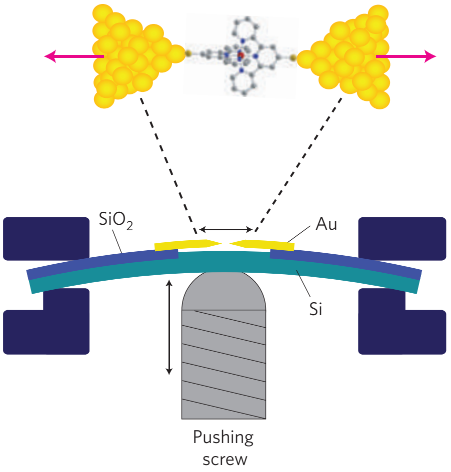
MAGNETIC MOLECULES

At a stretch

Science **328,** 1370–1373 (2010)



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Controlling the properties of single molecules is a challenge in many areas of nanotechnology. A first step is to understand the behaviour of the molecules in great detail, which is often done by measuring how a single molecule responds to changes in, for example, temperature or an applied voltage or optical field. Daniel Ralph of Cornell University and co-workers have now shown that mechanical effects can be used to probe the properties of single magnetic molecules. This means that mechanical force might be able to replace magnetic fields in some proposed applications of magnetic molecules.

Ralph and co-workers — who are at Cornell, the Jülich Research Centre in Germany and the CNEA in Argentina — used a mechanical break junction to explore the properties of a molecular complex, Co(tpy-SH)$_2$, that contains a single magnetic cobalt ion at its centre. They attached the complex to gold electrodes on a silicon substrate and measured its electronic properties as the distance between the electrodes was increased by bending the substrate. Stretching the molecule changes both its shape and symmetry, which leads to changes in the electronic and magnetic properties. For instance, Co(tpy-SH)$_2$ exhibits a single Kondo peak, but this peak splits into two as the molecule is stretched. The experiments confirmed a number of theoretical predictions about the behaviour of correlated electrons in nanoscale magnetic systems.

NANOSTRUCTURES

Undercover patterning

Angew. Chem. Int. Ed. **49,** 4669–4673 (2010)

Injecting electrons into a material can be used both to make and break chemical bonds. Electrons from the tip of a scanning tunnelling microscope have, for example, been used to manipulate individual bonds, and electron beams in electron microscopes have been employed to create intricate nanostructures. Of particular technological interest is the approach known as electron-beam-induced deposition, in which an electron beam decomposes adsorbed precursor molecules, leaving non-volatile fragments behind on the surface. By using an organometallic precursor and a focused electron beam, the technique can create arbitrary metallic structures with high resolution. Hubertus Marbach and colleagues at the University of Erlangen-Nürnberg have now developed an alternative, two-step version of the approach that uses the electrons as ‘invisible ink’.

The researchers first activated a silicon oxide surface with a 3-nm-wide electron beam, a procedure that creates oxygen vacancies in the substrate through an electron-induced oxygen-desorption mechanism. The pattern written by the electron beam was then revealed by exposing the surface to iron pentacarbonyl, Fe(CO)$_5$, precursor molecules. The organometallic molecules catalytically decompose at the irradiated regions on the surface and grow autocatalytically to form pure iron nanocrystals. The growth of the iron nanostructures can continue until the supply of precursor molecules is turned off.

MASS SENSORS

Inside track

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A mechanical cantilever has a natural resonance frequency that decreases when mass is added to it. This phenomenon has been exploited to make nanomechanical devices that can measure the mass of samples with atomic resolution when working in vacuum. However, the performance of these mass sensors deteriorates when they are operated in liquid environments because the vibrations of the cantilever are damped by the liquid. The ability to measure samples in liquid is essential in many biological applications.

In 2002 Thomas Burg and Scott Manalis showed that this problem could be overcome by confining the liquid to channels inside the cantilever; four years later they went on to use this approach to weigh single nanoparticles, cells and proteins with a mass resolution of better than one femtogram. Now, by reducing the size of the cantilever and the channel inside it, they have improved the performance of their system further to achieve a mass resolution of 27 attograms.

They also exploited the centrifugal force caused by the vibrations to trap particles at the free end of the cantilever. This reduces the error caused by uncertainty in the position of the particle and also improves resolution by allowing measurements to be averaged over longer periods of time. The work was carried out at the Massachusetts Institute of Technology, the Max Planck Institute for Biophysical Chemistry, and Innovative Micro Technology.

QUANTUM COMPUTERS

Electric entanglement

Nature **465,** 594–597 (2010)

Optical quantum computers promise to solve problems that are intractable using conventional logic by manipulating photons whose properties are inextricably linked, or entangled. At present, entangled photons are generated by using lasers and optics to excite a luminescent material, a method that is relatively bulky and complicated. Now, Andrew Shields and colleagues at Toshiba Research Europe and Cambridge University have constructed an electrically driven source of entangled photon pairs.

The team’s device consists of a single layer of quantum dots embedded inside a semiconductor light-emitting diode. Charges are injected from heavily doped regions of the device onto the quantum dots, where they form a bound state consisting of two electrons and two holes, called a biexciton. The biexciton then releases a pair of entangled photons when it decays. Entanglement is encouraged by spatially separating the quantum-dot layer from the heavily doped regions, and by careful tuning of the quantum-dot emission energy.

The device can emit entangled photons at a particular time when it is driven with pulsed current. Pulsed current also increases the degree of photon entanglement, or ‘fidelity’, as does limiting the time that the photon detectors are active. The demonstrated fidelity is high enough to be used for teleportation (useful for quantum computers) and quantum relays and keys (useful for communications).