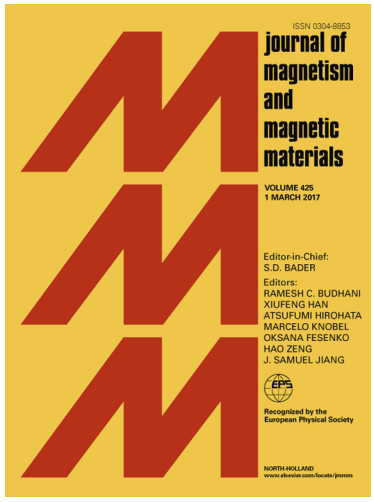

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Determination of the force acting on biocompatible ferrofluid droplets in inhomogeneous magnetic field

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Abstract

We studied the magnetic properties of biocompatible ferrofluids containing magnetite nanoparticles stabilized by polyelectrolyte shell. These materials have many potential medical applications, where the fluid is interacting with biological tissues. We measured the force acting on ferrofluid droplets in inhomogeneous magnetic field of varying strength, in order to estimate the forces arising between the magnetic fluid and the surrounding tissue inside a living body. The results were compared with theoretical calculations.

Keywords: magnetic fluid, magnetite, superparamagnetic nanoparticles, biocompatible ferrofluid, inhomogeneous magnetic field

1. Introduction

The interest in magnetic nanoparticles is growing lately. Many biomedical research is focusing on to create ferrofluids, which could be used in both diagnostics and therapy. These fluids contain superparamagnetic (SPM) nanoparticles (mostly magnetite) in homogeneous distribution in a liquid medium. The particle size is at the scale of ~10 nm, so the nanoparticles are composed of a single magnetic domain, therefore they have a permanent magnetic dipole moment. These materials may be used in MRI tests as contrast agent, for drug delivery to specific location in human body [1–3] and to treat tumors with magnetic hyperthermia [4–6]. For diagnostic and therapeutic application only biocompatible fluids can be used, which retain their stability inside the human body. To make the ferrofluid biocompatible, the surface of the nanoparticles is covered with different organic molecules [7,8].

During a treatment the magnetic fluid has to be transported, and then kept in place with inhomogeneous magnetic field produced by an electromagnet or a permanent magnet [1,9,10]. To carry out these two steps, the knowledge of magnetic properties is important, so that the movement of magnetic droplets can be modeled in different tissues. Furthermore, it is important to know the force acting between the liquid droplets and the surrounding tissues under the effect of magnetic field.

In our research, we measured the force acting on ferrofluid droplets. We determined how the measured force depends on the size and the concentration of the droplet. The results were compared to theoretical calculations.

Mefford et al. [11] calculated the force acting on spherical shaped ferrofluid droplet using the following equation:

$$F = VM(y)\mu_0 \frac{dH_e}{dy}, \quad (1)$$