Influence of ligand exchange on crystallography, magnetic and thermal behavior of iron oxide nanoparticles for hyperthermia

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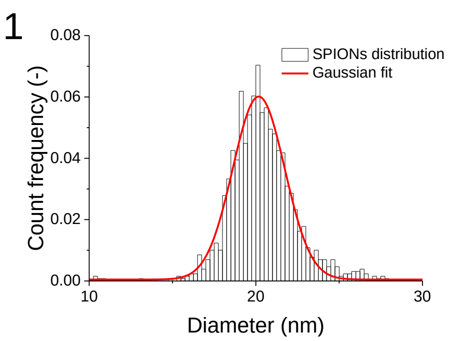
Abstract

The thermal decomposition of iron oleate complexes in organic solvent is a robust and popular route to synthesize highly monodisperse superparamagnetic iron oxide nanoparticles (SPIONs)[1]. However, the resulting oleic acid coated nanoparticles are not stable in polar solvents and therefore unsuitable for biomedical applications. To overcome this limitation, these synthesized SPIONs are commonly subjected to a phase transfer step prior to any subsequent surface functionalization or application[2]. Here, we investigate how ligand exchange procedures may affect the magnetic and thermal properties of SPIONs, subsequently making them attractive candidates for magnetic hyperthermia.
Large-scale synthesis of oleic acid coated SPIONs (core diameter = 20 nm) is achieved by thermal decomposition of the iron oleate complex in an automated reactor that controls crucial reaction parameters. High Resolution Scanning Transmission Electron Microscopy and X-Ray Diffraction studies of oleic acid coated SPIONs show a wüstite (FeO)/magnetite (Fe_3O_4) core/shell structure (Figure 1). This observation is in agreement with magnetic measurements and hyperthermia tests that highlight weak superparamagnetism and poor thermal properties. However, when the particles are transferred to water with a high temperature ligand exchange procedure, the wüstite core is oxidized to a single crystal of magnetite. In particular, we observe that the magneto-thermal properties of functionalized SPIONs are significantly enhanced by the thermal annealing process that occurs during ligand exchange. The nanoparticles show a pronounced superparamagnetic behavior, and their thermal signature is increased by more than ten times.
The possibility for large-scale synthesis is given by thermal decomposition and post-processing treatments. Consequently, the altering of the crystalline structure renders the SPIONs more efficient for magnetic hyperthermia.

References

[1] Park J. et al., Nature Materials, **3** (2004) 891-895.
[2] Lattuada M. and Hatton T.A., Langmuir, **23** (2007) 2158-2168.

Figures



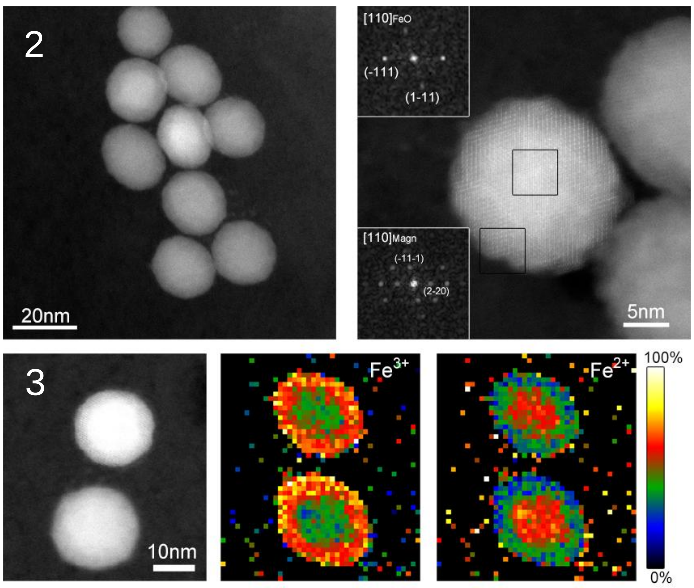


Figure 1: TEM size distribution (1), high angle annular dark field-STEM (2) and STEM- electron energy loss spectroscopy (3) measurements of 20 nm oleic acid coated SPIONs revealing a core/shell crystalline structure.