EFFECT OF THERMAL FLUCTUATIONS ON HYSTERESIS OF CHAINS OF MAGNETITE CRYSTALS

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Although magnetic hysteresis is usually modeled as a set of equilibrium curves with jumps at critical fields, jumps will always occur before the critical field is reached because of thermal fluctuations. The probability of a jump at a given field depends on the network of connections between stable states by way of saddle points. The most difficult part of modeling such connections is finding the saddle points. A new method finds all the saddle points using a special tool for finding roots of polynomial systems. All equilibrium states are found and classified as stable, saddle, or other, and a two-stage solver finds the downhill paths from each saddle point to the nearest minima. A master equation is solved to get the time dependence of the magnetic moment.

This method is applied to a chain of magnetostatically interacting single-domain particles such as those in magnetotactic bacteria. If there are N particles in a chain, there are up to 2^N saddle points. The number of saddle points decreases until there are at most two for particles in contact with each other. In zero field, the relaxation mode for chains of 5 or more particles is a new mode that I call the two-domain fanning mode. This mode has only a limited domain of stability and is replaced by a symmetric fanning mode in larger fields. If the critical size for the transition to superparamagnetism is expressed as the cube root of the volume, it approaches about 10 nanometers as the number of particles increases, independent of the shapes of the particles.

Hysteresis, superparamagnetism, single-domain, magnetotactic

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