nanoTherics

Applications of Nanoparticle Heating by Radio Frequency Magnetic Fields

Magnetic Fluid Hyperthermia (MFH) In Vivo/In Vitro Research

Hyperthermia (thermal therapy or thermotherapy) is a type of cancer treatment in which body tissue is exposed to high temperatures (up to 50°C). Research has shown that high temperatures can damage and kill cancer cells, usually with minimal injury to normal tissues.

By killing cancer cells and damaging proteins and structures within cells, hyperthermia may shrink tumours. Magnetic fluid hyperthermia (MFH) is based on the transformation of magnetic energy into heat, governed by thermal fluctuations that occur in magnetic nanoparticles in an AC magnetic field.

Depending on the equilibrium temperature set in the tumour tissue, this heat may either destroy the tumour cells directly (thermo ablation) or result in a synergic reinforcement of radiation/chemo efficacy (hyperthermia).

Magnetherm Nanoparticle Heating System

Magnetherm from NanoTherics allows researchers to perform MFH studies *in vivo* or *in vitro*. The spcifications of the machine inclue:

- Clinically trialled AC magnetic fields of 1- 15 kA/m
- Frequency of 40 to 100 kHz (the system can actually achieve up to 25 mT from 40 kHz to 1 MHz)
- Vertical and horizontal positioning of the in vivo model
- Water jacket which can maintain 37°C temperature within the study chamber
- Options to use an IR camera, an optical sensor and biological gas connections within the animal chamber.

Earlier research also suggests that use of a water jacket for such experiments is important for the elimination of non-specific heating of the animal due to heat transfer from the coil.

A

B

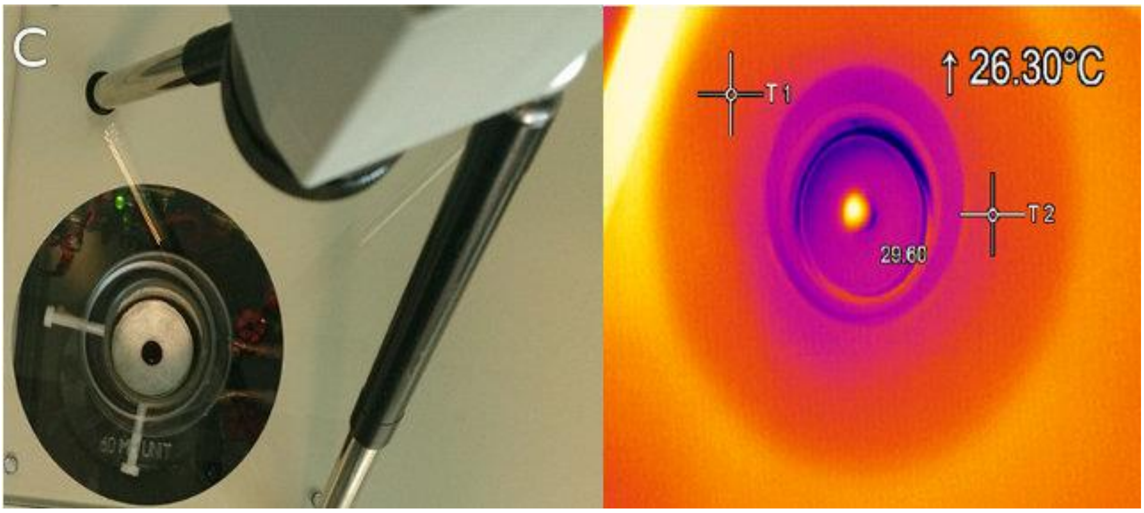

***Figure 1:** **A)** & **B)** Water jacket with a mock animal in vivo setup connected to a fibre optic temperature sensor. **C)** In vitro infra-red camera setup showing temperature measurement in a tissue culture treated 35 mm petri dish.*

Magnetic Nanoparticle Calorimetric Experiments

When magnetic nanoparticles are subjected to an AC magnetic field they show heating effects, due to losses during the magnetization reversal process. This remarkable heating effect shown by magnetic nanoparticles has opened up numerous applications within the natural sciences sector.

Heating of magnetic nanoparticles is governed by the particle type, size, stabilization and functionalization, as well as the frequency and magnetic field strength of the applied AC magnetic field.
Magnetherm provides an adiabatic shield, insulates the sample, enables accurate positioning, provides homogenous field strength over the sample, and can generate AC magnetic fields from 40 to 1000 kHz at 1 to 25 mT for testing different types of magnetic nanoparticles.

