Supporting Information

Ultrahigh magnetically responsive microplatelets with tunable fluorescent emission

Rafael Libanori[1], Frieder B. Reusch[1], Randall M. Erb[2] and André R. Studart[1]*

[1] Complex Materials, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland
[2] Department of Mechanical and Industrial Engineering, Northeastern University, Boston-MA, USA

* Corresponding Author: andre.studart@mat.ethz.ch

Content:

i. Size distribution of the micron-sized alumina platelets

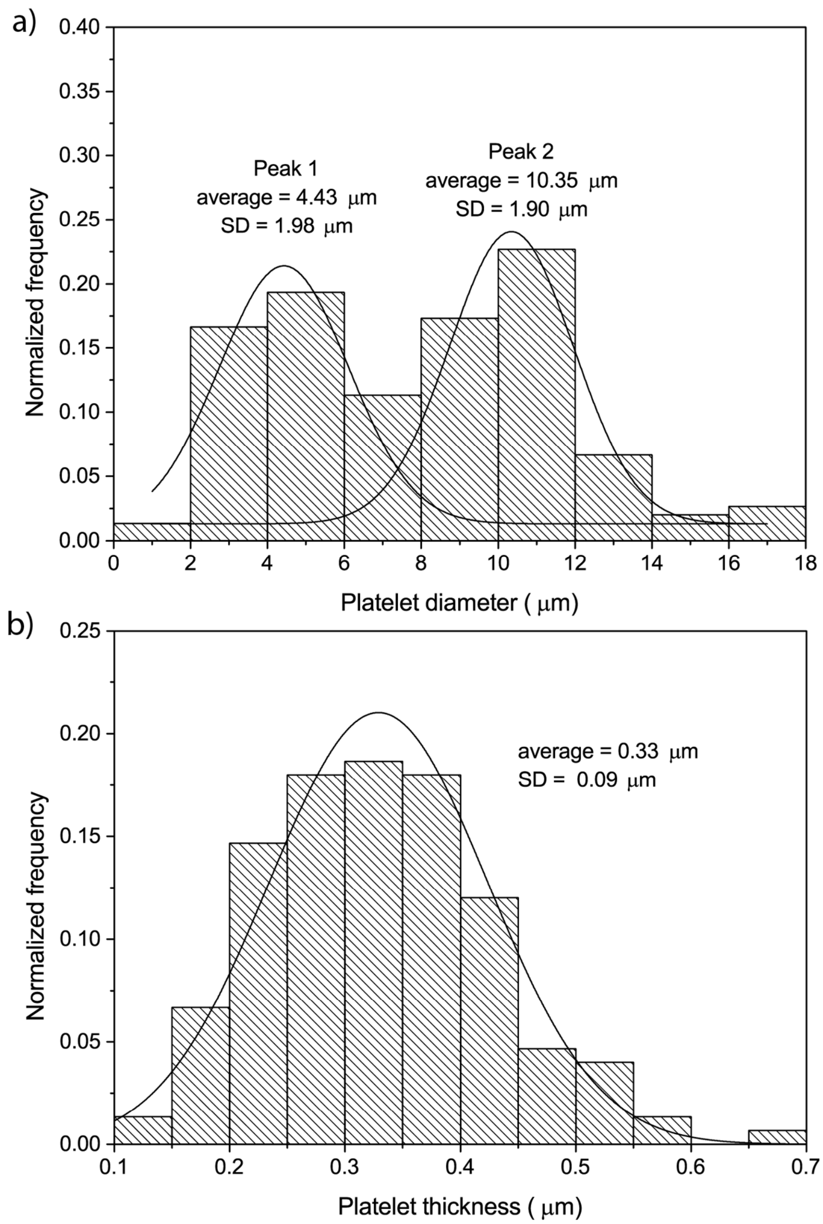

Figure S1. (a) Diameter and (b) thickness distribution curves for the alumina platelets used in this study. Platelet diameter values represent the average values of the maximum and minimum Ferret's diameter measured through SEM images of individual platelets. For the theoretical model used to estimate the minimum magnetic field needed for platelet alignment, a single averaged diameter of 7.9 μm was used. A total of 150 platelets were measured to obtain the size distribution curves shown above.

ii. Calculation of minimum magnetic field required for alignment

The dependence of the minimum magnetic field, H_{min}, required to align the UHMR platelets as a function of its surface coverage is calculated by estimating the field at which the magnetic energy starts to dominate the gravitational energy. [1, 2] It is important to note that the thermal energy of the micron-sized platelets used in this study can be neglected, as it is orders of magnitude lower than the gravitational and magnetic energies. The gravitational energy, U_g, of a platelet with diameter 2b and thickness 2a is:

$$U_g = V_p(\rho_p - \rho_f)gbsin\theta$$

where V_p is the volume of the platelet, g is the gravitational constant, ρ_0 and ρ_f are the respective densities of the platelet and the surrounding fluid, and θ is the angle between the platelet long axis and the horizontal plane. For out-of-plane alignment, θ is 90° and the gravitational energy has a maximum value.

