grain size of nanoparticles. Based on the value of coercivity is so far away from the bulk value which is suggested that the sample began to transform from ferromagnetic properties to superparamagnetic properties, though cannot be said as a superparamagnetic properties because the value of coercivity is not zero, as shown in Fig.1. The shape of MNPs is close to spherical geometry. The results give information that it has a great potency for active materials in SPR-based biosensor application. The results showed that the grain size increases with increase in the synthesis temperature and decreases with increase of concentration of coprecipitant. The coersivity decreased with the decrease of grain size which indicated transformation from ferromagnetic of superparamagnetic properties. The higher saturated magnetization is due to the degree of the better crystallinity of the sample. The utilization of MNPs as active materials not only depends on the magnetic properties and dispersibility of magnetite nanoparticles in biology fluid but also depends on being active of magnetite binds biomolecules. Therefore, nanoparticles which have been obtained by process synthesis were modified by polymer. Actually, surface modification of MNPs can improve dispersibility of sample effectively

4. その他・特記事項（Others）

なし。

5. 論文・学会発表（Publication/Presentation）

1. Edi Suharyadi, Arif Eko, Nanda Sabrina, Takeshi Kato, and Satoshi Iwata, “Magnetic Properties and Microstructures of Polyethylene Glycol (PEG)-Coated Cobalt Ferrite (CoFe2O4) Nanoparticles Synthesized by Coprecipitation Method”, *Advanced Materials Research*, Vol. 896 (2014) pp 126-133.
2. E. Suharyadi, D. Oshim, T. Kato, and S. Iwata, Fabrication of CrPt3 Nanodots by Kr+ Ion Irradiation for Planar Bits Patterned Media, International Conference on Superconductivity and Magnetism, Turkey, 27 April – 1 May 2014.
3. Edi Suharyadi, Takeshi Kato, and Satoshi Iwata, “Controlling the Magnetic Properties of Cr-Implanted Co/Pt Multilayer Film using Ion Irradiation for Planar Patterned Media”, *IEEE Transactions on Magnetics,* vol. 50, no. 1, January 2014, p. 3000104.

6. 関連特許（Patent）

なし。