One-pot synthesis and encapsulation of iron iodate ($Fe(IO_3)_3$) hybrid nanoparticles *via* water-in-oil miniemulsion polymerization for bioimaging.

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INTRODUCTION AND OBJECTIVE

Hybrid nanoparticles are one of the most important classes of colloidal materials due to the current interest in biomedical field. These hybrid materials bearing intrinsic optical properties can be used as nanoprobes for biomedical imaging (Grange 2011). Iron iodate nanocrystals ($Fe(IO_3)_3$) having a noncentrosymmetric structure (Mugnier 2011) can be used as nonresonant nonlinear optical probes for bioimaging applications using the second order processes of second harmonic (Bonacina 2007). These nonresonant processes provide advantages above and beyond traditional two photon bioimaging: (i) no photobleaching effect; (ii) coherent and stable signals with good flexibility in the choice of excitation wavelength; and (iii) no heat dissipation into the cells, ensuring longer cell viability and ultimately longer imaging times. The second harmonic generation is nonlinear optical properties when two-photon excitation can be interact with a noncentrosymmetric nanocrystals to combine a new photon with a twice energy, therefore, twice frequency and half wavelength of initial photons (Pantazis 2011).
The aim of this work is to prepare and optimize $Fe(IO_3)_3$ hybrid nanoparticles using inverse miniemulsion polymerization process (Kobitskaya 2010, Cao 2010). To this end, the water-soluble monomers have been used, such as 2-hydroxyethyl methacrylate (HEMA) and cross-linked by methylenebisacrylamide (MBA). The combination between organic and inorganic compounds offers crucial advantages including biocompatibility, colloidal stability and non-toxicity effect.
The SHG signal can be observed by Hyper-Rayleigh Scattering (HRS). In addition, the physicochemical properties of the water droplets containing iron iodate nanoparticles are characterized by TEM and SEM to examine the morphology of particles, DRX analysis to study the noncentrosymmetric crystalline structure, dynamic light scattering for particle size analysis, and potential zeta for electrochemical surface properties.

MATERIALS AND METHODS

Sorbitan mono-oleate 80 (Span 80) (purity, 99%), Cyclohexane (purity, 99%), Iodic acid (99.5%), Iron nitrate (99.9%), hydroxyethyl methacrylate (HEMA) (purity, 99.5%) and methylenebisacrylamide (MBA, 99 %) are purchased from Sigma-Aldrich and used without purification or recrystallization.
Azobisisobutyronitrile (AIBN, 99%) are purchased from Aldrich and recrystallized by ethanol.

Briefly, two water-in-oil miniemulsions have been prepared by mixing the aqueous phase containing HEMA, MBA and iodic acid or iron nitrate with nonpolar phase containing surfactant (Span 80) and cyclohexane. The fragmentation is obtained by ultrasonication at 90 % of amplitude for 5 minutes. The global inverse miniemulsion is obtained by sonication of two inverse miniemulsions prepared first at 90 % of amplitude for 5 minutes (Figure 1). Then, polymerization is carried inside reactors with addition of initiator AIBN (4% per monomers) and heated 70°C for 3 hours. The final nanoparticles are washed several times via centrifugation- redispersion cycles.

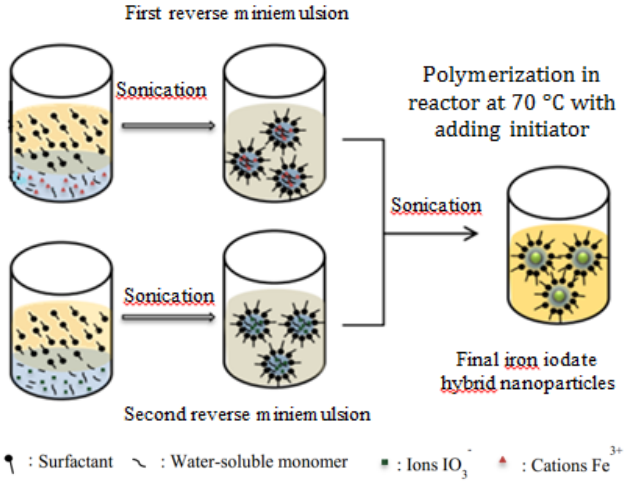

Figure 1: Schematic illustration of synthesis of iron iodate nanoparticles with and without HEAM-MBA.

