4 years PhD position at EESA - UGent - Belgium

The Department of Electrical Energy, Systems and Automation (EESA) welcomes applications for a PhD-position in Engineering Science. The PhD-position is available from October 1st 2014 under the supervision of Luc Dupré and Guillaume Crevecoeur in the frame work of an interdisciplinary project ' Magnetic nanoparticle hyperthermia for the treatment of spinal metastases'.

Candidates must have completed a Master of science in Engineering, or another relevant graduate program, with excellent grades.

Candidates for the vacancy are invited to submit

- a 2 page curriculum vitae
- a transcript of courses taken (including grades, for candidates obtained their master degree outside UGent)

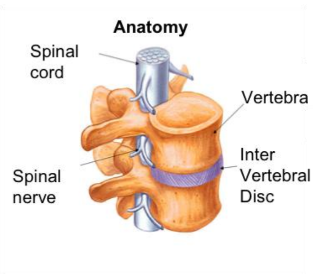
Applications should be sent to luc.dupre@ugent.be

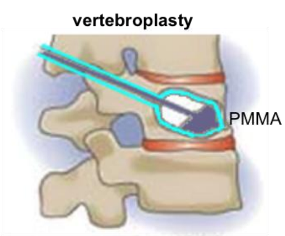
For more information, please contact Prof. dr. ir. Luc Dupré, via above mentioned email address.

Research proposal

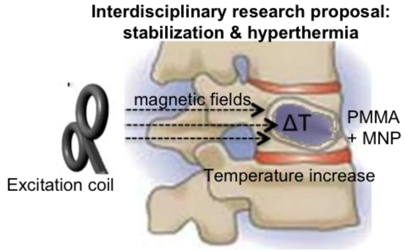
A. Problem statement & Objectives

Cancer is the abnormal proliferation of cells and remains one of the most life-threatening challenges worldwide. Traditional curative options for malignant tumors are surgery, chemotherapy, and radiotherapy. Unfortunately, surgical eradication is sometimes not possible because of unfavourable tumor location and stage, limited organ functional reserve, and/or high operative risk, or bad general condition of the patient. Chemotherapy and radiotherapy have the disadvantage to affect healthy tissues as well and that they represent a high cost for society. Hyperthermia consists in heating the tumor tissue locally and has a relatively lower cost with limited negative side effects. Cancer cells are dependent on a narrower temperature range and can be killed by heat over a period of time. Moreover, hyperthermia improves the effect of radio- and chemotherapy. Hyperthermia based on magnetic nanoparticles (MNP) consists in locally heating tissue with magnetic nanoparticles using an external radiofrequent magnetic field. Magnetic fields are often used in biomedical engineering because they are able to penetrate biological tissues. A current that is flowing through a coil is able to generate a time varying magnetic field. This magnetic field can interact with magnetic materials and lead to a heating of the magnetic material because of different types of loss processes. The exact mechanisms that lead to the heating of the magnetic nanoparticles cannot yet be fully captured and hamper the applicability of MNP based hyperthermia. The heating of tissue, typically with an elevation starting from 5°C, induces a sequence of biological processes leading to tumor cell degradation. The primary effect starts with the thermal de-activation of the mitochondrial energy conversion within the cell and in a next stage dissociates and degrades the cellular membranes. Secondary, delayed thermal effects appear as pathologic responses to cell and tissue injury.





In spinal metastatic tumor disease the vertebral body is invaded and weakened by pathological tissue, which can lead to the collapse of the vertebral body and a progressive compression of the spinal cord. This in turn may lead to a severe neurological function deficit. At the moment, there are methods which allow to either stabilize or oncologically treat the spinal column. Vertebral body augmentation by the injection of "cement" (polymethylmetacrylate, PMMA), so-called vertebroplasty (direct injection of PMMA with high pressure device) or kyphoplasty (making a cavity in the vertebral body with a balloon before filling it with PMMA at relatively low pressure) readily stabilizes the spine, but does not stop tumor progression. Current spinal metastatic disease treatments, such as the standard and most common neurosurgery, radiofrequency ablation and laser induced thermotherapy techniques are performed before the injection of the cement and can thus be performed only once. Surgical procedures are possible for 10-15% of the patients, but because of the frequent progression of spinal metastases, the surgery needs to be repeated which is costly and unwanted for the patient. There is no modality that integrates both the stabilization of the spinal column and the treatment of the spinal metastases. Because of the spinal metastases' progressions, the treatment should ideally be performed in a repetitive way, without additional invasive manipulations.



This project proposes the development and the understanding of a therapy that enables on the one hand stabilization of the spine and on the other hand the hyperthermia of the spinal metastatic tumors. Traditional bone cement does not contain any magnetic materials inside and thus does not interact with the magnetic field. This cement loaded with magnetic nanoparticles, can be clinically administered in a minimally invasive way as it is being done in vertebroplasty or kyphoplasty. The magnetic nanoparticles can then be activated through an externally generated magnetic field so that they heat the bone cement and thus the surrounding biological tissue. MNPs can be magnetic resonance scanner compatible so that it is possible to perform radiology without artifacts. The heating of the magnetic nanoparticles occurs due to the magnetization processes within and between the nanoparticles.

The following major questions are addressed: 1) what are the basic heating principles of magnetic nanoparticles based hyperthermia, 2) what is the impact of temperature variations on the spinal metastases? The development of a spinal metastases therapy device is technologically challenging since the required magnetic fields are both high in amplitude and frequency. Current magnetic nanoparticle based hyperthermia requires magnetic field frequencies in the radiofrequency range (100-250kHz) and magnetic induction fields in the range of 0.05-0.1T. Attaining these high frequencies and amplitudes is a difficult task because of the very high currents (orders of multiple hundred ampères) that need to flow in the excitation coil and that need to be in the radiofrequency range. This is possible by internally cooling the excitation coil and by using a resonance circuit capacitor. The possibilities and limitations of hyperthermia and the repetitive application thereof for spinal metastases will be elucidated.

B. Workplan & Timing

The PhD student is essential for achieving the project's objectives:: engineering magnetic nanoparticle hyperthermia through the understanding of the heating mechanisms on the one hand, and proposing a clinically relevant treatment modality through understanding of cell degradation of spinal metastases due to applied temperature on the other hand.

WP1.1: Micromagnetic heat process calculations
Aim: numerical description and analysis of the micromagnetic phenomena of nanoparticle heat processes
Discipline: nanomagnetism, numerical methods;

WP1.2: Temperature dynamics in the vertebra
Aim: numerical description of the thermal processes in the vertebra and the identification of the necessary heat source originating from the magnetic nanoparticles system so to achieve hyperthermia
Discipline: numerical methods in biomedical engineering;

WP1.3: Numerical electromagnetic optimization of the thermal process and design of hyperthermia device
Aim: determine the optimal treatment parameter values: magnetic nanoparticle concentration, size, type and the design parameters of the magnetic field excitation device
Discipline: electrical and biomedical engineering;