carboxyl group of the molecule is exposed to the surrounding water solution. The varying curvature of the 'nano-dumbbells' causes the molecules adsorbed on different regions to ionize at different pH values. The carboxyl groups on the external part of the nano-dumbbell, where curvature is lower, are readily ionized at any pH above 7. In contrast, the carboxyl groups on the 'neck' region, where one of the radii of curvature is negative, are compressed onto one another, and have less propensity to ionize (they do so only above pH ~9). This behaviour leads to pH-dependent chemical patchiness on the nano-dumbbell surface and, as a result, to pH-dependent interparticle interactions and self-assembly behaviour. The researchers show, through experiment and simulation, how the dumbbell shape changes the ionization state of the SAM layers and how this leads to switchable mutual alignment of the particles, enabling the formation of new types of highly porous nano-dumbbell crystal.

An important aspect of the work of Grzybowski and colleagues is that it offers fundamental insight into the role that nanoparticle curvature plays on assembly mediated by a molecular layer. The fields of nanoparticle assembly and molecular self-assembly have, to a large extent, been developing independently, and there is a lot to be understood about how molecules and particles affect each other's structure and properties. Studying this synergism is likely to bring unexpected and exciting developments in the near future. Beyond the relatively exotic examples of crystals made from dumbbell-shaped particles, it is easy to imagine that similar differences in the local charge of an adsorbed molecular layer can be found in analogous curved regions in other types of nanoparticle and nanowire. One potentially interesting question is whether topological features with nanoscale curvature manufactured onto planar solid surfaces can control the ionization state of molecular layers and generate charge patterns that will subsequently guide the attachment of nanoparticles, proteins or other biomolecules. Overall, the work by the group at Northwestern represents an intriguing alternative to add directionality to nanocomponent assembly (Fig. 1b,c). ❐

Orlin D. Velev is at the Department of Chemical and Biomolecular Engineering, North Carolina State University, Raleigh, North Carolina 27513, USA.
e-mail: odvelev@ncsu.edu

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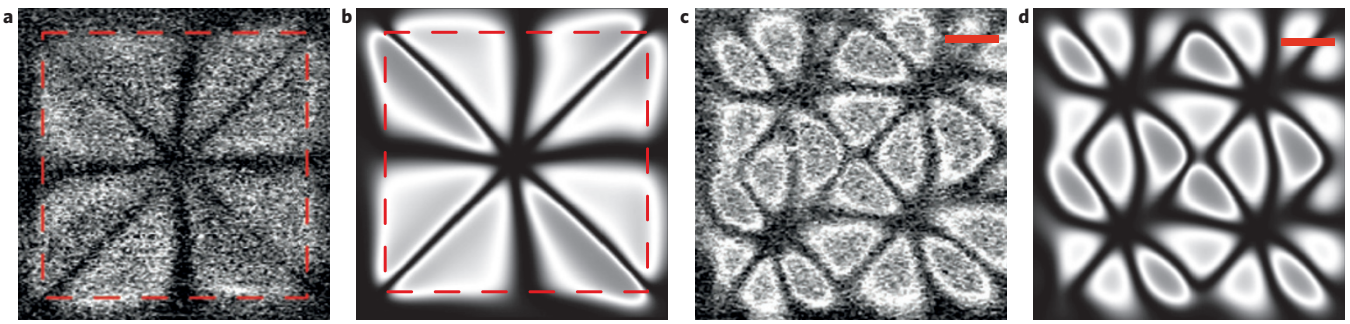
SINGLE-SPIN MAGNETOMETRY

Capturing stray fields



Single spins localized at nitrogen–vacancy defects in diamond are currently being investigated as sensitive magnetometers with nanoscale spatial resolution. Vincent Jacques and colleagues at the Ecole Normale Supérieure de Cachan, Université Paris-Sud and CNRS have now used nitrogen–vacancy magnetometry to image magnetic vortices — magnetic nanostructures with a curling in-plane magnetization and an out-of-plane magnetized core — in thin ferromagnetic films (*Nature Commun.* **4,** 2279; 2013). The technique provides quantitative, vectorial information on the three-dimensional distribution of stray magnetic fields above the magnetic nanostructures, in good agreement with the results of the simulations.

The researchers combined an optical confocal microscope with an atomic force microscope, and attached a diamond nanocrystal containing a single nitrogen–vacancy defect to the tip of the atomic force microscope. As the sample is scanned by the probe, spin-dependent photoluminescence is collected and analysed to extract information on the value of the local magnetic field in a given direction. By using different orientations of the nitrogen–vacancy defect, it is possible to image various components of the magnetic field.

The images (edge of red square, 5 μm; scale bars, 1 μm) show maps of the out-of-plane component of the stray field of magnetic vortices in a permalloy thin film. The pixel brightness is proportional to the intensity of the magnetic field, with black corresponding to zero field. The experimental images (**a**,**c**) are recorded at a probe-to-sample distance of 300 nm and can be quite accurately reproduced by micromagnetic simulations (**b**,**d**). The field of a single magnetic vortex is shown in **a**,**b** where the vortex core is located at the centre. Panels **c**,**d** are maps of the field distribution in a higher-order magnetization state, with four vortices around an anti-vortex at the centre of the images.

ELISA DE RANIERI