Magnetic nanoparticles for biomedical applications

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Superparamagnetic iron oxides (SPIOs) including γ-Fe_2O_3 and Fe_3O_4 nanoparticles are biocompatible and relatively easy to synthesize; these properties make them the most used magnetic nanoparticles (MNPs) in biomedicine to date. They have been studied for several decades and have contributed to both diagnostics such as MRI contrast agents and therapeutics such as magnetic hyperthermia. However, the relatively low saturation magnetization (M_S) of SPIOs limits their potential in these applications.

Enhancement of the magnetic moment of MNPs is key for improvement of many applications in biomedicine. Considering the characteristic size of biological systems, MNPs with smaller dimensions than normally used SPIOs are preferred as they would increase the spatial resolution. Using MNPs, which have higher M_S and higher magnetocrystalline anisotropy energy than SPIOs, one can significantly improve efficiency in various biomedical applications. Moreover, these magnetically superior ultrasmall MNPs could lead to revolutionary and novel clinical applications.

Recently, mono- and bimetallic superparamagnetic MNPs have become readily available thanks to the development of a range of synthetic techniques. In general, the metallic MNPs exhibit higher magnetic properties than oxide MNPs, and thus those MNPs increasingly attract attention in various biomedical fields. In addition, various heterostructured multi-functional MNPs including magnetic-plasmonic core/shell/shell MNPs (Figs. 1 and 2)[1] have been recently developed for bioimaging, magnetic separation, magnetic immunoassay, etc. We review the progress of research on MNPs for biomedical applications.

References

1) S. Maenosono *et al.*, *Langmuir*, **31** (2015) 2228.

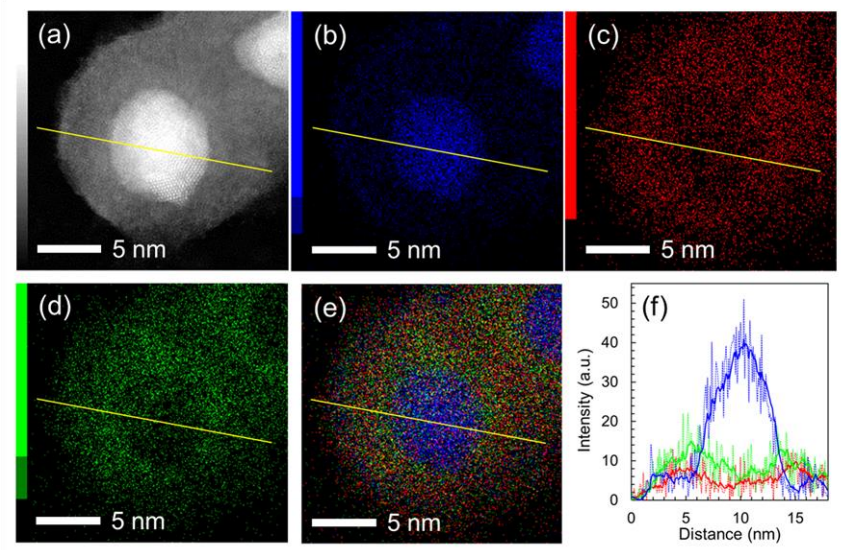

Fig. 1. (a) STEM-HAADF image of a single Ag/FeCo/Ag core/shell/shell MNP. (b–e) EDS elemental mapping images of the single Ag/FeCo/Ag MNP: (b) Ag L edge, (c) Fe K edge, (d) Co K edge, and (e) overlaid image. (f) The EDS line profile at the center of the MNP indicated by a yellow line in (a–e). Blue, green and red lines correspond to Ag L, Co K and Fe K edge intensities, respectively.

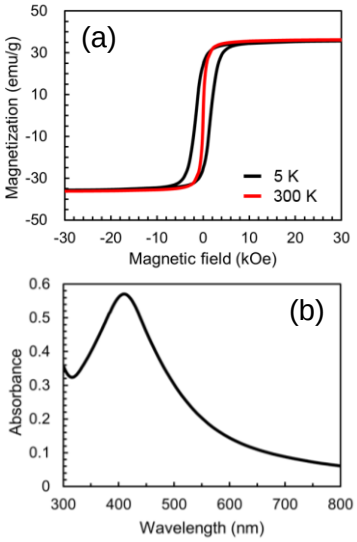

Fig. 2. (a) Magnetization curves of Ag/FeCo/Ag MNPs measured at 5 (black) and 300 K (red). (b) UV-vis spectrum of a hexane dispersion of as-synthesized Ag/FeCo/Ag MNPs.