Ribbons of superparamagnetic colloids

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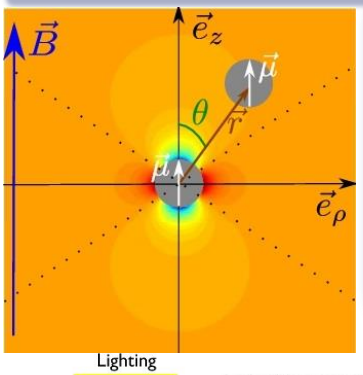
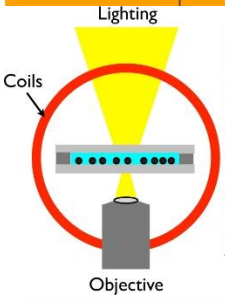
Introduction

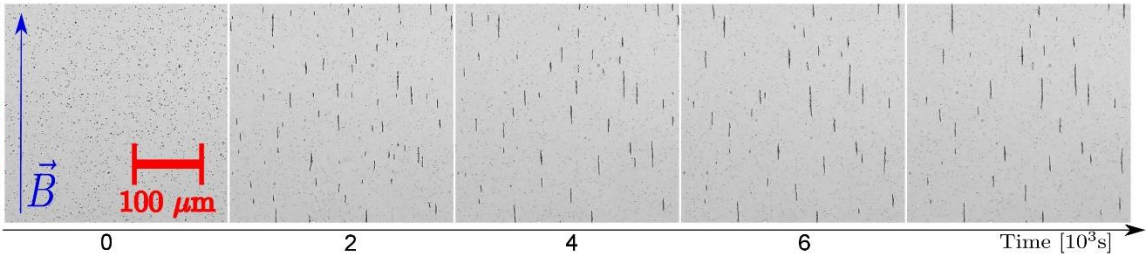


Immersed in a constant magnetic field, superparamagnetic colloids interact as magnetic dipoles. Their magnetic energy, illustrated on the left, can be written as: $U(r,\theta) = \frac{\mu_0 \mu^2}{4\pi}\left(\frac{1-3\ \cos^2\theta}{r^3}\right)$ (left picture).

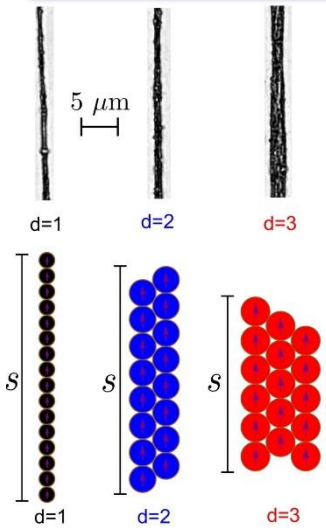
Therefore, two particles tend to attract each other and to create a pair of particles aligned with the field $\vec{B}$.Consequently, the particles form structures aligned with the field, as pictured below.

Such structures can be functionalized to capture specific target in protein isolation, cell separation, waste capture, etc. [1]

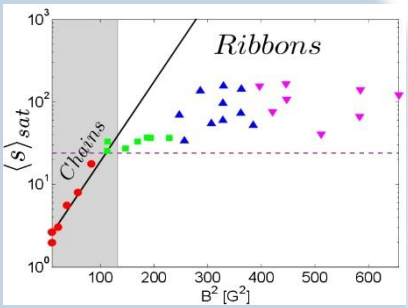




Structures

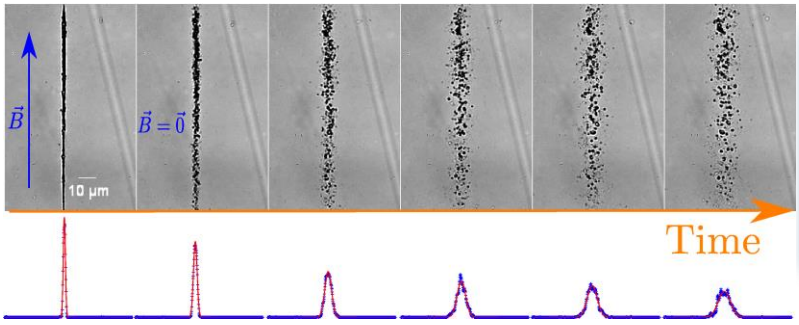


Those structures were believed to be only chains ($d = 1$). [1] We observed that the longest chains also aggregate laterally, creating ribbons of superparamagnetic colloids ($d > 1$). This effect is surprising because interactions with nearest neighbors are repulsive, and only long range interactions stabilize such structures above a given threshold length ($s > 15$ for $d = 2$). This has significant effects on the growth rate of the structures and on the mean value of the structures' length at thermodynamic equilibrium. [2]



Those observations then highlight unexpected aggregation processes of magnetic material which are a current topic of research. [3] It also opens prospects to achieve controlled generation of such micro-structures.

Diffusion



When the magnetic field is removed, the particles then freely diffuse from the chain. Since all the particles initially have the same coordinate on the axis perpendicular to the initial chain, this configuration enables an observer to study the one dimensional diffusion process, which can be useful in pedagogical purposes. Moreover, by studying the evolution of the particle distribution, a measurement of the diffusion coefficient may be obtained. [4]

References

[1] J. Faraudo, J. S. Andreu, and J. Camacho, Soft Matter **9**, 6654 (2013).
[2] A. Darras, J. Fiscina, M. Pakpour, N. Vandewalle, and G. Lumay, EPJE **39**(1) (2016).
[3] R. Messina, and L. Spiteri, EPJE 39(8) (2016).
[4] A. Darras, J. Fiscina, N. Vandewalle, and G. Lumay, Am. J. Phys. , conditionally accepted (2016)