Researchers develop method for mass production of nanogap electrodes

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Researchers at the University of Pennsylvania have developed a reliable, reproducible method for parallel fabrication of multiple nanogap electrodes, a development crucial to the creation of mass-produced nanoscale electronics.

Charlie Johnson, associate professor in the Department of Physics and Astronomy and the Department of Materials Science and Engineering at Penn, and colleagues created the self-balancing single-step technique using feedback controlled electromigration, or FCE. By using a novel arrangement of nanoscale shorts they showed that a balanced self-correcting process occurs that enables the simultaneous electromigration of sub-5 nm sized nanogaps. The nanogaps are controllably formed by carefully applying an electric current which pushes the atoms of the metallic wire through the process of electromigration.

In the study, the researchers described the simultaneous self-balancing of as many as 16 nanogaps using thin sheets of gold and FCE methodology originally developed at Penn. Using electron-beam lithography, Penn researchers constructed arrays of thin gold leads connected by narrow constrictions that were less than 100 nm in width. Introducing a voltage forced electrons to flow through these narrow constrictions in the gold, meeting with greater resistance as each constriction narrowed in response to electromigration. The narrower the constriction, the more the electrons were forced to the other, wider constrictions, in order to take a path of least resistance.

This balanced interplay ensured that the electromigration process occurred simultaneously between the constrictions. After a few minutes, the applied electrons narrowed the constrictions until they opened to form gaps of roughly one nanometer in size with atomic-scale uniformity. By monitoring the electric-current feedback, researchers could adjust the size of the nanogaps as well.

Nanotechnology shows promise for revolutionizing materials and electronics by reducing the size and increasing the functionality of new composite materials; however, creating these materials is time consuming and costly, and it requires precise control at the atomic level, a scale that is difficult or impossible to achieve with current technology.

During the last several years there has been progress towards developing single nanometer-sized gaps and nanodevices. Yet their extremely low reproducibility has hindered any real chance of their use on the industrial scale, which is crucial to the development of the complex circuits that would be required to build, for example, a computer out of nanoelectronics.

“Reproducibility is one of the major issues facing nanotechnology, and it’s required us to depart from the standard ways of achieving this in micro-electronics processing.” Said Douglas Strachan of the Department of Materials Science and Engineering and the Department of Physics and Astronomy at Penn. “When you first hear of opening up a wire with a current, you usually think of a fuse. To think that this sort of technique could actually lead to atomically-precise nanoelectronics is sort of mind blowing.”

Danvers Johnston of the Department of Physics and Astronomy said, “Since it is impossible to mold nanoscale-size objects with any other lab tools, we direct the electrons to get them to do the work for us.”

Source: University of Pennsylvania