Electronic Supplementary Material (ESI) for Soft Matter

Supporting Information

The Fabrication and Assembly of Micron-Sized Superparamagnetic Non-Spherical Particles

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S1: Simulations on Superparamagnetic Shapes

To find the relative magnetic energies of a selection of magnetic particles within a homogenous magnetic field, the Laplace equation for the vector potential was solved using the finite element method: FreeFem++ (1). A condition of uniform field is enforced on the computational domain boundary. This method was used to calculate the magnetic energy of a pair of triangles independently rotated around their center of gravity, with a center-to-center separation of 1.3 side lengths as well as the magnetic energy of a single shape as a function of field orientation. See main text.

(1) freeFEM++, www.freefem.org/Pionneau O, Hecht F, Morice J.

S2: Protein grafting onto fabricated particles.

The magnetic chaining of superparamagnetic colloidal particles has been used to extract the mechanical properties of polymers adsorbed on their surface. However, the capturing of non-linear responses is difficult due to the curved nature of the sphere-sphere contacts. As outlined in the main text, flat contacts between shapes with a cylindrical geometry are ensured on chaining. Such contacts permit the probing of non-linear effects and the cylinders promise to extend to magnetic chaining technique. The figure S1demonstratesthe reconstitution of branched actin networks grown from the surface of the particles (Bernheim-Grosswasser et al., Nature 2002).

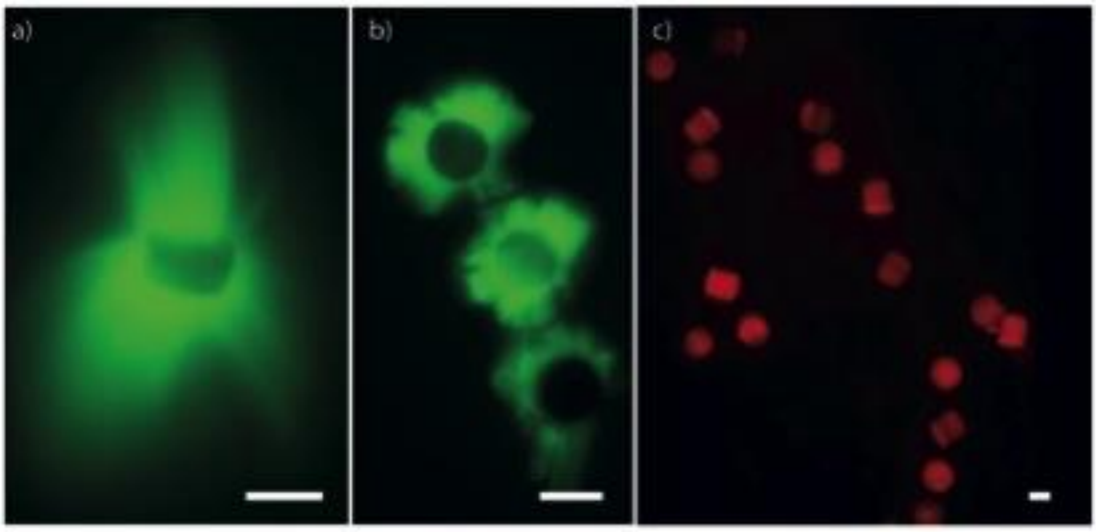
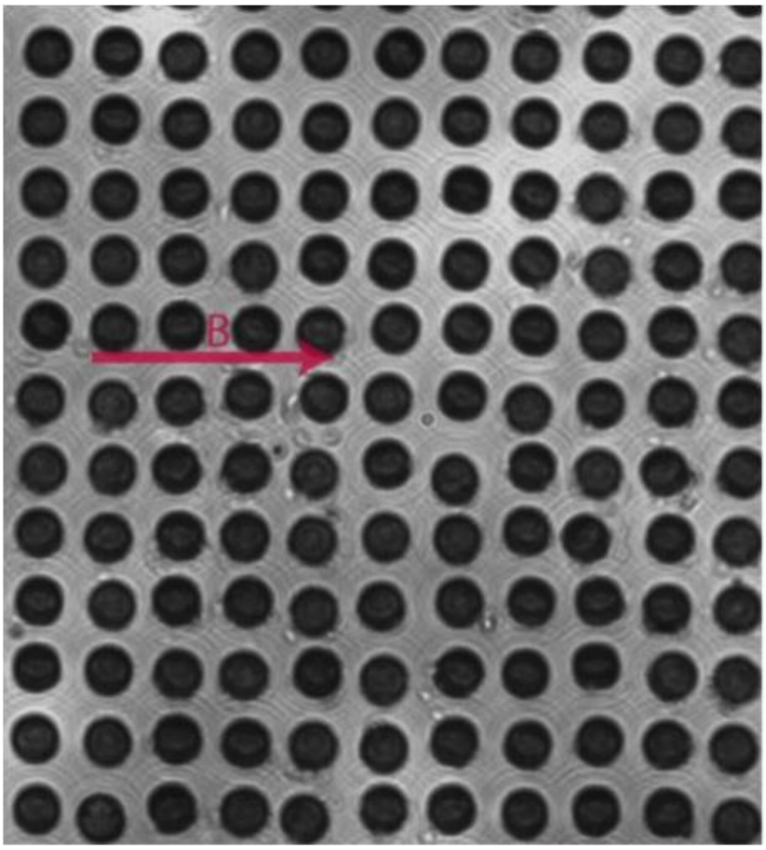


Figure S1. Superparamagnetic cylinders with actin networks (a) and (b) and BSA (c) on their surface. Each scale bar is 10 µm.

