Heat generation of aqueously dispersed CoFe$_2$O$_4$ nanoparticles as heating agents for magnetically-activated drug delivery and hyperthermia

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INTRODUCTION

Magnetic hyperthermia in the various biomedical applications of magnetic nanoparticles is a promising modality of hyperthermia that has the potential to address the targeting and tissue heat distribution shortcomings of other hyperthermia modalities. We report here the successful development and characterization of magnetic nanoparticles based on CoFe$_2$O$_4$ and their ability to generate heat induced by an magnetic field. For this application, the magnetic nanoparticles should be biocompatible and form stable aqueous suspensions without agglomeration in water-based fluids, and can be functionalized for linking with targeting and drug releasing components.

OBJECTIVE

Investigate feasibility of heating CoFe$_2$O$_4$ nanoparticles with an AC magnetic field

EXPERIMENTAL PART

1. Synthesis of CoFe$_2$O$_4$ nanoparticles

1) Materials : Fe(acac)$_3$,Co(acac)$_2$, 1,2-hexadecanediol, Oleic acid, Oleylamine, Benzyl ether.

2) Method

① Mix Fe(acac)$_3$, Co(acac)$_2$, 1,2-hexadecanediol and benzyl ether under N$_2$.
② Heat to 100 °C for 30 min under a blanket of N$_2$.
③ Add Oleic acid and oleylamine
④ Heat to 200 °C for 1 h and reflux for 1 h at 285 °C
⑤ Wash with ethanol and redisperse in hexane.

2. Water dispersible CoFe$_2$O$_4$ using 11-MUA

Ligand exchange conducted using 11-Mercaptoundecanoic acid

11-Mercaptoundecanoic acid

Nanoparticles successfully dispersed in 0.13 M NaOH

(a) CoFe$_2$O$_4$ with oleic acid and oleylamine in hexane
(b) CoFe$_2$O$_4$ in water after washing with ethanol
(c) CoFe$_2$O$_4$ with 11-MUA in water.

11-MUA Dispersed CoFe$_2$O$_4$ nanoparticles are stable in water (pH 6-10)

3. Heat generation as f(magnetic field intensity, frequency)

1) Heating equipment

① Custom-Designed heating station with coil and chiller (Induction Atmosphere, 50-495 kHz)
② 5KW magnetic field power supply (Ameritherm)
③ IR Thermacam®

IR images used to generate heating profiles for aqueous dispersions at different field intensities and frequencies

Thermacam images of heating sample at a 634 Oe (266KHz).

Temperature profiles of aqueous CoFe$_2$O$_4$ dispersions and precipitated nanoparticles in water

Conclusion

1. The synthesized CoFe$_2$O$_4$ nanoparticles were successfully dispersed in water using 11-MUA ligand exchange method.
2. The temperatures profiles when exposed to ac magnetic fields were measured using an IR thermacam.
3. The heat generation shows the proportionality to the squared the field intensity.
4. The desired heating to achieve magnetothermally-triggered drug delivery and hyperthermia can be achieved using CoFe$_2$O$_4$ nanoparticles by adjusting the magnetic field and frequency.

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