The concentrations of aqueous solution of iodic acid (0.4 M) and iron nitrate (0.1 M) were varied as reported in Table 1.

Table 1: Varying concentration of reagent (iodic acid and iron nitrate).

	HEMA (g)	MBA (g)	IO_3^- 0.4 M	Fe^{3+} 0.1M
EXP-1	0.15	0.008	0.45 g	-
	0.15	0.008	-	0.45 g
EXP-2	0.15	0.008	1.5 g	-
	0.15	0.008	-	1.5 g

Constant products: Cyclohexane (44 g), water (6 g), Span 80 (3%, below critical micelle concentration (CMC)).

RESULTS AND DISCUSSION

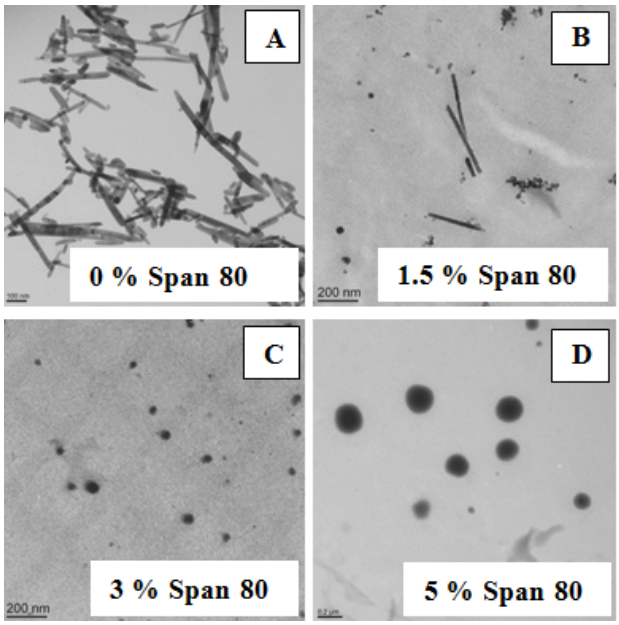

Figure 2: TEM images of iron iodate nanoparticles at different weight % of Span 80: 0 (A), 15 (B), 30 (C), 50 (D).

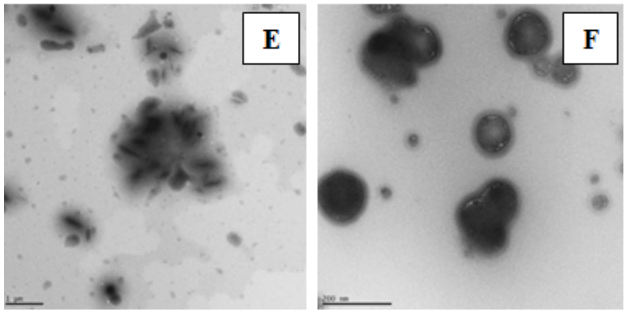

Figure 3: TEM images of poly (HEMA-MBA) encapsulated iron iodate nanoparticles: Exp-1 (E), Exp-2 (F)

The morphology of iron iodate nanocrystals can be controlled by the amount of surfactant (Span 80) as shown in Figure 2. The iron iodate nanorods shown in figure 2-A were obtained by Ostwald ripening. At 1.5 % of Span 80, both iron iodate rods and spherical nanocrystals were obtained. The spherical iron iodate nanoparticles were obtained when at least 3 % of span 80. In this later, there is no Ostwald ripening of nuclei because the excess of IO_3^- ions can act as osmotic pressure agent stabilizing nanodroplets (figure 2-E, 2-F).

As shown in figure 3, iron iodate nanoparticles were encapsulated with a polymeric matrix of poly (HEMA-MBA) as shell. The morphology of iron iodate cores was found to be nanorods with 0.45 g of water solution of iron nitrate and iodic acid (figure 3-E). However, spherical nanocapsules were produced with increase of water solution of iron nitrate and iodic acid (figure 3-F).

CONCLUSION

Hybrid iron iodate nanoparticles were prepared using inverse miniemulsion polymerization of HEMA and MBA as cross-linker agent. Therefore, spherical polymeric nanocapsules were obtained. However, iron iodate nanocrystals can be crystallized in water nanodroplets *via* inverse miniemulsion. Consequently, shapes controlled iron iodate nanorods and spherical nanocrystals were achieved by varying the amount of Span 80 in the precipitation recipient.

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