Heat Dissipation and Relaxation Phenomena of Magnetic Nanoparticles

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The emergence of magnetic nanoparticles has been discussed for biomedical applications. Magnetic nanoparticles yields thermal energy due to magnetic relaxation losses in an AC magnetic field. The imaginary part of the AC magnetic susceptibility, χ”, contributes to this heat generation. Two types of magnetic relaxation mechanisms exist for magnetic nanoparticles[1]. Néel relaxation τ_N, caused by rotation of the magnetic moment and Brownian relaxation τ_B, caused by rotation of the nanoparticles themselves.
We have produced magnetic nanoparticles of various compositions and reported their properties and efficacy in hyperthermia treatment. As an example, we observed the AC magnetic susceptibility characteristics of Ni-ferrites from 3 to 17 nm, and their temperature rise in an AC magnetic field. The results confirmed that the particle size of 17 nm according to Néel's theory releases the most heat, and showed a temperature rise of more than 42.5°C, which is high enough to suppress cancer cells.
We analyzed whether the heating mechanism would be due to Néel relaxation τ_N, or Brownian relaxation τ_B. The relaxation time of the particles was estimated from the obtained anisotropy constant by analysing the imaginary part of the AC magnetic susceptibility, and it was found that or $NiFe_2O_4$ nanoparticles, the Néel relaxation was dominant for particles with a particle size less than 20 nm (Fig.1). The largest heat dissipation (SAR) was predicted to be obtained for particles of 13-17 nm.
We also carried out in vitro experiment using cultured human breast cancer cells, and a significant hyperthermia effect was observed[2].

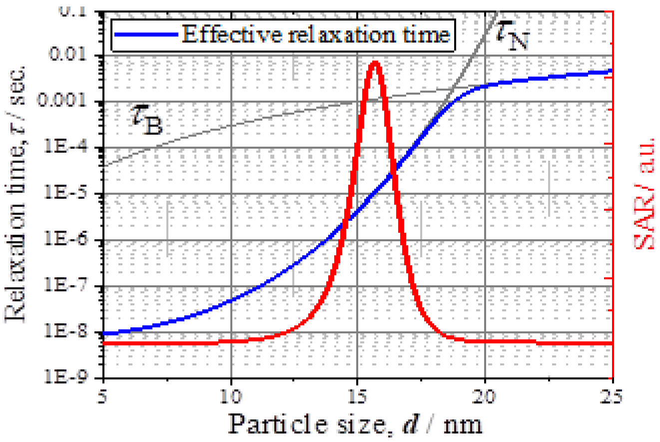

Fig.1 Relaxation time and specific absorption rate vs. particle diameter of $NiFe_2O_4$ nanoparticles

References

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