

Magnetic moment of ferrimagnetic microspheres

There is much confusion about units and measures of the magnetic moment of particles; this has been caused by the parallel use of Gaussian and SI units, and two different definitions of the magnetic moment (Ampère's vs. Coloumb's definition). In the following attempt to characterize the magnetic moment of our ferrimagnetic particles, we use SI units and Ampère's definition (the magnetic torque due to a magnetic induction). Accordingly,

$$T_{\text{mag}} = \mu_0 \vec{H} \times \vec{M} = \mu_0 H M \sin \nu$$

with the torque T_{mag} [Nm], the magnetic permeability μ_0 [$4\pi 10^{-7}$ N/A²], the particles magnetic moment M [Am²], the magnetic field strength H [A/m] and the angle between magnetization direction and field direction ν .

We calibrate our particles by placing them in a fluid of known viscosity η [Pa s], magnetizing them horizontally, and measuring the particle's speed of rotation ω when they are twisted in a constant, homogeneous magnetic field that is aligned vertically. According to Stoke's law, the viscous drag (or torque) on the beads is

$$T_{\text{vis}} = -\kappa V \eta \omega$$

with the particle's shape factor κ and the particle volume V [m³].

Because

$$T_{\text{vis}} + T_{\text{mag}} = 0$$

we find

$$M = \frac{\kappa V \eta \omega}{\mu_0 H}$$

With the following values for ferrimagnetic beads with 1.8 μm diameter:

$$\kappa = 6 \text{ (for spheres)}$$

$$V = 3.1 \cdot 10^{-18} \text{ m}^3$$

$$\eta = 91.7 \text{ Pa s}$$

$$\omega \text{ of typically } 0.052 \text{ s}^{-1} \text{ for a magnetic induction } \mu_0 H \text{ of } 2 \text{ mT (or 20 Gauss)}$$

we compute **$M = 4.4 \cdot 10^{-14} \text{ Am}^2$**

In Gaussian units, this corresponds to $4.4 \cdot 10^{-11}$ erg/G (or emu). Assuming a bead density of 4900 kg/m³, the beads have a mass of $1.5 \cdot 10^{-11}$ g, and a specific magnetization $\sigma = 2.94$ emu/g.