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www.elsevier.com/locate/jmmm

PII: S0304-8853(14)00901-9
DOI: http://dx.doi.org/10.1016/j.jmmm.2014.10.005
Reference: MAGMA59444

To appear in: *Journal of Magnetism and Magnetic Materials*

Received date: 13 June 2014
Revised date: 12 September 2014
Accepted date: 2 October 2014

Cite this article as: Saburo Tanaka, Hayaki Murata, Tomoya Oishi, Toshifumi Suzuki and Yi. Zhang, 2D magnetic nanoparticle imaging using magnetization response Second harmonic, *Journal of Magnetism and Magnetic Materials,* http://dx.doi.org/10.1016/j.jmmm.2014.10.005

2D Magnetic Nanoparticle Imaging using Magnetization Response Second Harmonic

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Abstract

A detection method and an imaging technique for magnetic nanoparticles (MNPs) have been investigated. In MNP detection and in magnetic particle imaging (MPI), the most commonly employed method is the detection of the odd harmonics of the magnetization response. We examined the advantage of using the second harmonic response when applying an AC magnetic modulation field and a DC bias field. If the magnetization response is detected by a Cu-wound-coil detection system, the output voltage from the coil is proportional to the change in the flux, $d\phi/dt$. Thus, the dependence of the derivative of the magnetization, M, on an AC magnetic modulation field and a DC bias field were calculated and investigated. The calculations were in good agreement with the experimental results. We demonstrated that the use of the second harmonic response for the detection of MNPs has an advantage compared with the usage of the third harmonic response, when the Cu-wound-coil detection system is employed and the amplitude of the ratio of the AC modulation field and a knee field H_{ac}/H_k is less than 2. We also constructed a 2D MPI scanner using a pair of permanent ring magnets with a bore of ϕ80 mm separated by 90 mm. The magnets generated a gradient of G_z = 3.17 T/m transverse to the imaging bore and G_x = 1.33 T/m along the longitudinal axis. An original concentrated 10 μl Resovist solution in a ϕ2 × 3 mm vessel was used as a sample, and it was imaged by the scanner. As a result, a 2D contour map image could be successfully generated using the method with a lock-in amplifier.

PACS: Type pacs here, separated by semicolons ; 75.30.Cr; 75.75.-c; 75.75.Fk; 85.25.Dq;

Keywords: nanoparticle; detection; magnetic sensor; harmonic; SQUID

1. Introduction

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