

1 Large-Scale Molecular Memory

UCLA AND CALTECH CHEMISTS report the creation of large-scale molecular memory, an important step toward building molecular computers. The electric power industry has a keen interest in all improvements to the technology of computation. Developments augmenting the speed and fault tolerance of integrated circuits hastens the reality of the vision many of us have, of a power system capable of assessing threats to stability in almost real time, responding intelligently to changing system conditions and faults, and using local and remotely acquired data to navigate like a modern fighter jet through a field of quickly and dramatically changing end use priorities. A team of UCLA and California Institute of Technology chemists reports in the Jan. 25 issue of the journal *Nature* the successful demonstration of a large-scale, “ultra-dense” memory device that stores information using reconfigurable molecular switches. This research represents an important step toward the creation of molecular computers that are much smaller and could be more powerful than today’s silicon-based computers.

The 160-kilobit memory device uses interlocked molecules manufactured in the UCLA laboratory of J. Fraser Stoddart, director of the California NanoSystems Institute (CNSI).

The memory is based on a series of perpendicular, crossing nanowires, similar to a tic-tac-toe board, with 400 bottom wires and another 400 crossing top wires. Sitting at each crossing of the structure and serving as the storage element are approximately 300 bistable rotaxane molecules. These molecules may be switched between two different states, and each junction of a crossbar can be addressed individually by controlling the voltages applied to the appropriate top and bottom crossing wires, forming a bit at each nanowire crossing. The 160-kilobit molecular memory was fabricated at a density of 100,000,000,000 bits per square centimeter — “a density predicted for commercial memory devices in approximately 2020. For this commercial dream to be realized, many fundamental challenges of nano-fabrication must be solved first,” Stoddart said. “The use of bistable molecules as the unit of information

storage promises scalability to this density and beyond. However, there remain many questions as to how these memory devices will work over a prolonged period of time.”

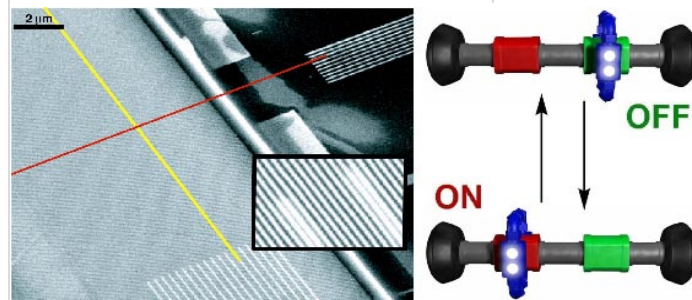
“Using molecular components for memory or computation or to replace other electronic components holds tremendous promise,” Stoddart said. “This research is the best example of building large molecular memory in a chip at an extremely high density, testing it and working in an architecture that is practical, where it is obvious how information can be written and read. Our goal was to demonstrate that large-scale, working electronic circuits could be constructed at a density that is well-beyond 10 to 15 years where many of the most optimistic projections say is possible,” said James R. Heath, Professor of Chemistry and a co-author of a *Nature* paper.

“One of the most exciting features of this research is that it moves beyond the testing of molecular electronic components in individual, non-scalable device formats and demonstrates a large, integrated array of working molecular devices,” said William R. Dichtel, a member of both Stoddart’s and Heath’s research teams.

The CNSI, a joint enterprise between UCLA and the University of California, Santa Barbara, is exploring the potential of organizing and manipulating matter to engineer new integrated systems and devices, by starting down at the nanoscale level.

The bi-stable rotaxanes behave as switches by incorporating two different recognition sites for the ring that can be induced to move from one side to the other

Bi-stable rotaxane behaviour



BlueGene/L,
Terascale
Simulation
Facility (TSF),
Photo courtesy of
LLNL

2 The super computers are here. And super they are.

What exactly makes a computer super? In our industry we are used to measuring things in Kva and Mva, horse power, voltage, PSI, degrees Celsius. But our highly integrated power systems are depending more and more on computational "power", which is measured in flops. (Hey, don't laugh, we measure things in darafs, a unit of electrical elastance, the reciprocal of farads.) Flops are floating point operations per second and are somewhat similar to instructions per second, especially for computer tasks requiring lots of calculations. Flops are a measure of a computer's ability to compute. As you would expect, there are: Megaflops (Mflops = 1,000,000 flops), Gigaflops (Gflops = 1,000 Mflops), Teraflops (Tflops = 1,000

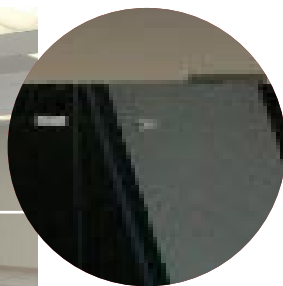
Gflops). So let's get some perspective. The CPU of a typical desk top personal computer today, say a Pentium 4, would have a rating of around 10 Gflops, somewhat less when the entire computer is taken into account. So do you have a need for FLOPS? Do you want to calculate state estimation with real time measured data, and have your power system assess its own threats and take corrective action? Do you want your protective relays to become the eyes and ears of an intelligent power grid that predicts its own performance and recommends its own enhancements, or reconfigures itself based on expected load patterns, or weather conditions? You need flops? You got flops!

