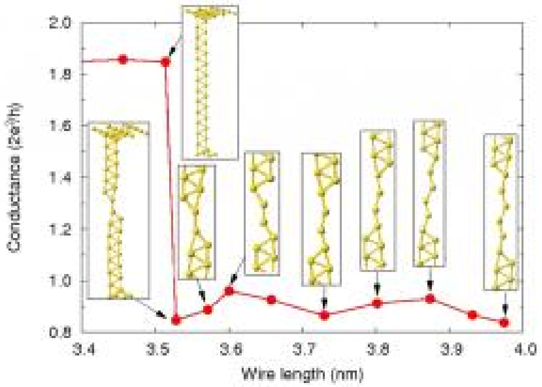
Researchers Holding Steady in an Atomic-Scale Tug-of-War

March 31 2010



A quantum-mechanics-based simulation demonstrates how a new NIST instrument can delicately pull a chain of atoms apart. The chart records quantum jumps in conductivity as a gold contact is stretched 0.6 nanometer. The junction transitions from a 2-dimensional structure to a one-dimensional single-atom chain, with a corresponding drop in conductivity. Following the last point, at a wire length of 3.97 nm, the chain broke. Credit: Tavazza, NIST

(PhysOrg.com) -- How hard do you have to pull on a single atom of -- let's say -- gold to detach it from the end of a chain of like atoms?* It's a measure of the astonishing progress in nanotechnology that questions that once would have interested only physicists or chemists are now being asked by engineers. To help with the answers, a research team at the National Institute of Standards and Technology has built an ultra-stable instrument for tugging on chains of atoms, an instrument that can maneuver and hold the position of an atomic probe to within 5 picometers.**

The basic experiment uses a NIST-designed instrument inspired by the scanning tunneling microscope (STM). The NIST instrument uses as a probe a fine, pure gold wire drawn out to a sharp tip. The probe is touched to a flat gold surface, causing the tip and surface atoms to bond, and gradually pulled away until a single-atom chain (see figure) is formed and then breaks. The trick is to do this with such exquisite positional control that you can tell when the last two atoms are about to separate, and hold everything steady; you can at that point measure the stiffness and electrical conductance of the single-atom chain, before breaking it to measure its strength.

The NIST team used a combination of clever design and obsessive attention to sources of error to achieve results that otherwise would require heroic efforts at vibration isolation, according to engineer Jon Pratt. A fiber-optic system mounted just next to the probe uses the same gold surface touched by the probe as one mirror in a classic optical interferometer capable of detecting changes in movement far smaller than the wavelength of light. The signal from the interferometer is used to control the gap between surface and probe. Simultaneously, a tiny electric current flowing between the surface and probe is measured to determine when the junction has narrowed to the last two atoms in contact. Because there are so few atoms involved, electronics can register, with single-atom sensitivity, the distinct jumps in conductivity as the junction between probe and surface narrows.

The new instrument can be paired with a parallel research effort at NIST to create an accurate atomic-scale force sensor—for example, a microscopic diving-board-like cantilever whose stiffness has been calibrated on NIST's Electrostatic Force Balance. Physicist Douglas Smith says the combination should make possible the direct measurement of force between two gold atoms in a way traceable to national measurement standards. And because any two gold atoms are essentially identical, that would give other researchers a direct method of calibrating their equipment. “We’re after something that people that do this kind of measurement could use as a benchmark to calibrate their instruments without having to go to all the trouble we do, " Smith says. "What if the experiment you’re performing calibrates itself because the measurement you’re making has intrinsic values? You can make an electrical measurement that’s fairly easy and by observing conductance you can tell when you’ve gotten to this single-atom chain. Then you can make your mechanical measurements knowing what those forces should be and recalibrate your instrument accordingly.”

In addition to its application to nanoscale mechanics, say the NIST team, their system’s long-term stability at the picometer scale has promise for studying the movement of electrons in one-dimensional systems and single-molecule spectroscopy.

More information:

* The answer, calculated from atomic models, should be something under 2 nanonewtons, or less than 0.000 000 007 ounces of force.
** D.T. Smith, J.R. Pratt, F. Tavazza, L.E. Levine and A.M. Chaka. An ultra-stable platform for the study of single-atom chains. *J. Appl. Phys.*, in press, March, 2010.

Provided by National Institute of Standards and Technology

Citation: Researchers Holding Steady in an Atomic-Scale Tug-of-War (2010, March 31) retrieved 23 April 2024 from https://phys.org/news/2010-03-steady-atomic-scale-tug-of-war.html