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Recent advances in magnetic nanoparticles with bulk-like properties

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Magnetic nanoparticles (NP) are an excellent example of nanostructured materials and exhibit fascinating properties with applications in high-density recording and biomedicine. Controlling the effects of the nanostructure and surface chemistry and magnetism at the monolayer level have become relevant issues. As the size is reduced below 100 nm, deviations from bulk behavior have been attributed to finite-size effects and changes in the magnetic ordering at the surface, thus giving rise to a significant decrease in the magnetization and increase in the magnetic anisotropy. The existence of a surface spin glass-like state due to magnetic frustration has been widely suggested in ferrimagnetic NP [1]. However, in this talk, we will show that high crystal quality magnetite $Fe_{3-x}O_4$ NP of about a few nanometers in diameter and coated with different organic surfactants [2] display bulk-like structural, magnetic and electronic properties. Magnetic measurements, transmission electron microscopy, X-ray absorption and magnetic circular dichroism and Monte Carlo simulations, evidenced that none of the usual particle-like behavior is observed in high quality NP of a few nm [3]. Consequently, the magnetic and electronic disorder phenomena typically observed in those single-phase ferrimagnetic NP should not be considered as an intrinsic effect. We also performed a real-space characterization at the sub-nanometer scale, combining scanning transmission electron microscopy, electron energy loss spectroscopy and electron magnetic chiral dichroism. For the first time, we found that the surface magnetization is as high as about 70% of that of the core [4]. The comparison to density functional theory suggested the relevance of the strong surface bond between the Fe ions and the organic surfactant. All the foregoing demonstrates the key role of both the crystal quality and surface bond on the physical properties of ferrimagnetic NP and paves the way to the fabrication of the next generation of NP with optimal magnetic properties [5]. Some bio-applications will also be discussed [6].

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