

Supporting Information

Anisotropic magnetite nanoclusters with enhanced magnetization as an efficient ferrofluid in mass transfer and liquid hyperthermia

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1. FT-IR analysis

Magnetite nanoparticles were prepared and successful formation of Fe₃O₄ NPs and their modification was proved by FT-IR analysis, as shown in Figure 1S [a) Fe₃O₄, b) PAA and c) Fe₃O₄@PAA]. These show the changes in functional groups through modification reaction. The characteristic peaks of magnetite NPs are Fe²⁺-O and Fe³⁺-O stretching bands at 580 cm⁻¹ and 430 cm⁻¹ (Figure 1S-a and Figure 1S-c), respectively. The peaks around 3420 and 1623 cm⁻¹ are ascribed to the stretching and bending vibrations of hydroxyl groups on the surface of magnetite NPs, respectively, which confirm the preparation of magnetite nanoparticles. The appearance of C=O stretching vibration peak (1705 cm⁻¹), C-O-C stretching vibration peak (1102 cm⁻¹), C-H stretching vibration peak (2915 cm⁻¹), CH₂ bending vibration peak (796 cm⁻¹) and the characteristic absorption peaks of carboxylic groups at 1592 cm⁻¹ and 1398 cm⁻¹ in Figure 1S-c confirm successful attachment of PAA on the surface of the Fe₃O₄ NPs.

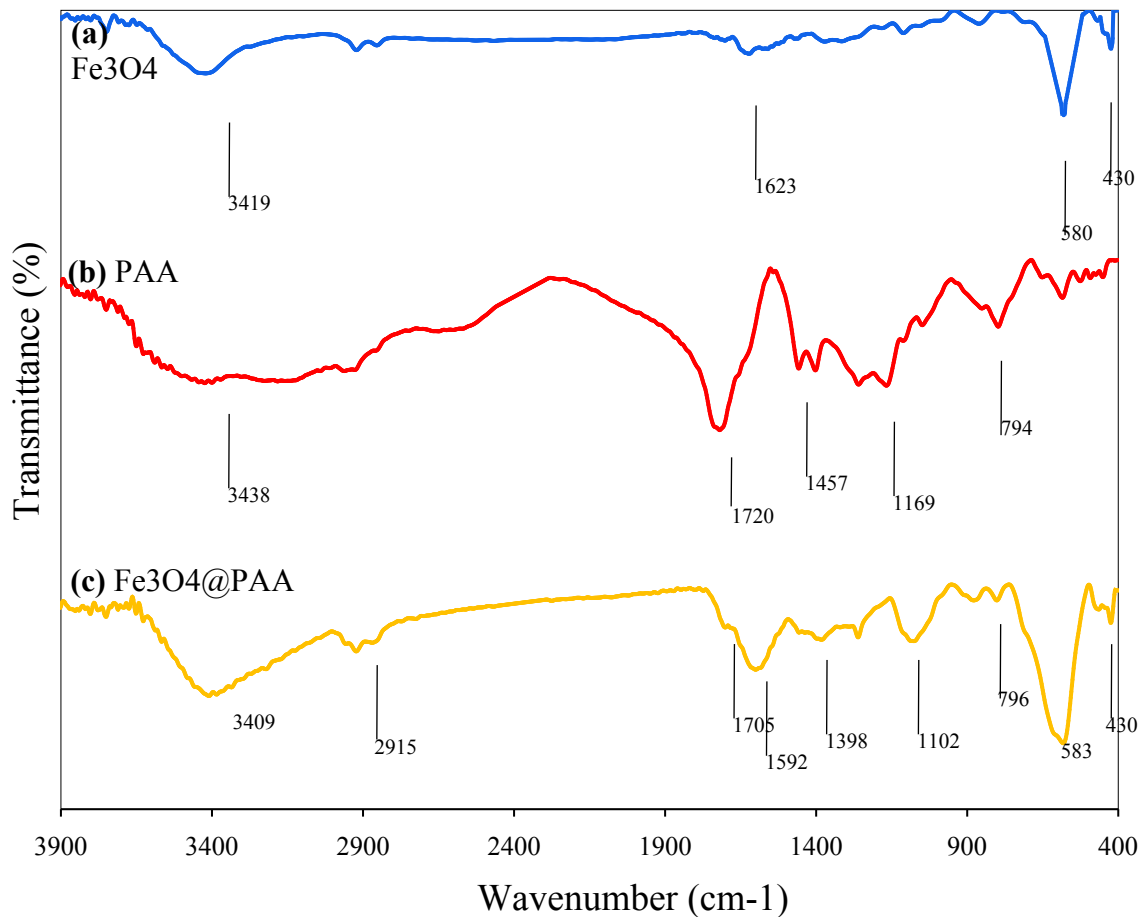


Figure 1S. FT-IR spectra of: (a) pristine Fe₃O₄ NPs, (b) prepared PAA, and (c) Fe₃O₄@PAA nanoclusters

