Application Note 1 (2009)

Application Note 1 (2009) for MFG-1000 (E0200) and paramagnetic fluid (F0300), 090223 version A

Effect of Magnetic Field Strength and Exposure Time on Heating of Paramagnetic Fluids

ABSTRACT

The In Vitro Magnetic Field Generator MFG-1000 (E0200, EURIS, Sweden) was used to generate strong high-frequency (1 MHz) alternating magnetic fields into which paramagnetic fluids (F0200, EURIS, Sweden) were exposed. It was observed that 150 µl of paramagnetic fluid generated 8.8 Joules of heat energy which resulted in a temperature increase of 3.5 °C, when exposed for 60 seconds at a magnetic field strength of 4.9 mT. In a control experiment using 150 µl water the observed temperature increase was less than 0.1 °C. It was concluded that the investigated system is suitable for heating superparamagnetic particles.

Introduction

This application note describes the use of the In Vitro Magnetic Field Generator MFG-1000 (E0200, EURIS, Sweden) for heating of superparamagnetic particles with a strong high-frequency alternating magnetic field.

When exposing a sample of paramagnetic fluid to an external high-frequency alternating magnetic field, heat is generated. This ability to self heat when exposed to electromagnetic radiation is a critical property if it could be used as a therapeutic agent itself or induces a local drug release[1, 2]. Qualities such as size, magnetism and geometries concerning paramagnetic fluid together with medium properties and frequency and magnitude of external magnetic field have a correlation to the heating mechanism. The heating process could be due to hysteresis loss e.g. energy losses when particles emit energy of the field in the form of heat, or according to Neel relaxation, where the absorbed energy is dissipated in the form of heat when magnetic moments (spin) relaxes. Heat could also emerge due to the rotation of magnetic moments and physical movements or by rotational friction (Brownian relaxation) between medium and particles when introducing it to a magnetic field[3].

In this application note we will present the observed experimental data from the introduction of a PCR vial containing paramagnetic fluid or water into the In Vitro Magnetic Field Generator MFG-1000.

Materials and Methods

A PCR vial containing paramagnetic fluid (F301, EURIS, Sweden) or alternatively water (150µl) was inserted into the In Vitro Magnetic Field Generator MFG-1000 (E0200, EURIS, Sweden). A portable fiber optic temperature sensor (PalmSENSE, Photon Control, Canada) was placed in the PCR vial for real-time temperature measurements. The MFG-1000 was adjusted to generate a constant magnetic field strength in the range of 0 - 4.9 mT and exposure time in the range of 0 - 120 s.

The relationship between observed temperature changes versus released heat energy, was established by controlled heat generation using a 100 Ohm resistor (connected to 5 V) which was immersed into a PCR vial containing 150 µl destilled water.

Results and Discussion

Effect of exposure time According to the exposure time experimental data illustrated in Figure 1, a rapid temperature increase of approximatelly 0.05 °C/s was observed for the paramagnetic fluid sample while the water sample showed less than 0.008 °C/s. Almost all of the temperature increase of the water sample occurred after 60 s indicating that this increase was caused by unspecific heating generated from the MFG-1000. Consequently, an exposure time of 60 s was chosen for the subsequent experiments.

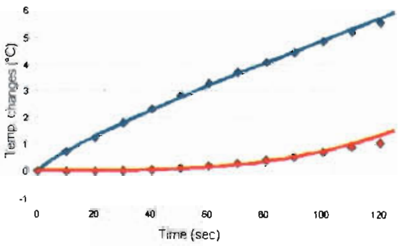

Figure 1. The diagram illustrates observed temperature increase (°C) against exposure time (0 - 120 s) for 150 µl paramagnetic fluid (blue) and 150 µl water (red) at 4.9 mT and 1 MHz.

Effect of magnetic field strength The experimental data illustrated in Figure 2 shows a clear releationship between the observed temperature increase (0 to 3.5 °C) of the paramagnetic fluid and the applied magnetic field strength (0 to 4.9 mT) after a 60 s exposure time. No such relationship could be observed for the water sample and thus, it was concluded that the interaction with the external magnetic field caused the superparamagnetic particles in the paramagentic fluid to absorb energy and subsequently, release it as heat to the fluid.

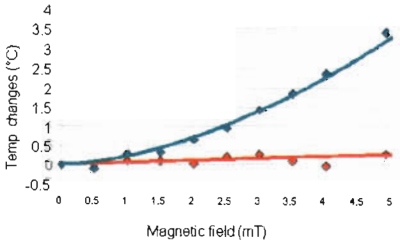

Figure 2. The diagram illustrates observed temperature changes (°C) against applied magnetic field strength (0 - 4.9 mT) for 150 µl paramagnetic fluid (blue) and 150 µl water (red) after a 60 s exposure time.

Heat energy generated In a series of five separate experiments 150 µl paramagnetic fluid was exposed during 60 s to a 4.9 mT applied magnetic field strength at 1 Mhz. The mean value of the observed temperature increase was 3.50 °C (SD=0.18 °C, RSD=5.1%, n=5). The relationship between observed temperature changes versus released heat energy was determined to be 2.5 J per °C. This was based on the observation that the 100 Ohm resistor generated a 5.9 °C temperature change when connected to 5 V during 60 s (P=U*U/R=0.25 W; Heat generated=0.25 W*60 s=15 J; Relationship=15 J/5.9 °C=2.5 J per °C). Thus, the observed temperature increase of 3.50 °C for the paramagnetic fluid corresponds to a heat generation of 8.8 J.

References

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