their work with strontium-doped lanthanum nickelate (LSNO) in the October 24 issue of *Nature Communications* (DOI: 10.1038/ncomms3643).

Lead author Giacomo Coslovich, a postdoctoral researcher at Berkeley Lab, said, "We chose to work with LSNO because it has essential similarities to the cuprates (an important class of high-temperature superconductors), but its lack of superconductivity lets us focus on understanding the stripe phase alone."

In this LSNO crystal, stripes form only at cryogenic temperatures of about –168°C, yet at far higher temperatures, the team hit upon large changes in the material's infrared reflectivity. These invisible "color" changes represent an energy threshold for electrical currents, dubbed the energetic "pseudogap," which grows as the crystal cools, revealing progressive localization of charges around the nickel atoms.

The scientists then examined the dynamics of LSNO in pump-probe experiments, where they melted stripes with an initial ultrafast pulse of laser light and measured the optical changes with a second, delayed pulse. This allowed them to map out the early steps of charge ordering, exposing surprisingly fast localization dynamics preceding the development of organized stripe patterns. A final twist came when they probed the vibrations between nickel and oxygen atoms, uncovering a strong coupling to the localized electrons with synchronous dynamics.

Beyond the ultrafast measurements, the team also studied x-ray scattering and the infrared reflectance of the material to develop a thorough, cohesive understanding of the stripe phase and why it forms.

Having illuminated the origins of the stripe phase in LSNO, the researchers expect their results to provide new impetus to understand the pseudogap in other correlated oxides—especially in high-temperature superconductors where fluctuating stripes occur while their role in the superconductivity mechanism remains unclear.

Alison Hatt

Bio Focus

Bacteria construct tiny flagella "nanomachines" outside the cell

Researchers at the University of Cambridge have uncovered the mechanism by which bacteria build their surface propellers (flagella). The results, published in the November 10, 2013 online edition of *Nature* (DOI:10.1038/nature12682), demonstrate how the mechanism is powered by the subunits of the flagella themselves as they link in a chain that is pulled to the flagellum tip.

Previously, scientists thought that the building blocks for flagella were either pushed or diffused from the flagellum base through a central channel in the structure to assemble at the flagellum tip, which is located far outside the cell. However, these theories are incompatible with recent research that shows that flagella grow at a constant rate. The unexpected chain mechanism, in which subunits linked in a chain pull themselves through the flagellum, transforms current understanding of how flagellum assembly is energized.

The research team, led by Gillian Fraser and Colin Hughes, found that as each flagellum "nanomachine" is assembled, thousands of subunit building blocks are made in the cell and are then unfolded and exported across the cell membrane. Like other processes inside cells, this initial export phase consumes chemical energy. However, when subunits pass out of the cell into the narrow channel at the center of the growing flagellum, there is no conventional energy source and they must somehow find the energy to reach the tip.

The research team has shown that, at the base of the flagellum, subunits connect by head-to-tail linkage into a long chain. The chain is pulled through the entire length of the flagellum channel by the entropic force of the unfolded subunits themselves. This produces tension in the subunit chain, which increases as each subunit refolds and incorporates into the tip of the growing structure. This pulling force automatically adjusts with increasing flagellum length, providing a constant rate of subunit delivery to the assembly site at the tip.

Co-researcher Eugene Terentjev, of the Cavendish Laboratory, said, "Understanding how polymers move through channels is a fundamental physical problem. Gaining insight into this [research on bacteria] has potential applications in other disciplines, for instance in nanotechnology, specifically the building of new nanomaterials."

Nano Focus

Slowly cooled DNA transforms disordered nanoparticles into orderly crystal

"Single crystals are the backbone of many things we rely on—diamonds for beauty as well as industrial applications, sapphires for lasers, and silicon for electronics," said nanoscientist Chad A. Mirkin of Northwestern University. "The precise placement of atoms within a well-defined lattice defines these high-quality crystals." Now Mirkin's research group has built near-perfect single crystals out of nanoparticles and DNA, suggesting that DNA hybridization can drive the assembly of nanoparticles by a similar route to the traditional crystallization of atomic species.

His research group developed the "recipe" for using nanomaterials as atoms, DNA as bonds, and a little heat to form tiny crystals. This single-crystal recipe builds on superlattice techniques that Mirkin's laboratory has been developing for nearly two decades.

In this recent work, reported in the November 27 online edition of *Nature* (DOI:10.1038/nature12739), Mirkin, an

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experimentalist, teamed up with Monica Olvera de la Cruz, a theoretician at Northwestern, to evaluate this technique. Given a set of nanoparticles and a specific type of DNA, Olvera de la Cruz showed they can accurately predict the three-dimensional structure, or crystal shape, into which the disordered components will self-assemble.

