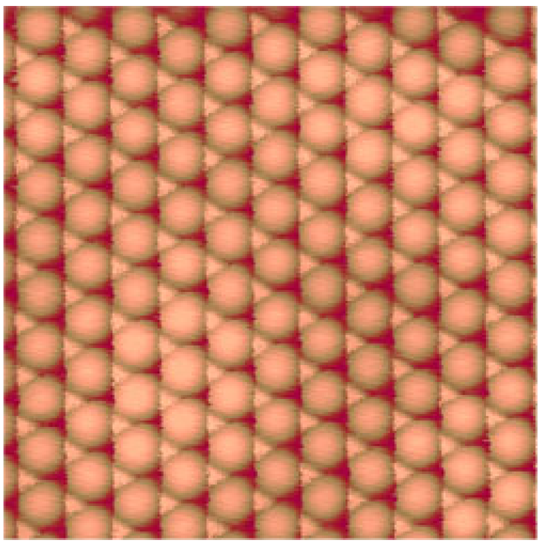
Atoms Precision Placement Helps Building Nanoscale Devices

September 10 2004



In an effort to put more science into the largely trial and error building of nanostructures, physicists at the Commerce Department's National Institute of Standards and Technology (NIST) have demonstrated new methods for placing what are typically unruly individual atoms at precise locations on a crystal surface. Reported in the Sept. 9, 2004, online version of the journal Science, the advance enables scientists to observe and control, for the first time, the movement of a single atom back and forth between neighboring locations on a crystal and should make it easier to efficiently build nanoscale devices "from the bottom up," atom by atom.

The NIST team was surprised to find that the atoms emitted a characteristic electronic "noise" as they moved between two different types of bonding sites on the crystal surface. By converting this electronic signal into an audio signal, the researchers were able to "hear" the switching take place. The sound resembles a hip hop musician's rhythmic "scratching" and can be used by researchers to know in real time that atoms have moved into desired positions.

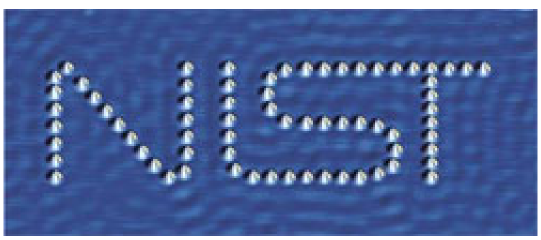
Several research groups already are using specialized microscopes to build simple structures by moving atoms one at a time. The NIST advance makes it easier to reliably position atoms in very specific locations. "What we did to the atom is something like lubricating a ball bearing so that less force is required to move it," says Joseph Stroscio, co-author of the Science paper.

Such basic nanoscale construction tools will be essential for computer-controlled assembly of more complex atomic-scale structures and devices. These devices will operate using quantum physics principles that only occur at the atomic scale, or may be the ultimate miniaturization of a conventional device, such as an “atomic switch” where the motion of a single atom can turn electrical signals on and off.

The research involved using a custom-built, cryogenic scanning tunneling microscope (STM) to move a cobalt atom around on a bed of copper atoms that are closely packed in a lattice pattern. In a typical STM, a needle-like tip is scanned over an electrically conducting surface and changes in current between the tip and the surface are used to make three-dimensional images of the surface topography. The tip can be brought closer to the surface to push or pull the cobalt atom.

In the research described in Science, NIST scientists discovered that the cobalt atom responds to both the STM tip and the copper surface, and that the atom “hops” back and forth between nearby bonding sites instead of gliding smoothly. With slight increases in the current flowing through the tip to the atom, the researchers were able to make the cobalt atom heat up and vibrate and weaken the cobalt-copper bonds. This induced the cobalt atom to hop between the two types of lattice sites, with the rate of transfer controlled by the amount of current flowing.

The NIST researchers also found that they could use the STM tip to reshape the energy environment around the cobalt atom. This allows control over the amount of time the cobalt atom spends in one of the lattice sites. Using this technique the researchers found they can even trap the cobalt atom in a lattice site that the atom normally avoids. Sounds of the “protesting” atom give rise to the “hip hop” scratching sound described in Science.



“The impact of the work is twofold,” says Stroscio. “We learned about the basic physics involved in atom manipulation, which will help us build future atomic-scale nanostructures and devices. We also learned that we can control the switching of a single atom, which has potential for controlling electrical activity in those devices.”

The experiments represent initial steps in exploring a new system of measurement, atom-based metrology, in which single atoms are used as nanoscale probes to collect information about their environment. In particular, the NIST-built instrument can be used to draw detailed maps of binding sites on a metal surface that cannot be made with standard STM measurements.

Source: NIST

Citation: Atoms Precision Placement Helps Building Nanoscale Devices (2004, September 10) retrieved 27 April 2024 from
https://phys.org/news/2004-09-atoms-precision-placement-nanoscale-devices.html