S3: The Formation of Doublets



A movie of doublet formation of superparamagnetic micron-sized cylinders (width=10 µm and depth=3 µm) arranged in a square centered lattice. The original square array of cylinders are positioned at 0° to the applied magnetic field. The applied field was 6 mT. The video is at 5fps. The experimental images were captured at 2fps.

S4: Calculations of the Magnetic Energy of Doublets

A calculation of the magnetic energy for the various pathways of aggregation for magnetic circles, initially arranged in a square array aligned with the field, demonstrates that the formation of a square centered lattice of doublets is the lowest energy route towards aggregation. The calculations were made by moving each circle a fixed distance laterally and in this way various final states could be compared. In figure S4 the energy of the experimentally observed state (the square centered lattice of doublets (iib)) is compared to one alternative state (iic).

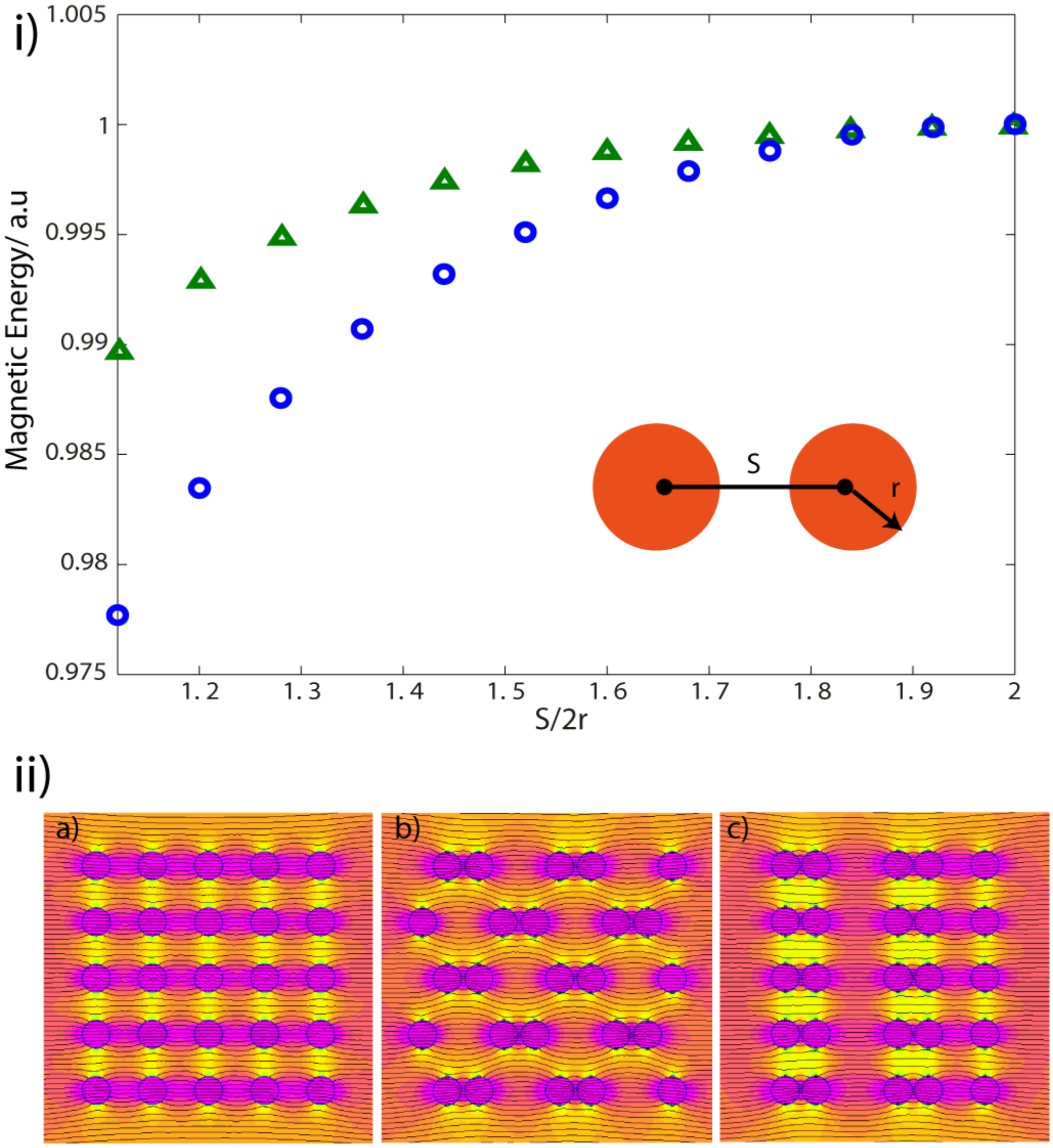
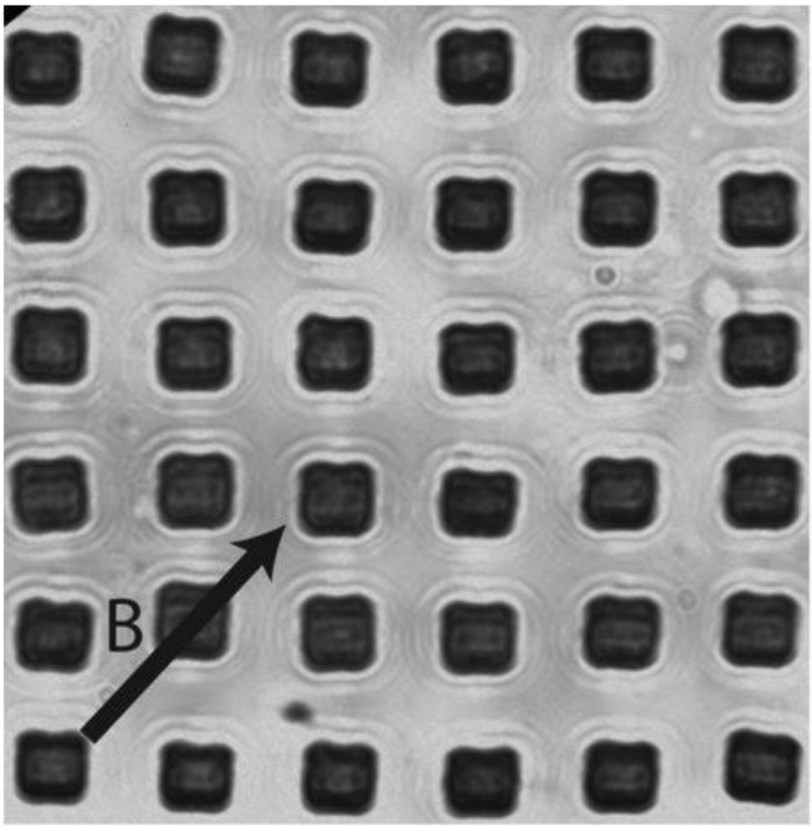


