New advance could lead to even smaller features in the constant quest for more compact, faster microchips

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The microchip revolution has seen a steady shrinking of features on silicon chips, packing in more transistors and wires to boost chips' speed and data capacity. But in recent years, the technologies behind these chips have begun to bump up against fundamental limits, such as the wavelengths of light used for critical steps in chip manufacturing.

Now, a new technique developed by researchers at MIT and the University of Utah offers a way to break through one of these limits, possibly enabling further leaps in the computational power packed into a tiny sliver of silicon. A paper describing the process was published in the journal *Physical Review Letters* in November.

Postdoc Trisha Andrew PhD '10 of MIT's Research Laboratory of Electronics, a co-author of this paper as well as a 2009 paper that described a way of creating finer lines on chips, says this work builds on that earlier method. But unlike the earlier technique, called absorbance modulation, this one allows the production of complex shapes rather than just lines, and can be carried out using less expensive light sources and conventional chip-manufacturing equipment. "The whole optical setup is on a par with what's out there" in chip-making plants, she says. "We've demonstrated a way to make everything cheaper."

As in the earlier work, this new system relies on a combination of approaches: namely, interference patterns between two light sources and a photochromic material that changes color when illuminated by a beam of light. But, Andrew says, a new step is the addition of a material called a photoresist, used to produce a pattern on a chip via a chemical change following exposure to light. The pattern transferred to the chip can then be etched away with a chemical called a developer, leaving a mask that can in turn control where light passes through that layer.

While traditional photolithography is limited to producing chip features larger than the wavelength of the light used, the method devised by Andrew and her colleagues has now been shown to produce features one-eighth that size. Others have achieved similar sizes before, Andrew says, but only with equipment whose complexity is incompatible with quick, inexpensive manufacturing processes.

The new system uses "a materials approach, combined with sophisticated optics, to get large-scale patterning," she says. And the technique should make it possible to reduce the size of the lines even further, she says.

The key to beating the limits usually imposed by the wavelength of light and the size of the optical system is an effect called stimulated emission depletion imaging, or STED, which uses fluorescent materials that emit light when illuminated by a laser beam. If the power of the laser falls below a certain level, the fluorescence stops, leaving a dark patch. It turns out that by carefully controlling the laser's power, it's possible to leave a dark patch much smaller than the wavelength of the laser light itself. By using the dark areas as a mask, and sweeping the beam across the chip surface to create a pattern, these smaller sizes can be "locked in" to the surface.

That process has previously been used to improve the resolution of optical microscopes, but researchers had thought it inapplicable to photolithographic chip making. The innovation by this MIT and Utah team was to combine STED with the earlier absorbance-modulation technique, replacing the fluorescent materials with a special polymer whose molecules change shape in response to specific wavelengths of light.

In addition to enabling the manufacture of chips with finer features, the technique could also be used in other advanced technologies, such as the production of photonic devices, which use patterns to control the flow of light rather than the flow of electricity. “It can be used for any process that uses optical lithography,” Andrew says.

Professor Stefan Hell, head of the Department of NanoBiophotonics at the Max Planck Institute for Biophysical Chemistry in Göttingen, Germany, calls this work “strikingly simple and elegant” and “a most impressive demonstration of the idea of using photochromic molecules to create features that are both finer and closer together than half the wavelength of the light.”

“The work shows a concrete pathway to creating tiny and dense features at the nanoscale.” he adds. “Because of its future potential it needs to be actively pursued. ... These methods have the potential of shifting the paradigm of what we think that focused light can do for making nanosized features and hence mastering the nanoworld.”

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