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How shape anisotropy affects bulk magnetic properties: Observation of magnetosome chains in magnetotactic bacteria

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Magnetotactic bacteria have ability of forming dozens to hundreds of magnetosomes, which are commonly arranged into a single or multiple chains. Previous studies have demonstrated that for magnetosome chain(s), the strong intra-chain interactions generate a behavior of non-interacting uniaxial single domain (SD) particle. As a result, the chain configuration of magnetosomes maximizes its total moments and facilitates MTB cells to be efficiently oriented by geomagnetic field as they swim. To evaluate the magnetic anisotropy of magnetosome chains, this study systematically measured both room and low-temperature magnetic properties of oriented Magnetospirillum magneticum AMB-1 cells at various directions relative to the magnetosome chain axes. Experimental results show that, the shape anisotropy of magnetosome chains has pronounced impact on the hysteresis loop, IRM acquisition and demagnetization curves, FORC distribution and the Verwey transition behavior. Specifically, with the angle θ changed from 0° (parallel to the chain axis) to 90° (perpendicular to the chain axis), the hysteresis loop gradually becomes narrower and more slanting, while the IRM acquisition and demagnetization curves shifts toward higher field. This results in a trend of hysteresis parameters from SD to pseudo SD (PSD) region on the Day plot. Likewise, the horizontal spread of FORC distribution becomes more expanded and the corresponding peak shifts toward higher microcoercivity field. And, the percentages of remanence losses crossing the Verwey transition are small as measured parallel to the chain axis but distinctively enhanced for that measured perpendicular to the chain axis, because of the shape anisotropy of magnetosome chains. Therefore, the experimental data of angular-dependence of the parameters Bc, Bcr, Bcr/Bc, Mrs/Ms, Hc,FORC, δFC, δZFC and δ ratio for the oriented magnetotactic bacteria cells, provide new insights for understanding magnetic properties of SD magnetite particles with significant shape anisotropy.