

Hermetically-coated superparamagnetic Fe₂O₃ particles with SiO₂ nanofilms

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Magnetic nanoparticles are frequently coated with SiO₂ to improve their functionality and biocompatibility in a range of biomedical and polymer nanocomposite applications (Gupta & Gupta, 2005). Silica is stable in aqueous conditions and prevents magnetically-induced self-agglomeration of magnetic cores. Silanol groups on the silica surface react with alcohols and silane coupling agents to produce stable dispersions in non-aqueous solvents and can be further modified by covalent bonding of specific ligands. Furthermore, silica-coated or -embedded γ -Fe₂O₃ (maghemite) nanoparticles exhibit improved thermal stability. Typically iron oxide nanoparticles are coated with SiO₂ by a sol-gel process that involves several steps, similar to the SiO₂-coating of pigmentary titania. Co-oxidized, flame-made SiO₂/Fe₂O₃ particles typically consist of several, small maghemite nanoparticles embedded in larger silica particles or aggregates (Li *et al.*, 2006). The reduction of Fe_xO_y particle size by adding relatively large amounts of non-magnetic SiO₂ to ensure complete encapsulation significantly decreases the magnetic performance of these composite materials. Clearly, it is important to develop a scalable process for the synthesis of maghemite particles encapsulated by thin SiO₂ layers, thereby minimizing the non-magnetic silica content.

Thus, iron oxide nanoparticles were produced by FSP and the resulting aerosol was *in-situ* coated with SiO₂ by oxidation of swirling HMDSO vapour (Teleki *et al.*, 2008a). The process allows independent control of core Fe₂O₃ particle properties and the thickness of their silica coating film. The complete encapsulation of the core particles (22 nm) at > 12 wt% SiO₂ (Figure 1) was demonstrated by isopropanol chemisorption as had been developed for SiO₂-coated TiO₂ (Teleki *et al.*, 2008b). The silica content in the product can be minimized to decrease the negative impact of silica on the saturation magnetization of γ -Fe₂O₃. The magnetization of flame-made nanoparticles was measured by a vibrating sample magnetometer at room temperature. The highest magnetization corresponds to pure Fe₂O₃, as expected. The addition of 23 – 46 wt% SiO₂ by FSP co-oxidation reduces the magnetization by the presence of silica, and by the reduction of Fe₂O₃ crystallite size for SiO₂/Fe₂O₃ particles. In contrast, the magnetization of 23 wt% SiO₂ *in-situ* coated Fe₂O₃ is very close to pure Fe₂O₃ and higher

than that of commercially available MagSilica. This demonstrates that Fe₂O₃ nanoparticles coated *in-situ* by thin SiO₂ films retain most of their magnetic properties. The coercivity and remanence of all samples is low indicating superparamagnetism.

Also these particles exhibited excellent dispersibility compared to flame-made co-oxidized silica-iron oxide and commercially available particles. The low isoelectric point of SiO₂ facilitates the dispersion of such particles in aqueous solutions even in the absence of surfactants. A ferrofluid was prepared from 23 wt% SiO₂-coated Fe₂O₃ suspended in water and exposed to a magnetic field. The superparamagnetic properties can be observed as the fluid returns to the original state after removal of the magnet. Such suspensions can facilitate the contrast of MRI as they interact with external magnetic fields and can be positioned in a specific area. Thus, the FSP *in-situ* coating process enables complete encapsulation of Fe₂O₃ nanoparticles at relatively low SiO₂ contents resulting in highly superparamagnetic Fe₂O₃ particles at reduced cost (as less Si is needed compared to co-oxidized products).

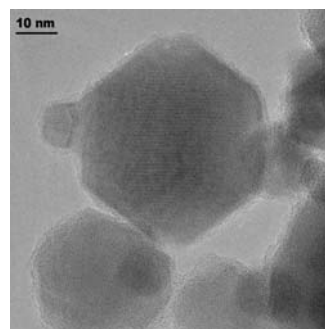


Figure 1. TEM image of γ -Fe₂O₃ *in-situ* FSP-coated with 23 wt% SiO₂.

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