BACTERIAL MAGNETOSOMES AS A NEW TYPE OF BIOGENIC MPI TRACER

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Introduction & Objective

Biomineralization is the process whereby minerals are formed by living organisms. Biomimetic exhibit extraordinary material properties such as the combination of extreme mechanical robustness and extreme lightweight as in the case of nacre. Another amazing example are so-called magnetosomes, membrane-enclosed iron oxide nanoparticles biomineralized by magnetotactic bacteria as magnetic sensor for magnetotaxis [1]. Such magnetosomes are characterized by distinctive monodispersity in size and shape and consist of a monocristalline magnetite (Fe₃O₄) phase. Magnetic Particle Imaging (MPI) is a new and promising imaging technology that requires the use of a magnetic tracer material. Different theories and approaches exist, involving iron oxide nanoparticles comprising, on the one hand, particles of crystal clusters [2] and, on the other hand, monocristalline particles of large size [3]. For the first time, we present the investigation of the MPI performance of magnetosomes isolated from the bacterium Magnetospirillum gryphiswaldense. Magnetic particle spectroscopy (MPS) studies as well as static M/H-measurements are performed and compared with the current MPI gold-standard, Resovist®.

Materials & Methods

Magnetospirillum gryphiswaldense strains were grown under anoxic conditions in modified FSM medium [4] at 25°C in a Biostat C fermentor (B. Braun Biotech International, Melsungen, Germany). Magnetosome isolation was performed as described previously [5]. To evaluate the results, the current MPI gold-standard, Resovist®, was used for comparison (Resovist is no longer a marketed product but was still stocked in the author’s lab).

Results & Discussion

TEM images highlight the presence of large and non-interacting particles (Fig. 1). Samples LMU02 and LMU03 mainly consist of randomly distributed particles whereas the TEM image of sample LMU01 shows, besides single particles (not present in Fig. 1a), also the typical chain alignment of biological magnetosomes. The crystal size, here designated as average core diameter dₕ, is determined at values of 33.0 nm, 30.5 nm, and 25.7 nm for LMU01, LMU02 and LMU03, respectively. All samples provide sufficient colloidal stability attributed to the magnetosomes membrane, which stabilizes the particles in aqueous media. The hydrodynamic diameter dₕ is measured by DLS. The dₕ of all samples is in the range of 80 – 100 nm indicating only minor interactions/aggregation in aqueous media (Fig. 2). The results confirm the TEM findings where mostly separated particles are visible. MPS spectra of the measured magnetosome suspensions in comparison to Resovist are shown in Fig. 3. It can be clearly seen, that the amplitudes of the magnetosomes over the entire range of the harmonics exceed that of Resovist by far, with a reduced decay of the amplitudes at higher harmonics. The third harmonic of the magnetosomes is at least about 4.7 times higher compared to that of Resovist, in which the sample with the smallest core diameter LMU03 exhibits the strongest amplitude. The amplitude of LMU03 is, in fact, higher by a factor of about 6.8; and is indeed one of the highest values found so far.

Conclusion

We show that the MPS signal exhibited by the magnetosomes is significantly improved compared to Resovist, the hitherto gold-standard in MPI. This is made possible through the magnetosomes’ structural features such as high crystallinity and large crystal size, which result in large magnetic moments and negligible magnetic anisotropy. Furthermore, we observe a size-dependence of the MPS signal with the highest signal for the smallest magnetosome particles, showing that not only a strong magnetic moment but also dynamic aspects are important for a good MPI performance. Although technical applications of magnetosomes have been hampered due to their technically challenging bioproduction, our contribution proves their great potential as tracers and may stimulate new research efforts to synthesize such particles in the lab by biological and biomimetic synthetic routes [6].

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References


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