Researchers fabricate 3-D silicon structures with a focused infrared laser

October 11 2017

Physicist Richard Feynman once gave a lecture titled "There is plenty of room at the bottom." This lecture is often quoted to highlight the successes of modern micro- and nano-fabrication techniques, and the value of available space that comes with advances in miniaturization. In this respect, silicon, the bedrock of modern computers, mobile communications, and photonic devices, has proven to be extremely capable. These advances are usually described in terms of Moore's law. However, modern processors are essentially stacks of planar structures. In this sense, silicon microelectronics and photonics are still 2-D.

Now, a diverse team of scientists centered at Bilkent University and Middle East Technical University (both in Ankara, Turkey) have found a way to pack laser-written structures deep inside silicon chips. In the latest issue of *Nature Photonics*, the researchers describe their novel approach, which uses a focused infrared laser beam to create 1-µm-resolution building blocks in a sliver of silicon. For the first time, the researchers demonstrate arbitrary 3-D fabrication inside silicon, without structures above or below.

Then, the researchers converted these complex 3-D architectures into functional optical devices such as lenses, waveguides, holograms and other optical elements. "We achieved this by exploiting dynamics arising from nonlinear laser-material interactions, leading to controllable building blocks," says Dr. Onur Tokel of the Department of Physics at Bilkent, who is the lead author of the paper. "In any 3-D fabrication method, there is a trade-off between speed, resolution, and complexity.

With our approach, we are hitting the sweet spot. The critical realization is noticing that most practical components can be made out of rod- or needle-like building blocks. Our method enables creating precisely such blocks, while also preserving a width of about 1 micrometer for each block. Better yet, the rods can be combined to create a 2-D layer, or even more complex 3-D shapes, which can simply be created by scanning the laser beam over the chip."

A further outcome of the method is related to 3-D printing or sculpting. The researchers found that by exposing the laser-modified areas to a specific chemical etchant, it is possible to realize 3-D sculpturing of the entire wafer. They demonstrated various microscopic components, such as microchannels, thru-Si vias, cantilevers and micropillars. Creation of some of these is prohibitively difficult with other methods. "I should note that this is a direct-laser writing approach, without the use of masks, inexpensive compared to reactive ion etching and e-beam lithography," says Dr. Serim Ilday, of the Department of Physics, one of the coauthors of the paper. The team's approach has the added benefit that all the optical and MEMS devices demonstrated are in principle compatible with the established CMOS fabrication methods.

Inspired by the successes of "on-chip" silicon devices, the team coined the term "in-chip" devices, as a shorthand descriptor for this new class of components based on direct 3-D laser-fabrication. "The possibilities are endless. It is likely that the method will enable entirely new in-chip devices, such as Si-photonics components that can be used for near- and mid-IR photonics, or meandering microfluidic channels that may be used to efficiently cool electronic chips," observed Prof. Ömer Ilday, another co-author of the paper and member of the Electrical and Electronics Engineering and Physics Departments.

"As a matter of fact," he continued, "we have already started to show new in-chip architectures and functionalities, such as developing novel in-chip waveguides, laser-slicing of wafers and exploring expansion to other semiconductors."

More information: Onur Tokel et al, In-chip microstructures and photonic devices fabricated by nonlinear laser lithography deep inside silicon, *Nature Photonics* (2017). DOI: 10.1038/s41566-017-0004-4

Provided by Bilkent University