On the architecture of multicore iron oxide nanoparticles

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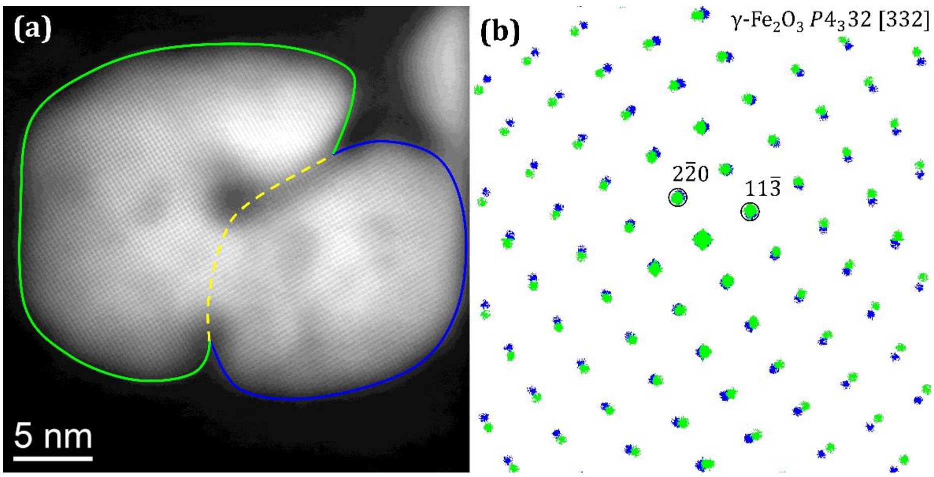
Iron oxide nanoparticles are the first choice for the applications in biomedicine because of their excellent biocompatibility, biodegradability, easy synthesis and interesting magnetic properties [1]. It has been demonstrated that multicore iron oxide nanoparticles show superior properties, for instance a much higher efficiency for magnetic hyperthermia [2], in comparison to their monocore counterparts. The aim of this work is to reveal the architecture of multicore maghemite nanoparticles, in particular the intergrowth of individual cores within the particles, which plays a tremendous role for their performance.

High-resolution (scanning) transmission electron microscopy in combination with local fast Fourier transforms as well as selected area electron diffraction confirmed the maghemite structure (space group $P4_332$) of the nanoparticles. In addition, high-resolution micrographs revealed that the particles consist to some extend of one core and partly of several cores. The individual crystallites of the multicore particles were always intergrown along certain crystallographic directions, although a mutual twist of a few degrees of the crystallites was often observed. The size distributions of the nanoparticles and the cores as well as the amount of multi- and monocore particles were determined statistically using a multi-step semi-automatic segmentation routine that is based on a marker-based watershed transformation. This routine was applied to several low-magnification high-angle annular dark field scanning transmission electron microscopy images [3]. The sizes of the nanoparticles and the individual cores were correlated with the crystallite size determined by X-ray diffraction. The effect of the crystallographic coherence on the crystallite size is discussed.



(a) High-resolution high-angle annular dark-field scanning transmission electron microscopy image showing a multicore iron oxide nanoparticle composed of two cores that are slightly misoriented with respect to each other. (b) Filtered fast Fourier transforms of the individual cores illustrating their mutual misorientation.

[1] Sangaiya, P, Jayaprakash R. A Review on Iron Oxide Nanoparticles and Their Biomedical Applications. J. Supercond. Nov. Magn., 31, 3397-3413 (2018).

[2] Hemery G, Genevois C, Couillaud F, Lacomme S, Gontier E, Ibarboure E, Lecommandoux S, Garanger E, Sandre O. Monocore vs. multicore magnetic iron oxide nanoparticles: uptake by glioblastoma cells and efficiency for magnetic hyperthermia. Mol. Syst. Des. Eng., 2, 629-639 (2017).

[3] Neumann S, Menter C, Mahmoud A S, Segets D, Rafaja D. Microstructure characteristics of non-monodisperse quantum dots: on the potential of transmission electron microscopy combined with X-ray diffraction. CrytEngComm, 22, 3644-3655 (2020).