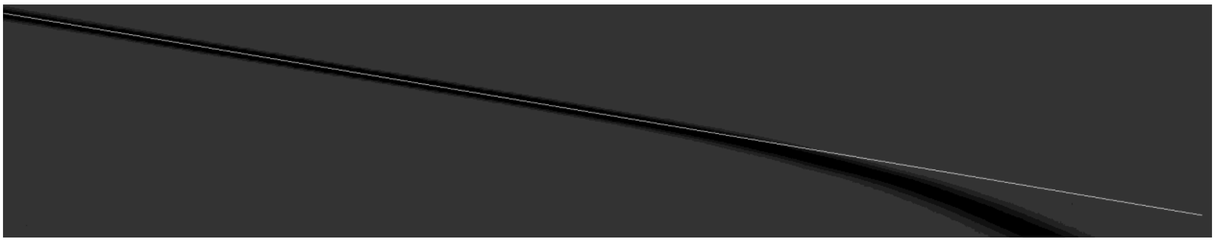
Figure S4. i) The reduction of the magnetic energy as the magnetic circles form dimers across an array row via two different routes of aggregation. The energetically favored route (○) is the pathway proceeding to the conformation shown in (iib) and is the experimentally observed case. The less energetically favored route (Δ) leads to the conformation shown in iic). ii) The starting conformation of the array magnetic circles before aggregation (a) and two alternative conformations of dimers formed in the same number of lateral translations of the circles (b and c). In each caption the field lines and field intensity are shown. The purple indicates areas of high and the yellow areas low magnetic flux density

S5: The Chaining of Superparamagnetic Square Prisms

A movie of the side-to-side chaining of superparamagnetic squares (width=10 μm and depth=3 μm) starting from a square array positioned at 45° to the applied magnetic field. The applied field was 6 mT. The video is at 5fps. The experimental images were captured at 2fps.



S6: Effect of the bottom of the chamber on the speed of a cylinder moving in a field gradient.



Kymograph of sedimenting cylinder under gradient of magnetic field (oriented in the right direction). Time is increasing from top to bottom (total 3.8 sec). As the cylinder comes closer to the bottom of the chamber it slows down as shown by the deviation from the white line. The width of this image is 186 µm. The magnetic field is 30mT and the gradient is 1.12 T/m.