DNA For Information Processing and Data Storage

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The DNA molecule--nature's premier data storage material--may hold the key for the information technology industry as it faces demands for more compact data processing and storage circuitry. A team led by Richard Kiehl, a professor of electrical engineering at the University of Minnesota, has used DNA's ability to assemble itself into predetermined patterns to construct a synthetic DNA scaffolding with regular, closely spaced docking sites that can direct the assembly of circuits for processing or storing data.

The scaffolding has the potential to self-assemble components 1,000 times as densely as the best information processing circuitry and 100 times the best data storage circuitry now in the pipeline. Members of the team first published their innovation in 2003, and they have now refined the technique to allow more efficient and more versatile assembly of components. The new work, which was a collaborative effort with chemistry professors Karin Musier-Forsyth and T. Andrew Taton at Minnesota and Nadrian C. Seeman at New York University, is reported in the December issue of Nano Letters, a publication of the American Chemical Society.
"There's a need for programmability and precision on the scale of a nanometer--a billionth of a meter--in the manufacture of high-density nanoelectronic circuitry," said Kiehl. "With DNA scaffolding, we have the potential for arranging components with a precision of one-third of a nanometer.

"In a standard silicon-based chip, information processing is limited by the distance between units that process and store information. With DNA scaffolding, we can lay out devices closely, so the interconnects are very short and the performance very high."

The DNA scaffolding is made from synthetic DNA "tiles" that spontaneously assemble in a predetermined pattern to form a sheet of molecular fabric, much like corduroy. The ripples in the fabric are formed by rows of sticky DNA strands that occur at regular intervals in the scaffolding and function as a strip of Velcro® hooks that fasten to nanocomponents coated with matching DNA strands. The nanocomponents could be metallic particles designed to process or store data in the form of an electrical or magnetic state, or they could be organic molecules--whatever would best process or store the information desired.

In the earlier work, members of the Kiehl team made DNA scaffolding with regularly spaced gold nanocomponents pre-woven into the fabric, completing the synthesis all in one operation. Now, the team first makes DNA scaffolding with regularly spaced sticky DNA strips and then adds the nanocomponents, which stick to the DNA strips in rows. This allows them to use optimal synthetic methods for both steps. It's analogous to using strips of Velcro® in cloth: It's much easier to get a useful pattern by first weaving cloth and Velcro® strips together, and then attaching beads or other objects to the strips later, than it is by adding the objects during the weaving process.

The new procedure also lets the team add any one of various nanocomponents--such as other metals, organic molecules or tiny electronic devices--at a later time, depending on what is needed for the application. The result is a more perfect scaffolding, better and more regular attachment of electronic units, and more diversity in the types of units and the types of circuitry that can be made.

"We can now assemble a DNA scaffolding on a preexisting template, such as a computer chip, and then--on the spot--assemble nanocomponents on top of the DNA," said Kiehl. The nanocomponents can hold electrical charge or a magnetic field, either of which would represent a bit of data, and interactions between components can act to process information. Circuitry based on regular arrays of closely spaced components could be used for quickly recognizing objects in a video image and detecting motion in a scene -- slow and difficult tasks for conventional computer chips. The technology could help computers identify objects in images with something approaching the speed of the human eye and brain, Kiehl said. The technology could also be used for various other applications, including chemical and biological sensing, in which case the strips would be designed to stick to the tiny objects or molecules to be detected.

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