Figure 2: Vacuum chamber to eliminate non-specific heating for calorimetric set up

Controlled Drug Release

Delivery of drugs in response to external stimuli or time lapse is known as controlled drug release, and delivery of drugs to a particular location/component within a system is known as targeted drug delivery.

Drug release systems triggered by alternating magnetic fields can be created by surface-functionalizing iron oxide nanoparticles with a thermally labile molecule, linking them to a therapeutic drug. The linking molecule can be selected to decompose at the desired speed – a slower disintegration allows slow release of drugs, to keep the dosage low but extend exposure over a longer period.

magneTherm facilitates these studies, as the SAR value increases over the increase in frequency in a constant field amplitude.

Biofilm Treatment

Pathogenic bacterial colonies can adhere onto a surface, proliferating and aggregating within its hydrated polymeric matrix secretion to form biofilms. This gives the bacteria antibiotic resistance, and supports the development of chronic infections. The higher doses of antibiotics necessary to deal with biofilms have been found to be a major factor in the development of antibiotic-resistant strains, which are a global health crisis.

Magnetic targeting of Super Paramagnetic Iron Oxide Nanoparticles, (SPIONs) allows them to penetrate deep within the biofilms, and heating them using an AC magnetic field reduces the viability of the bacterial community. This treatment is very effective, as it can be used to treat antibiotic resistant biofilms and antibiotic resistant strains.

magneTherm can accept biofilms either grown on a coupon or directly in a 35mm petri dish, allowing researchers to perform experiments with magnetic nanoparticle mediated biofilm treatment.

Reactors for Nanomaterial Synthesis

Continuous flow reactors are a promising development in nanoparticle synthesis, providing many advantages over conventional batch synthesis. Radio frequency electromagnetic heating is an effective option in this application, with cost and convenience benefits over other alternatives.

One common problem of nanoparticle synthesis in a controlled environment is the replication procedure. Fluidic synthesis of nanoparticles with the help of RF heating, when included in the procedure by passing the reactor chamber through the coil enclosure helps to overcome this difficulty.

This technology has been gaining interest over the past few years for its efficient heat and mass transfer, and temporal and spatial control of the synthesis conditions which makes alterations of the particle shape, size, and functionalization possible.

Magnetherm can be used to perform research on continuous synthesis of nanoparticles within the process engineering field.

Forward Osmosis Desalination

Desalination is a promising solution to meet the world's growing demand for fresh water. In the forward osmosis desalination technique, thermoresponsive hydrogels are being used as draw agents, which makes this technology promising for commercial use. However, an effective method to recover water from the thermoresponsive hydrogels is still required.

In recent years, researchers have come up with thermoresponsive hydrogels with magnetic nanoparticles embedded within their composition. As these particles are dispersed evenly within the thermoresponsive hydrogel, a uniform heat was produced when exposing these swollen hydrogels to an alternating magnetic field.

It has been demonstrated that AC magnetic field heating is a faster and effective method than conventional heating for dewatering thermoresponsive hydrogels. This promising technique requires more research for commercialization, and magneTherm is an ideal instrument for these studies.

Shape Memory Polymer Research

Shape memory polymers can store a permanent shape, and their temporary shape can change to their "memorized" permanent shape when exposed to heat. Applications of this effect include:

- space structures
- in vivo/ in vitro medical devices
- optical devices
- adhesive and fasteners

Embedding magnetic nanoparticles within these polymers allows us to control their shape memory effect non-invasively i.e. without direct contact. This remote controlled magnetic nanocomposite opens numerous applications within the aforementioned areas.

Recent advances show memory effects based on magnetic fields - i.e. the ability of memory magnetic nanocomposites to remember the magnetic field strength that was used earlier to change the shape of the polymer.

MagneTherm allows the user to perform shape memory polymer research due to its versatile frequency and magnetic field strength range.

Figure 3: *Memory polymer research setup*

Anti-Fouling Nanopaint Research

Research suggests that elevating the magnetic interaction through the application of AC magnetic fields should increase the aggregation of weakly magnetic particles due to the change in the particle interactions, in competition with the surface chemical repulsions caused by double layer forces.

The application of an AC magnetic field is likely to increase the contribution from the magnetic interaction in the total particle interactions. Thus the particle interactions should become more like the interactions expected from a system of strongly magnetic particles, and the aggregation of the weakly magnetic particles should become more like that of the strongly magnetic particles.