2. XRD analysis

The crystalline structure of modified Fe₃O₄ NPs was verified by X-ray diffraction pattern (Figure 2S). All of the diffraction peaks in the XRD pattern of Fe₃O₄@PAA match well with the characteristic diffractions of standard Fe₃O₄ inverse spinel structure (Joint Committee for Powder Diffraction Studies, JCPDS, Card No. 19-0629). There are two extra polymeric phases (polyacrylic acid (PAA) and poly ethylene glycol (PEG 600)) in our sample. Their total amount is about 9 wt%

(based on TGA result) and hence, their crystalline planes would be observable in the XRD spectra. The broad peaks around 22 and 45-50° could be attributed to both PAA and PEG on the surface of Fe₃O₄ NPs. Also, the signal around 55° is related to PEG 600. PEG represents more semi crystalline nature in comparison to PAA.

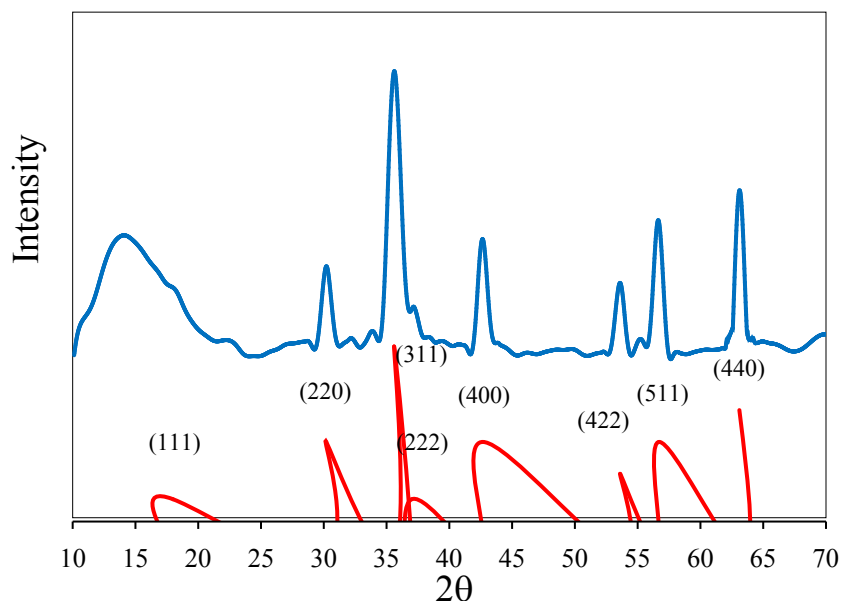


Figure 2S. X-ray diffraction pattern of Fe₃O₄@PAA nanoclusters

3. TGA analysis

Adsorption of PAA on the surface of magnetite was studied by thermogravimetric analysis (TGA). TGA was used to investigate thermal stability of Fe₃O₄ NPs and to characterize the approximate extent of modification. TGA analysis was carried out up to 600 °C to ensure the removal of volatile organic compounds. The weight loss in the range of 250–450 °C in Fe₃O₄ NPs (Figure 3S-a) is related to the degradation of adsorbed stabilizer agents (PEG and NaOAc) to Fe₃O₄. The difference between weight residues at 600 °C for Fe₃O₄@PAA NPs relative to pristine Fe₃O₄ NPs was found

9% and illustrates the relative amount of adsorbed PAA (Figure 3S-c). These data display that modification of Fe_3O_4 NPs with PAA has been performed successfully.

