

61ST ANNUAL CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS

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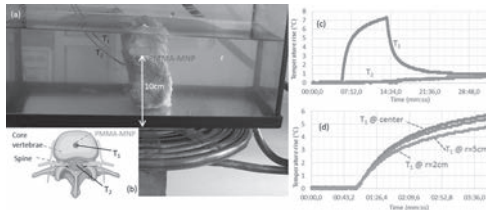
ABSTRACTS



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particles with a diameter of 10nm. The PMMA-MNP material was inserted in a beef vertebra. So to have clinical validity we appraised the thermal rise in the center of the PMMA (T_1) and in the spine (T_2) using Fiber Bragg Grating optical temperature sensors. The temperature in the spine needs to be safeguarded to have no damage of the spine [4]. We placed the vertebrae with PMMA-MNP at approximately 10cm from the coil, being a realistic distance for clinical applications. Figure (a) shows the setup and (b) the placement of the temperature sensors in the vertebra. Results in Figure (c) show a temperature rise of 7°C in PMMA-MNP (T_1) when having the PMMA-MNP 10cm above the coil whereas the temperature in the spine (T_2) remains limited. Figure (d) illustrates the robustness of the method by showing the temperature rise for various lateral displacements (with distance r from center). These experimental results validate the technical feasibility of having PMMA-MNP material as basic component in percutaneous vertebroplasty enabling hyperthermia treatment of metastatic bone tumors.

[1] P. Galibert, et al. *Neurochirurgie*, 33: 166–8 (1987). [2] M. H. Falk and R. D. Issels, *Int J Hyperthermia*, 17: 1–18 (2001). [3] M. Kawashita, et al. *Acta Biomaterialia*, 6: 3187–3192 (2010). [4] P. Sminia, et al. *Int. J. Hyperthermia*, 3: 441–452 (1989).



DW-04. Magnetic, Structural, And Magnetocaloric Properties Of Ni-Al And Ni-Si Binary Alloys For Self-Controlled Hyperthermia Applications. S. Pandey¹, A. Quetz¹, A. Aryal¹, I. Dubenko¹, D. Mazumdar¹, S. Stadler² and N. Ali¹ 1. *Physics, Southern Illinois University, Carbondale, IL*; 2. *Physics, Louisiana State University, Baton Rouge, LA*

Self-controlled hyperthermia is a new, non-invasive technique to employ heat treatment to cure cancer cells without overheating the normal cells. We have explored bulk magnetic as thermoseeds by substituting Si and Al for Ni. The samples were prepared by arc-melting, and subsequently annealed at 950°C for 12 hours in sealed quartz tubes. The structural, magnetic, and magnetocaloric properties of the samples were investigated, including saturation magnetization, Curie temperature, and hysteresis, using room temperature X-ray diffraction and a superconducting quantum interference device (SQUID) magnetometer. We have synthesized Ni-Al and Ni-Si alloys that have Curie temperatures in the desired range (310–320 K). Magnetocaloric parameters (magnetic entropy changes (ΔS_M), refrigeration capacity (RC), and hysteretic effects) have been calculated. It has been shown that recrystallization, i.e., annealing time and temperature, is crucial for controlling heating characteristics of the seeds. Thus, by controlling the doping concentration, extraordinary self-regulating heating effects have been observed in these types of magnetic materials, which may open doors to a new strategy for self-controlled hyperthermia cancer treatment. Acknowledgement: This work was supported by the Office of Basic Energy Sciences, Material Science Division of the U.S. Department of Energy DOE Grant No. DE-FG02-06ER46291 (SIU) and DE-FG02-13ER46946 (LSU).

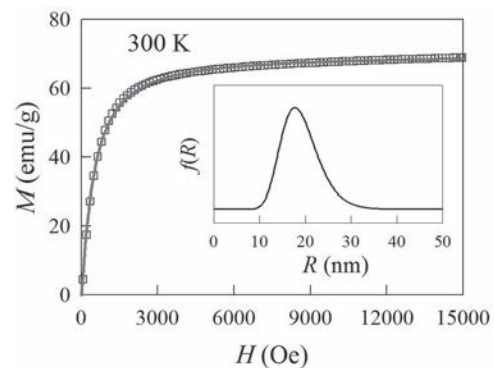
DW-05. Withdrawn

DW-06. Frequency Dependence of Initial Heat Generation in Magnetite Nanoparticles.

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Frequency dependence of heat generation in granular magnetite nanoparticles was studied using VSM (Vibration Sample Magnetometer) and nanoTherics Magnetherm® system. First, the polydispersity of the magnetite sample was investigated by fitting the M - H curve to the classical Langevin function $L(R, H)$ weight-averaged with a particle size distribution function $f(R)$: $M(H) = M_s \int L(R, H) f(R) dR$, where $f(R)$ is a modified log-normal distribution function [1]. Optimum fit was obtained for $\sigma=0.3$, $R_0=12.3$, and $\theta=0.9$ (Fig. 1). Taking the polydispersity of the sample into account, the heat generation of the sample was examined by measuring temperature variation as a function of elapsed time under ac magnetic field with amplitude H_0 of 250 Oe and frequencies f of 50 kHz, 112 kHz, and 523 kHz, respectively. Since the temperature uncertainty due to heat leakage is accumulative with the passage of time, we extracted only the initial rate of temperature increase in terms of frequencies, which were 0.53, 0.63, 1.68 K/s for 50, 112, 523 kHz, respectively (Fig. 2(a)). Volumetric power dissipation is usually expressed as [2]: $P_{Tf}(R) = \pi \mu_0 \chi_0 H_0^2 f \omega \tau / (1 + \omega^2 \tau^2)$, where χ_0 is the chord susceptibility of the Langevin function $\chi_0 = 3\chi_c (\coth \xi - 1/\xi)/\xi$; $\xi = \mu_0 M_d H_0 V / kT$. Here μ_0 is the permeability of free space $4\pi \times 10^{-7} (\text{Tm/A})$; τ is the Néel relaxation time given as $\tau = \tau_0 \exp(KV/kT)$, so $P_{Tf}(R)$ depends on temperature, frequency, and the particle size of the sample. The initial susceptibility χ_i was 4.66 obtained from the M - H curve. Numerically integrating the $P_{Tf}(R)$ over the distribution function $f(R)$ found above, we can get the averaged volumetric heating rate $\langle P \rangle_f$ as a function of frequency f where T was 300 K at initial stage: $\langle P \rangle_f = \int P_{Tf}(R) f(R) dR$. Temperature increase ΔT in a well-insulated sample is related the volumetric heating rate $\langle P \rangle_f$ as: $\Delta T = \langle P \rangle_f / c_p \Delta t$, where c and ρ are specific heat and density of magnetite. Experimental temperature increasing rate $\Delta T / \Delta t$ and the calculated volumetric heating rate $\langle P \rangle_f$ are shown together in Fig. 2(b). Good control for the polydispersity is crucial for achieving optimal results in hyperthermia.

[1] S. Yoon and K. M. Krishnan, *J. Appl. Phys.*, 109, 07B534 (2011).
[2] R. E Rosensweig, *J. Magn. Magn. Mater.*, 252, 370 (2002).



M-H curve and size distribution of the sample.