Size-Controlled Synthesis of Cobalt Doped Magnetite Nanoparticles with Enhanced Performance for Magnetic Particle Imaging

Ashkan Abdibastami,[1] H. T. Kim Duong,[1] Lucy Gloag,[2] Soshan Cheong,[3] Andre Bongers,[4] Saeed Shanehsazzadeh,[4] Scott A. Sulway,[1] J. Justin Gooding,[1,5] and Richard D. Tilley[1,3,5]*

(1) School of Chemistry, UNSW Sydney, NSW 2052, Australia.
(2) Mathematical and Physical Sciences, UTS, NSW 2007, Australia.
(3) Electron Microscope Unit, Mark Wainwright Analytical Centre, UNSW Sydney, NSW 2052, Australia.
(4) Biological Resources Imaging Laboratory, Mark Wainwright Analytical Centre, UNSW Sydney, NSW 2052, Australia.
(5) Australian Centre for NanoMedicine, UNSW Sydney, NSW 2052, Australia.

Presenting author: a.abdibastami@unsw.edu.au
Corresponding author: r.tilley@unsw.edu.au

Biomedical imaging plays a crucial role in the diagnosis and monitoring of various chronic diseases.[1,3] Magnetic Particle Imaging (MPI) is a technique for tomographic imaging that provides real-time visualisation of magnetic tracers' distribution.[1-3] So far the MPI tracer research is strongly focused on the development and optimisation of undoped superparamagnetic iron oxide nanoparticles (NPs) that are mainly magnetite.[1] However, selective doping of certain transition metal ions into magnetite NPs which replaces Fe^{3+} ions located in tetrahedral sites and leads to decrease in antiparallel magnetic spin moments on these sites, offers a great opportunity to utilise their appealing magnetic characteristics in MPI.[1-3] In this study, we explored the MPI performance of superparamagnetic Co-doped magnetite NPs by examining the impact of chemical composition and particle size on the magnetic properties and MPI signal. Our findings indicate that the doping of 12% Co into 9 nm magnetite NPs without increasing their size leads to a 1.6-fold improvement in signal intensity. Similarly, enlarging the average size of magnetite NPs from 9 nm to 20 nm in the absence of Co-doping amplifies the signal intensity by 4 times. Combining Co-doping with size enlargement has a strong potential to amplify the signal intensity by up to 7.4 times compared to undoped small NPs. This finding highlights the significance of integrating Co-doping with a process of size enlargement in order to improve the MPI signal. Moreover, we found that enlarging 12% Co-doped magnetite NPs from 9 nm to 20 nm resulted in a noteworthy improvement in spatial resolution. In preliminary Relaxometer measurements we found a 2.5-fold reduction in the full-width at half-maximum (FWHM) of the point spread function (PSF). Relaxation effects are impacted by both the chemical composition and particle size, as greater Co content and larger particle size resulted in relatively longer relaxation times. This was detected by observing a PSF peak shift from 0 mT, which is attributed to crystal anisotropy resulting from the doping process, and a potential shift from Néel to Brownian rotation in NPs with greater particle size.[5]

References:

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