Dependence of Frequency and Magnetic Field on Self-Heating Characteristics of $NiFe_2O_4$ Nanoparticles for Hyperthermia

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Self-heating temperature-rising characteristics of nano-size controlled $NiFe_2O_4$ particles were analyzed as a function of applied frequency and magnetic field in order to investigate the physical principle of self-heating and to confirm the possibility for a real *in vivo* hyperthermia application. According to the magnetic properties of 35-nm size $NiFe_2O_4$ nanoparticles, it was confirmed that the physical mechanism of self-heating is mainly attributed to the hysteresis loss. In addition, it was found that the self-heating temperature was linearly increased by increasing frequency and was proportionally square to the applied magnetic field. The self-heating temperature was rapidly increased in an initial stage and then it reached to the maximum. The maximum self-heating temperature was controlled from 2.8 °C to 72.6 °C by changing the applied frequency and magnetic field. The corresponding product of the frequency and the strength of magnetic field $H_0 f$ was between 1.9×10^8 $Am^{-1}s^{-1}$ and 13.4×10^8 $Am^{-1}s^{-1}$. These values are in the biological safety and tolerable range for hyperthermia considering deleterious physiological response of human body during hyperthermia treatment.

Index Terms—**Frequency dependence, hyperthermia, magnetic field dependence, $NiFe_2O_4$ nanoparticle, temperature-rising characteristics.**