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Magnetic force microscopy of magnetic particle clusters from sensory cells of salmon

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Abstract

Magnetite particles are present in a variety of species and fulfill biological functions which are only in part understood. In particular, they provide a base for the magnetic sensory ability of many animals. The arrangement of magnetic particles in the form of aggregates and clusters is crucial to their function. In this work, magnetite particle clusters were isolated from sensory cells of salmon, which are situated in the nose and the sideline organ. Clusters were imaged by magnetic force microscopy (MFM). In parallel, simulations of the magnetic structure of candidate clusters have been performed, assuming purely dipolar interaction between particles. Cluster size, cluster shape, particle diameter and temperature were taken from the experiment. The temperature is below the blocking temperature, so that the system can be considered ferromagnetic. Simulations result in a vortex magnetic structure that aligns in an external field by coherent rotation. Simulated magnetization curves are compared with experimental MR curves of the original tissue. In order to model the experimental MFM images, the susceptibility of the cluster with respect to the tip field must be taken into account. This can be done by modeling the cluster by a sphere of constant permeability, regardless of the system being ferromagnetic, or superparamagnetic. For this model, an analytic expression for the tip-sample force exists. A series of high-resolution MFM images of the same particle clusters show patterns of concentric rings emerging and disappearing in a complex manner in an applied magnetic field. We interpret such patterns as a consequence of a bistable cantilever amplitude. In conclusion, we suggest a permeable sphere model for the magnetic particle clusters isolated from salmon sensory cells.

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