In the study, strands of complementary DNA act as bonds between disordered gold nanoparticles, transforming them into an orderly crystal. The researchers determined that the ratio of the DNA linker's length to the size of the nanoparticle is critical.

The ratio affects the energy of the faces of the crystals, which determines the final crystal shape. Ratios that do not follow the recipe lead to large fluctuations in energy and result in a sphere, not a faceted crystal, Olvera de la Cruz said. With the correct ratio, the energies fluctuate less and result in a crystal every time.

To achieve a self-assembled single crystal, the research team took two sets of gold nanoparticles functionalized with complementary DNA linker strands. Working with approximately 1 million nanoparticles in water, they heated the solution to a temperature just above the DNA linkers' melting point and then slowly cooled the solution to room temperature, over a period of two to three days.

The very slow cooling process encouraged the single-stranded DNA to find its complement, resulting in a high-quality single crystal approximately 3 μm in size.

The researchers determined that the length of DNA connected to each gold nanoparticle cannot be much longer than the size of the nanoparticle. In the study, the gold nanoparticles varied from 5 nm to 20 nm in diameter; for each, the DNA length that led to crystal formation was about 18 base pairs and six single-base "sticky ends."

"There's no reason we can't grow extraordinarily large single crystals in the future using modifications of our technique," said Mirkin.

Magnetic moment of single holmium atoms stabilized by symmetry

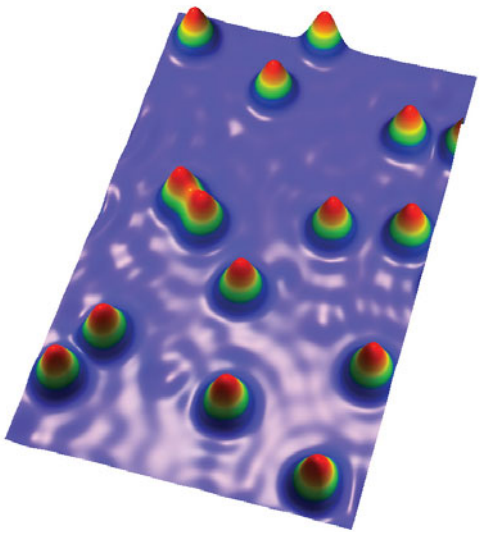
Single or assemblies of magnetic atoms positioned on non-magnetic substrates have great potential in high density magnetic data storage and quantum computing applications. However, they suffer the limitation that the magnetic moments of these atoms are easily destabilized by interactions with the substrate, resulting in very short lifetimes.

An international team including researchers from Karlsruhe Institute of Technology (KIT), the Max Planck Institute (MPI) of Microstructure Physics in Halle, the University of Leipzig, Germany, and the University of Tokyo, Japan, have now found a route to overcome this problem, as described in November 14 issue of Nature (DOI:10.1038/nature12759; p. 242). An individual holmium atom was fixed to a metal surface so that the spin of one holmium electron remains stable for more than 10 minutes. The spin can be descriptively understood as a rotation direction of an electron, giving it a magnetic moment that can align itself in a particular direction in an external magnetic field. A network of several hundred million atoms is necessary for a magnetic bit to remain stable enough for hard disk data to remain safe for years.

"One individual atom fixed to a substrate is usually so sensitive that it keeps its magnetic orientation for mere fractions of a microsecond (200 nanoseconds)," said co-author Wulf Wulfhekel from KIT. Their current research, Wulfhekel said, "not only opens the door to denser computer storage devices, but could also lay the foundation for constructing quantum computers."

In their latest experiment, the researchers placed one individual atom of the rare-earth metal holmium onto a platinum substrate. At temperatures around –272°C, they used scanning tunneling microscopy to measure how the spin of the atom and thus its magnetic moment aligns. They observed that it was almost 10 minutes before the magnetic moment changed its direction. "So once the system has established its magnetic spin, it keeps it for a billion times longer than comparable atomic systems," said Wulfhekel.

Normally, the electrons of the substrate and the atom interact frequently with each other on the quantum mechanical level and destabilize the spin of the atom in microseconds or faster. Holmium and platinum form a quantum system whose symmetry properties switch off the interfering interactions at very low temperatures. "Basically, holmium and platinum are mutually invisible, as far as the spin scattering is concerned," said Arthur Ernst of MPI in Halle and the University of Leipzig. With the aid of external magnetic fields, however, it is possible to align the spin of the holmium and thus to write information. This is precisely what the team of researchers now wants to attempt. If they are successful, this would lay the foundations for the development of compact data-storage devices or quantum computers. □



Individual atoms can store data: The image taken by a scanning tunneling microscope shows holmium atoms on a platinum surface. In this quantum system, the spins and thus the magnetic moments of individual holmium atoms remain stable for more than 10 minutes. This creates the basis for storing one data bit in an individual spin. © KIT.

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