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Supplementary Materials

Disposable Micro Stir Bars by Photodegradable Organic Encapsulation of Hematite-Magnetite Nanoparticles

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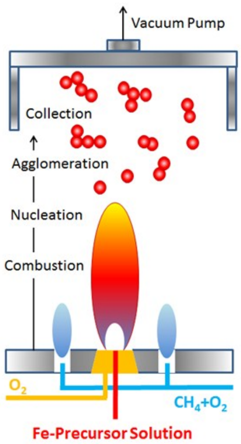

Fig. S1 Schematic of flame spray pyrolysis reactor

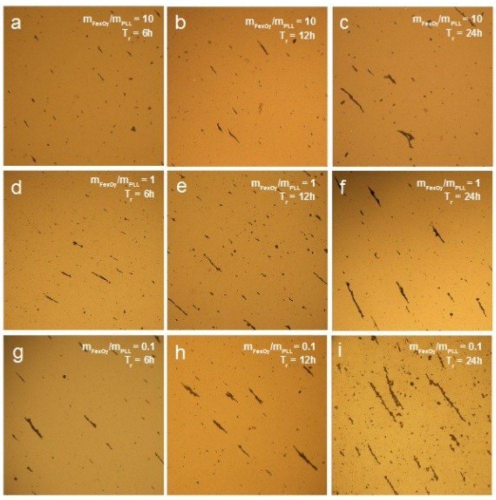

Fig. S2 Optical microscope images showing the effect of reaction time and lysine concentration on morphology of micro-bars synthesized at HAS = 2.5cm, pH 8.8 using FSP-made nanoparticles made at [Fe]/O_2 = 0.9 mmol/L.

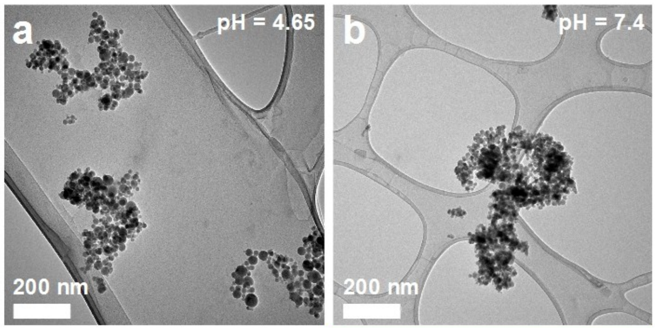

Fig. S3 Transmission Electron Micrographs of FSP-made iron oxide nanoparticles ([Fe]/O_2 = 0.9 mmol/L) encapsulated with lysine at (a) pH 4.65 and (b) 7.4.

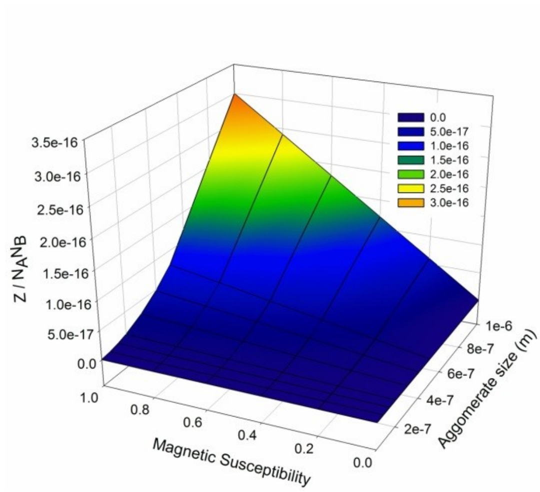

Fig. S4 Plot of collision frequency ratio showing square-dependence on agglomerate size and linear dependence on magnetic susceptibility of the material.

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Derivation of Equations

The force on the iron oxide agglomerate can be derived from (S1) considering the driving magnetic force (S2) applied at a certain distance from a cylindrical magnet and counterbalanced by the drag force (S4).

$$F = \rho V\vec{a} = \vec{F_m} + \vec{F_s} \quad \text{(S1)}$$

Where ρ = density of agglomerate; V = volume of the agglomerate.

F_m is the magnetic force, given as follows:

$$F_m = \frac{V\chi}{\mu}(\vec{B}\cdot\nabla)\vec{B} \quad \text{(S2)}$$

Where μ = permittivity of medium; χ = magnetic susceptibility of the iron oxide.

The magnetic field, B, for a cylindrical magnet is:

$$\vec{B} = -\frac{\mu m}{4\pi x^2} \quad \text{(S3)}$$

Where x = distance from the magnet; m = strength of the magnet.

The drag force, Fs, is:

$$F_s = -6\pi\eta r\vec{v} \quad \text{(S4)}$$

Where η = dynamic viscosity; r = radius of agglomerate; v = velocity of agglomerate.
Substituting (S2), (S3), (S4) into (S1), we arrive at (S5)

$$\rho V\vec{a} = \frac{\chi V}{\mu}(\vec{B}\cdot\nabla)\vec{B} - 6\pi\eta r\vec{v} \quad \text{(S5)}$$

Performing the differentiation and approximating agglorates as perfect spheres of radius r

$$\frac{\rho 4\pi r^3}{3}\vec{a} = \frac{\chi 4\pi r^3}{\mu}\left(\frac{\mu^2 m^2}{8\pi^2 x^5}\right) - 6\pi\eta r\vec{v} \quad \text{(S6)}$$

This can be rearranged into the following first order differential equation

$$\vec{a} = \frac{d\vec{v}}{dt} = -\frac{r\chi\mu m^2}{6\pi x^5} - \frac{18\eta\vec{v}}{4r^2} \quad \text{(S7)}$$

This can be solved in the following form

$$\frac{dv}{dt} + \beta v = \alpha \quad \text{(S8)}$$

$$v = \alpha + Ce^{-\beta t} \quad \text{(S9)}$$

Where

$$\beta = -\frac{18\eta}{4r^2} \quad \text{(S10)}$$

$$\alpha = -\frac{r\chi\mu m^2}{6\pi x^5} \quad \text{(S11)}$$

This leads to

$$v = Ce^{-\frac{18\eta}{4r^2}t} + \frac{3\chi\mu m^2}{8\pi^2 x^5\rho} \quad \text{(S12)}$$

Where C is an integration constant.

Combining (S12) and (1), we can compute the collision frequency of agglomerates (2) in the direction of the perpendicular applied field We note that for r = 100nm, the exponential term approaches 0 and may be neglected.

$$v \sim \frac{3\chi\mu m^2}{8\pi^2 x^5\rho} \quad \text{(S13)}$$

Applying conditions $\chi = 0.1$, μ = 710^{-12} $C^2N^{-1}m^{-2}$, m =1 T , x = 0.01 m, ρ=1000 kg m^3

$$v \sim 0.0003\ m/s \quad \text{(S14)}$$

The Peclet number can then be computed for the system:

$$Pe = \frac{vr}{D} \quad \text{(S15)}$$

Where D is the diffusion coefficient, given by Stokes-Einstein equation:

$$D = \frac{k_B T}{6\pi\eta r} \quad \text{(S16)}$$

Where k_B = Boltzmann constant

Substituting r = 100nm as a characteristic length scale, Pe ~ 22. Thus, this system is in the ballistic regime. Diffusion of the nanoparticles may be neglected.