Improving magnetic properties of iron oxide nanoparticles from the synthesis

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Abstract

There is an increasing need for magnetic nanoparticles for different applications that could be solved through high-performance techniques producing large quantities of nanoparticles, such as synthesis methods based on precipitation of Fe precursors in aqueous and organic media or aerosol pyrolysis. However, for real industrial applicability (kilogram-scale synthesis), especially in the case of biomedicine, it is necessary to overcome a series of difficulties such as surface disorder for the smallest nanoparticles, internal defects when growing large particles or the high tendency to aggregate in water that strongly affect their magnetic properties and finally their performance for a specific application [1].

Different approaches have been followed to optimize magnetic properties of iron oxide nanoparticles by controlling synthesis parameters. Thus, a considerable increase in the saturation magnetization, Ms (40%), and initial susceptibility of ultrasmall (<5 nm) iron oxide nanoparticles was achieved through an optimized acid treatment [2]. Moreover, a significant enhancement in the colloidal properties, such as smaller aggregate sizes in aqueous media and increased surface charge densities, was found after this chemical protocol. The results are consistent with a reduction in nanoparticle surface disorder induced by a dissolution-recrystallization mechanism and particles showed excellent NMR imaging relaxivity properties.

On the other hand, improvement of crystallinity and uniformity of large magnetite nanoparticles prepared by thermal decomposition of organic precursors can be achieved by controlling nucleation and growth rates by varying constituents and reaction time. Magnetite nanoparticles with diameters between 10 and 20 nm can be obtained with a size distribution lower than 10%, very good magnetic response and consequently high heating efficiency (100 W/g under 70 kHz, 40 mT) which makes then excellent candidates for hyperthermia treatments [3].

Finally, new inorganic hybrid nanoparticles integrating different materials in a core/shell structure of iron and bismuth oxides can be synthesized by a simple aqueous route. The method is based on the precipitation of an Fe(II) salt in the presence of bismuth(III) cations in a mild oxidant and leads to highly uniform and crystalline magnetic nanoparticles with sizes up to 30 nm. This robust material with very long chemical stability and resistance to degradation, showed both good magnetic properties and high X-ray attenuation, leading to a new generation of contrast agents for magnetic resonance and computed tomography imaging agents [4].

Optimization of magnetic properties of nanoparticles also allows their detection even at low doses by magnetic methods. Detection and quantification of nanoparticles in tissues or organs is possible from the magnetization curves and AC susceptibility curves giving valuable information about nanoparticle pharmacokinetic and biodistribution [5].

References

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