Magnetization and self-heating temperature of $NiFe_2O_4$ nanoparticles measured by applying ac magnetic field

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Abstract. Magnetic and self-heating properties of various size $NiFe_2O_4$ (7.7-242.0 nm) were evaluated. The self heating temperature of each sample measured by applying ac magnetic field was affected by its magnetic property. The particle size dependence was also explained by the magnetic properties of the samples. At the lower frequency, the self heating was contributed by hysteresis loss. The ac magnetization process was also evaluated and the result could clarify the origin of self-heating. The 7.7 nm particle was heated by relaxation losses by the applied field at higher frequency. The energy efficiency of a magnetic field to generate self heating was analyzed. It was found that the particle of 130.7 nm exhibited the highest temperature rise and heat generation efficiency for the applied field of low amplitude and frequency.

1. Introduction

Magnetic nanoparticles have high potential for cellular labeling, gene delivery and other biomedical applications. They exhibit unique properties, such as conjugation of biological materials, large specific surface area, guidance by magnet and heat dissipation in alternating magnetic fields. Owing to these properties, magnetic particles can be used for various applications such as magnetic separation, magnetic resonance imaging, drug delivery system and hyperthermia [1, 2, 3]. Hyperthermia is a cancer treatment which has fewer side effects than chemotherapy and radiotherapy. The self heating of magnetic nanoparticles in ac magnetic filed is caused by hysteresis loss and relaxation losses [1, 4]. The relaxation losses are caused by the delay in the magnetic moment relaxation. The Brownian relaxation loss and Néel relaxation loss are associated with magnetic moment rotations with the entire particles and within the particles, respectively. It is significant for hyperthermia to use the nanoparticles which induce high temperature rise. Ferrite nanoparticles are suitable materials for biomedical applications because of abundant size range, diversity and chemical stability compared to metal nanoparticles [5]. Many studies are reported on iron oxide nanoparticles, but there are few on other ferrite nanoparticles [6]. In this paper, the self heating properties and magnetic properties of $NiFe_2O_4$ nanoparticles were studied in order to clarify their heating origins.

2. Experiments