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Temperature distribution in nanoparticle hyperthermia

Abstract. *.In this article simulation of the electromagnetic field and temperature in human tissues is considered. First equations describing magnetic field in terms of magnetic potential A under sinusoidal excitation is derived and next distribution temperature inside human body was described. It was discussed influence of human tissue parameters on electromagnetic field and temperature*

Keywords: hyperthermia, nanoparticles, finite element method, temperature distribution.
Słowa kluczowe: hipertermia, nanocząsteczki, metoda elementów skończonych, rozkład temperatury.

Introduction

Magnetic nanoparticles used in medical applications have sizes ranging from a few nanometers up to thou-sands of nanometers, what means that their dimensions are smaller than or comparable to those of a cell (10–100μm), a protein (5–50 nm), a virus (20–450 nm), or a gene (2 nm wide and 10–100 nm long). Because of this they can to come in direct vicinity of biological tissues of interest. Such nanoparticles should be coated with biological molecules, such as a starch, to make them difficult to recognize by an organism's immune defense system, thereby providing a possibility to control the means of transport them to desire places. The nanoparticles are magnetic, what means that they obey Lorenz's low, what gives possibility to manipulate them by an external magnetic field with high magnetic gradient. This property of magnetic nanoparticles enables location of them in desired places. Next, magnetic nanoparticles can be made to respond to time varying electromagnetic field, what results in transfer of energy from external exciting energy sources to nanoparticles and in this way to treated tissues.

Power of heat sources

Now all coefficients can be deduced from the data supplied by manufacturers of given magnetic materials or by adequate laboratory measurements. The energy supplied when the magnetic field ones goes around hysteresis loop can be calculated as [2]:

(1) $$w_m = 4\pi\left[-\frac{c_2}{b_2}H_s + \left(\frac{c_2}{b_2} + c_1 H_s + c_2 H_s^2\right)I_1 + \left(\frac{b_1 c_2 - c_1 b_2}{b_2}\right)I_2\right]$$

Heat equation has following form

(2) $$\nabla\left(-k\nabla T\right) = \rho_b C_b \omega_b (T_h - T) + Q_{ext} + Q_{met}$$

Computational results

It was assumed that tumor occurs in liver as in Fig.1 right. The amount of $10\mathrm{mg/cm^3}$ nanoparticles was injected into tumor and uniformly inside distributed. Geometrical dimension are given in Fig.1. Exciting wirers with current have parameters I_{max} = 1e4 [A], r_5 = 0.01 [m] and frequency f = 100 [MHz], Physical parameters of blood are as follows: ρ_b = 1060 [kg/m^3], C_b =3639 [J/(kg·K)], T_b = 310.15 [K], ω_b= 0.005 [1/s]. Physical parameter of tissues are given by: relative permittivity $\varepsilon_r = 29.6$ in body, 70 in tumor and 5.8 in liver, electric conductivity $\sigma = 0.02$[S/m] in tumor, body and skin and 0.002[S/m] in liver. The hysteresis loss for one loop is $5\cdot10^{-4}$J/g when H_0=35kA/m. The frequency was assumed f = 100kHz. The exciting current was so adjusted to attain specific loss power 400, 450 and 500 mW/cm^3.

Results

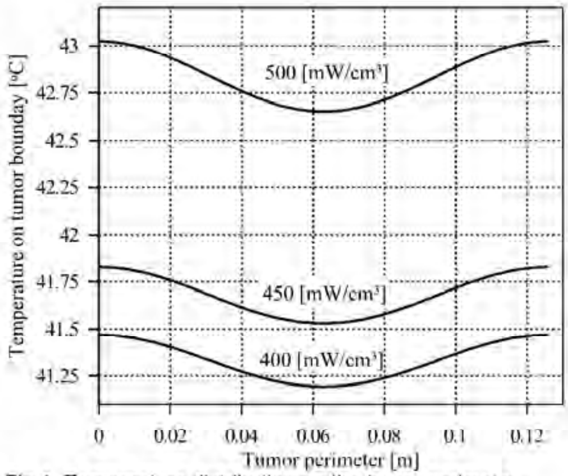

Fig.1. Temperature distribution on the tumor perimeter

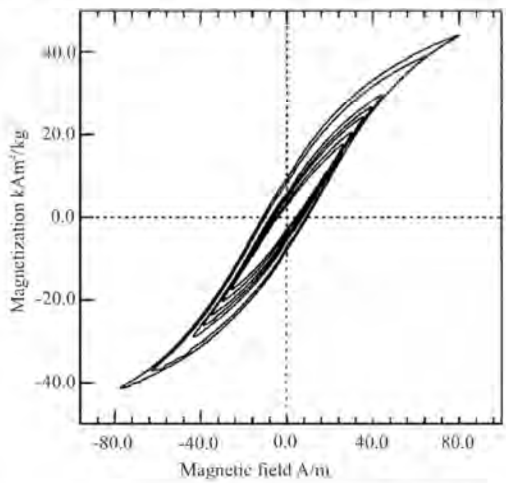

Fig.2. Hysteresis curve of the ferromagnetic particle

REFERENCES

[1] Kotsuka, Y.,Orii K.,Kojima H.,Kamogawa K., and Tanaka M., “New wireless-thermometer for RF and microwave thermal therapy using an MMIC in an Si BJT VCO Type,” IEEE *Trans. Microwave Theory Tech.*, vol. 47, Dec. (1999), 2630–2635

[2] Esho Taskgroup Comettee, Treatment planning and modelling in hyperthermia, a task group report of the European Society of Hyperthermic *Oncology*, Rome, 1992.