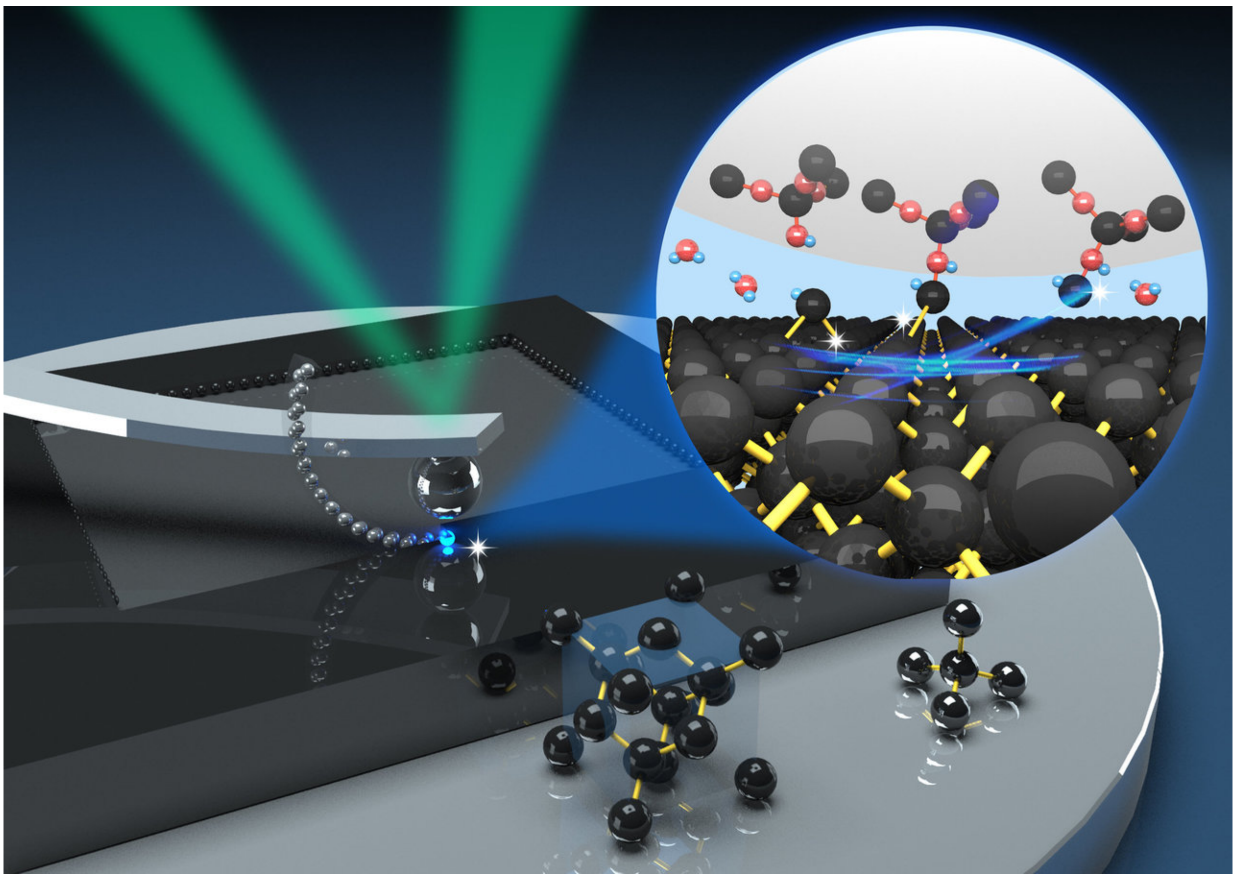
A simple method etches patterns at the atomic scale

April 26 2018



A single layer of silicon atoms (black) bind to the moving silica tip of a scanning probe microscope. Credit: Lei Chen/Southwest Jiaotong University

A precise, chemical-free method for etching nanoscale features on silicon wafers has been developed by a team from Penn State and Southwest Jiaotong University and Tsinghua University in China.

In standard lithography, a photosensitive film is deposited on a silicon wafer and a pattern called a mask is used to expose certain portions of the film. Then, chemicals—such as a potassium hydroxide solution—etch patterns into the silicon. Further steps are required to smooth out the roughened surface.

The Penn State and Southwest Jiaotong University researchers developed an entirely different, chemical- and mask-free, one-step process. They lightly rubbed a rounded silica tip of an instrument called a scanning probe microscope across a silicon substrate—the material base typically used to make electronic devices. When exposed to the water vapor in air, the top layer of silicon forms bonds with the tip of the scanning probe, and a single layer of atoms slides off as the probe moves across the silicon. Because the atoms below do not take part in the chemical reaction, they are completely undamaged.

"It's really quite a unique idea," said Seong Kim, professor of chemical engineering, Penn State. "It's a so-called tribochemical reaction. Unlike chemical reactions caused by heat, light or electric fields, which are all widely studied, mechanically-stimulated chemical reactions are less understood."

The removal mechanism is initiated when the silicon is exposed to air and the top atomic layer of silicon atoms reacts with water molecules to make silicon-oxygen-hydrogen bonds. Then the silicon oxide surface of the tip forms a silicon-oxide-silicon bond with the substrate surface under the shear force of the moving tip. This facilitates the removal of the silicon atom from the topmost surface of the substrate.

People in nanofabrication who are trying to reduce the size of device features down to atomic-scale dimensions could find this technique useful, Kim believes.

"Atomic layer etching can provide the depth resolution that people would like to get without the use of sacrificial layers and harsh chemicals," he said.

This kind of patterning method is too slow for microfabrication now, Kim acknowledged. However, researchers could use it to create a platform for testing electronic and microelectromechanical devices with features at the Angstrom or single-atom scale, far smaller than current devices. At least one company, IBM, has experimented with multiple probe arrays that could lead to large-scale patterning of devices.

"Our process could be combined with their process to scale up," Kim said. "This is the initial science part. Once we see the science, a lot of possibilities can be explored. For instance, we think this technique will work with other materials beyond silicon."

The researchers describe their technique in *Nature Communications* in an article titled "Nanomanufacturing of Silicon Surface With a Single Atomic Layer Precision Via Mechanochemical Reactions."

Provided by Pennsylvania State University

Citation: A simple method etches patterns at the atomic scale (2018, April 26) retrieved 24 April 2024 from https://phys.org/news/2018-04-simple-method-etches-patterns-atomic.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.