

DNA May Help Build Next Generation of Chips

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In the race to keep Moore's Law alive, researchers are turning to an unlikely ally: DNA molecules that can be positioned on wafers to create smaller, faster and more energy-efficient chips.

Researchers at IBM have made a significant breakthrough in their quest to combine DNA strands with conventional lithographic techniques to create tiny circuit boards. The breakthrough, which allows for the DNA structures to be positioned precisely on substrates, could help shrink computer chips to about a 6-nanometer scale. Intel's latest chips, by comparison, are on a 32-nanometer scale.

"The idea is to combine leading edge lithography that can offer feature size of 25 nanometers with some chemical magic to access much smaller dimensions," says Robert Allen, senior manager of chemistry and materials at IBM Almaden Research. "This allows us to place nano objects with 6-nanometer resolution. You don't have a hope of doing that with lithography today."

To keep pace with Moore's Law, which postulates that the number of transistors on an integrated circuit will double every two years, chip makers have to squeeze an increasing number of transistors onto every chip. One way to describe how well transistors are packed is the smallest geometric feature that can be produced on a chip, usually designated in nanometers. Current lithographic techniques use either an electron beam or optics to etch patterns on chips in what is known as top-down technique.

"You pattern, mask and etch material away," says Chris Dwyer,

assistant professor at the department of electrical and computer programming at Duke University. “It is very easy to make big structures, but tough to create molecular-scale chips using this.” Dwyer compares it to taking a block of marble and chipping away from it to create the required pattern.

Newer techniques attempt to take small chips and fuse them together to create the required larger pattern in what is called as molecular self-assembly.

“What the IBM researchers have shown is a good demonstration where top-down and bottom-up techniques meet.”

At the heart of their research is an idea known as DNA origami. In 2006, Caltech researcher Paul Rothemund explained a method of creating nanoscale shapes and patterns using custom-designed strands of DNA. It involves folding a single long strand of viral DNA and smaller ‘staple’ strands into various shapes. The technique has proven very fruitful, enabling researchers to create self-assembling nano machines, artworks and even tiny bridges.

Wallraff says the technique has a lot of potential for creating nano circuit boards. But the biggest challenge so far has been in getting the DNA origami nanostructures to align perfectly on a wafer. Researchers hope the DNA nanostructures can serve as scaffolds or miniature circuit boards for components such as carbon nanotubes, nanowires and nanoparticles.

“If the DNA origami is scattered around on a substrate, it makes them difficult to locate them and use to connect to other components,” says Greg Wallraff, an IBM research scientist working on the project. “These components are prepared off the chip, and the the origami structure would let you assemble them on the chip.”

It's important for the kind of work Dwyer and his colleagues at Duke have been doing. They see IBM's breakthrough as laying the groundwork for their research studying molecular sensors. "With this development we can look to integrate the sensors onto a chip and help build hybrid systems," says Dwyer.

Still there are some big steps that have to be covered before circuit boards based on DNA nanostructures can hit commercial production. Researchers have to be able to get extremely precise alignment, with no room for error.

Even with the latest demonstration of alignment techniques, there is still some angular dispersion, points out Dwyer.

"If you put a transistor down on a circuit board, there is no dispersion," says Dwyer. "Our computing systems cannot deal with that kind of randomness."

That's why commercial production of chips based on the DNA origami idea could be anywhere from five years to a decade away, says Allen.

"If you are going to take something from the bench-top scale to a fab, there are enormous barriers," he says. "You really need to understand the mechanisms of defect generation. What we don't want to imply is that this is ready to go into a factory and make Star Trek-like chips."