sion can be mapped to <110> directions in the Si crystal structure, a direction that provides large space between Si atoms allowing for ion diffusion to take place. The researchers propose fast lithium ion diffusion along the <110> directions and plastic deformation of the Li-Si alloy are responsible for the anisotropic growth behavior.

Unexpectedly, <100> and <111> pillars first exhibit a marked decrease in height, up to 9.5%, before ending within 1–2% of the initial height upon full lithiation. The <110> nanopillars increase in height throughout lithiation ending about 4% taller than they started. The researchers explain this height behavior by considering the relative effects of two processes: growth in <110> directions as just described versus decreased plane spacing between <111> planes due to broken Si–Si bonds where Li ions are inserted at tetrahedral sites.

An understanding of the structural evolution of Si nanostructures during electrochemical lithiation is important for guiding development of higher performance Si anodes. According to the researchers, this work describes mechanistic insights into nanopillar expansion during lithiation that can be used as experimental handles to continue improving upon existing Si anode architectures.

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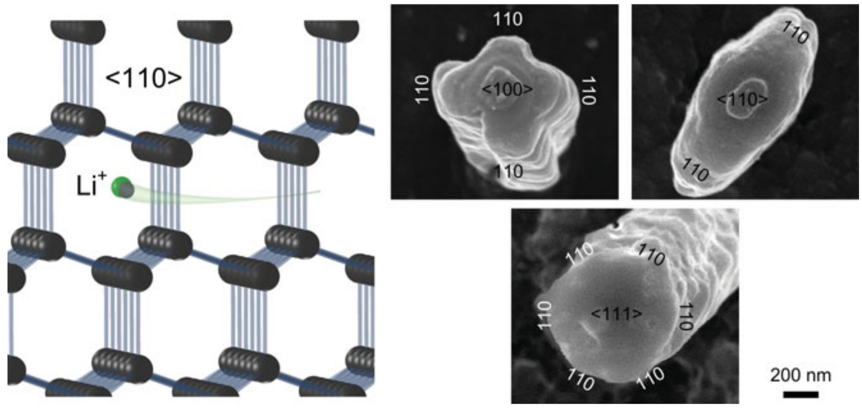

Upon lithiation, the initially circular cross sections of crystalline Si nanopillars with <100>, <110>, and <111> axial orientations expand into cross, ellipse, and hexagonal shapes, respectively. A high-speed lithium ion diffusion channel along the <110> direction causes preferential volume expansion along this direction. Reproduced with permission from *Nano Lett*. (DOI: 10.1021/nl201787r). © 2011 American Chemical Society.

Nano Focus

Micro drum chilled to quantum ground state

Showcasing new tools for developing quantum circuits made of mechanical parts, a team of researchers has demonstrated a flexible, broadly applicable technique for steadily damping the vibrations of a mechanical object down to the quantum "ground state," the lowest possible energy level.

As described in the July 6 online edition of *Nature* (DOI:10.1038/nature10261), experiments conducted by J.D. Teufel of the National Institute of Standards and Technology (NIST); K. Lehnert of JILA, a joint institute of NIST and the University of Colorado; and their colleagues nearly stop the beating motion of a microscopic aluminum drum made of about 1 trillion atoms, damping its motion below a single quantum, or unit of energy, and so placing the drum in a realm governed by quantum mechanics. Like a plucked guitar string that plays the same tone while the sound dissipates, the drum continues to beat 11 million times per second, but its range of motion approaches zero. According to the researchers, the cooling technique and drum device together promise new machinery for quantum computing and tests of quantum theory, and could help advance the field of quantum acoustics exploring the quantum nature of mechanical vibrations.

The research team used the pressure of microwave radiation to calm the motion of the drum, which is embedded in a superconducting circuit. The circuit is designed so that the drum motion can influence the microwaves inside an electromagnetic cavity. The cooling method takes advantage of the microwave light's tendency to change frequency, if necessary, to match the frequency, or tone, at which the cavity naturally resonates.

"I put in the light at the wrong frequency, and it comes out at the right frequency, and it does that by stealing energy from the drum motion," said Teufel, who designed the drum.

The drum can store individual packets of energy, or quanta, for about 100 μs without change, much longer than conventional superconducting quantum bits can maintain information. The drum, thus, might serve as a short-term memory device for a quantum computer as well as a platform for exploring complex mechanical and quantum states for tests of theories such as quantum gravity. The apparatus also allows researchers to measure the position of the drum directly, which is useful for force detection, with a precision closer to the ultimate limit allowed by quantum mechanics.

To make engineered bulk objects obey the rules of quantum mechanics, typically observed only in atoms and smaller particles, scientists must lower an object's temperature beyond the reach of conventional refrigeration. The drum experiments used a technique analogous to the way lasers are used to cool individual atoms to near absolute zero, lowering the drum temperature to below 400 μK, or just one-third of one quantum.

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