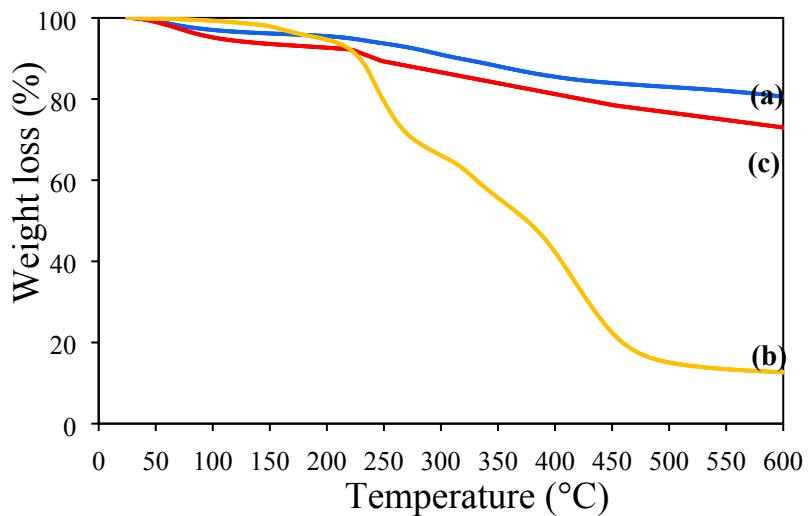


Figure 3S. TGA thermograms of (a) pristine Fe_3O_4 NPs, (b) PAA and (c) $\text{Fe}_3\text{O}_4@$ PAA nanoclusters

4. Magnetic tests



Figure 4S. Instant magnetic response of the prepared $\text{Fe}_3\text{O}_4@\text{PAA}$ nanoclusters dispersion in water to an external magnet

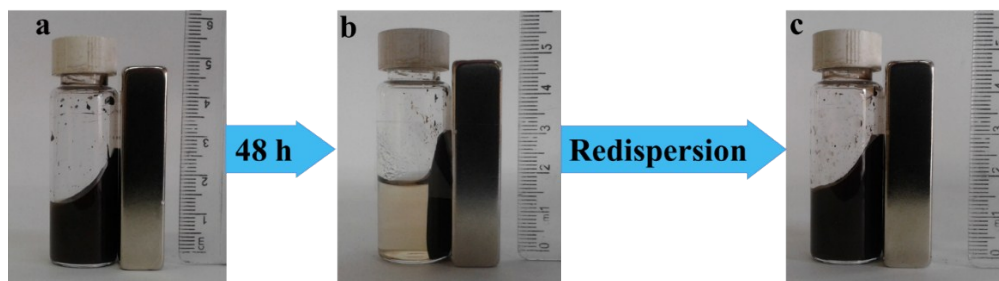


Figure 5S. Time-dependent pictures of the prepared $\text{Fe}_3\text{O}_4@\text{PAA}$ nanoclusters dispersion in water and under a 2500 gauss external magnetic field. The pictures were taken (a) at the beginning, (b) after 48 h of applying the magnetic field, and (c) after redispersion.

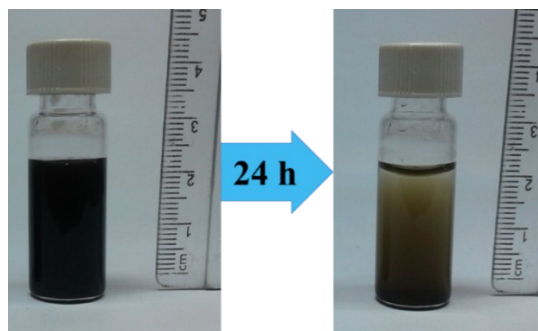


Figure 6S. The dispersibility of pristine Fe_3O_4 NPs in water after 24 h

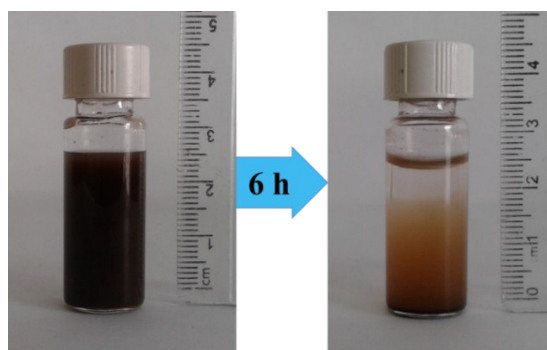


Figure 7S. Aqueous dispersion of $\text{Fe}_3\text{O}_4@\text{PAA}$ nanoclusters (1 wt%) at pH 4 primarily and after 6 h