The magnetic energy, U_m, is calculated using an ellipsoidal shell model that represents the platelet coated with a slight amount of magnetic material. Thus, assuming that the permeability of the fluid is the same as that of the free space ($\mu_f = \mu_0 = 4\pi.10^{-7}$ m.kg /s^{2}A^2), the magnetic energy of an ellipsoidal shell of material can be solved as:

$$U_m = \frac{2}{3}\pi[(a+\Delta)(b+\Delta)^2 - ab^2]\mu_0 \frac{\chi_p^2}{\chi_p + 1} H_0^2 sin^2\psi$$

where Δ is the diameter of the superparamagnetic iron oxide nanoparticles (SPIONs), χ_p is the platelet susceptibility, H_0 is the applied magnetic field and ψ is the angle between the applied magnetic field and the long axis of the ellipsoidal shell. The platelet susceptibility is determined by $\chi_p = \chi_{ff} \cdot \varphi_{ff}$, where χ_{ff} is the susceptibility of bulk iron oxide and φ_{ff} the concentration of SPIONs on the surface. According to previous work, the bulk susceptibility of iron oxide is taken as χ_{ff} = 21. [3] Thus, the magnetic energy for the platelets has a maximum absolute value when the angle between the platelet axis and the direction of the magnetic field is 0°. The dependence of the magnetic and gravitational energies on the angle θ for platelets with SPION surface coverage of 18% and under an applied field of 15 Gauss is shown in Figure S2a. The alignment field is estimated as the magnetic field required to increase the magnetic energy, U_m, just above the gravitational energy, U_g. Figure S2b shows how the magnetic field strength affects the difference between U_m and U_g for a platelet surface coverage of 13.0%. In this case, the transition from gravity aligned to magnetic aligned (U_m-U_g > 0) occurs when the magnetic field is higher than 13.5 Gauss.

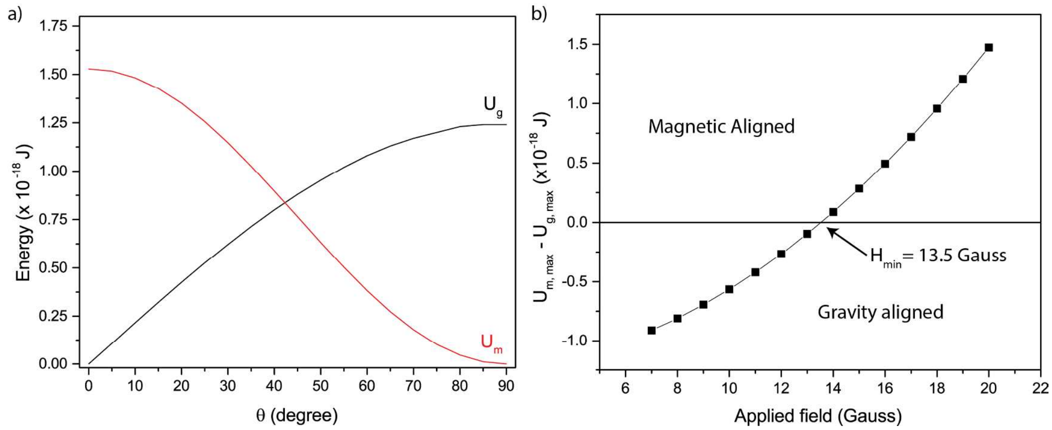

Figure S2. a) Gravitational and magnetic energies of UHMR platelets as a function of the angle θ relative to the substrate for 7.9 μm alumina platelets exhibiting a SPION surface coverage of 13% under an external magnetic field of 15 Gauss. b) Difference between the maximum magnetic, $U_{m,\ max}$, and gravitational, $U_{g,\ max}$, energies as a function of the external magnetic field, H_0, for 7.9 μm alumina platelets exhibiting a surface coverage of 13%. In this case, the minimum magnetic field, $H_{0,\ min}$, required for alignment is 13.5 Gauss

iii. References

1. Erb, R. M.; Libanori, R.; Rothfuchs, N.; Studart, A. R. Composites Reinforced in Three Dimensions by Using Low Magnetic Fields. *Science* **2012,** *335* (6065), 199-204.
2. Erb, R. M.; Segmehl, J.; Charilaou, M.; Loffler, J. F.; Studart, A. R. Non-linear alignment dynamics in suspensions of platelets under rotating magnetic fields. *Soft Matter* **2012,** *8* (29), 7604-7609.
3. Erb, R. M.; Son, H. S.; Samanta, B.; Rotello, V. M.; Yellen, B. B. Magnetic assembly of colloidal superstructures with multipole symmetry. *Nature* **2009,** *457* (7232), 999-1002.