At the top of the 500 supercomputers list (www.top500.org) are: IBM BlueGene/L system, installed at Department of Energy's Lawrence Livermore National Laboratory (LLNL), retains the No. 1 spot with a Linpack performance of 280.6 teraflops. The new No. 2 systems is Sandia National Laboratories' Cray Red Storm supercomputer, only the second system ever to be recorded to exceed the 100 Tflops mark with 101.4 Tflops. Slipping to No. 3 from No. 2 last June is the IBM eServer Blue Gene Solution system, installed at IBM's Thomas Watson Research Center with 91.20 Tflops Linpack performance. The ranking is constantly changing, as technology moves on. DOE, for example, is

looking at the next generation of supercomputers, capable of Petaflops (1000 Teraflops) operation. What are all these super computers doing? Some calculate the explosion of a nuclear weapon, from "button to bang" – a task that in 1994 the world's fastest computer would take 6000 years to calculate. Others are attempting to predict the weather 100 years into the future, based on satellite measurements today. Advances in computing technology trickle down to all levels. There are commercially available personal supercomputers (PSCs) capable of 256 Gflops, for about \$20,000, and it draws about 15 amps current. What is that equivalent to – say a clothes dryer or a very large refrigerator?



We used to let the tools available limit our imagination. In the world of computers at least, things appear reversed – imagine what you want done, the computers will be there to do it.



3 New World Record Achieved in Solar Cell Technology

NEW SOLAR CELL BREAKS THE "40 Percent Efficient" Sunlight-to-Electricity Barrier Based on DOE Press Release, pictures courtesy Spectrolab (a Boeing company)

The U.S. Department of Energy (DOE) recently announced that with DOE funding, a concentrator solar cell produced by Boeing-Spectrolab has recently achieved a world-record conversion efficiency of 40.7 percent, establishing a new milestone in sunlight-to-electricity performance. This breakthrough may lead to systems with an installation cost of only \$3 per watt, producing electricity at a cost of 8-10 cents per kilowatt/hour, thus making solar electricity a more cost-competitive and integral part of the United States' energy mix.

For the past two decades researchers have tried to break the "40 percent efficient" barrier on solar cell devices. In the early 1980s, DOE began researching what are known as "multi-junction gallium arsenic de-based solar cell devices," multi-layered solar cells which converted about 16 percent of the sun's available energy into electricity. In 1994 DOE's National Renewable Energy laboratory broke the 30 percent barrier, which attracted interest from the space industry. Most satellites today use these multi-junction cells.

The 40.7 percent cell was developed using a unique structure called a multi-junction solar cell. This type of cell achieves a higher efficiency by capturing more of the solar spectrum. In a multi-junction cell, individual cells are made of layers, where each layer captures part of the sunlight passing through the cell. This allows the cell to get more energy from the sun's light.

"Reaching this milestone heralds a great achievement for the Department of Energy and for solar energy engineering worldwide," Assistant Secretary Karsner said. "We are eager to see this accomplishment translate into the marketplace as



A Spectrolab, Inc. associate places wafers on platters to grow them into solar cells



The 40.7% efficient triple-junction concentrator cell

For more information, visit the Solar America Initiative website at: http://www.eere.energy.gov/solar/solar_america/.

soon as possible, which has the potential to help reduce our nation's reliance on imported oil and increase our energy security."

Attaining a 40 percent efficient concentrating solar cell means having another technology pathway for producing cost-effective solar electricity. Almost all of today's solar cell modules do not concentrate sunlight but use only what the sun produces naturally. Researchers call this "one sun insulation" and it achieves an efficiency of 12 to 18 percent. By using an optical concentrator, sunlight intensity can be increased, squeezing more electricity out of a single solar cell.

Reaching 40 percent efficiency helps further the Solar America Initiative (SAI) goals, which aims to win nationwide acceptance of clean solar energy technologies by 2015. By then, it is intended that America will have enough solar energy systems installed to provide power to one to two million homes, at a cost of 5 to 10 cents per kilowatt/hour. The SAI is also a key component of the Advanced Energy Initiative, which provides a 22 percent increase in research and development funding at DOE and seeks to reduce the US dependence on foreign sources of oil.

The state-of-the-art photovoltaic solar cells in concentrator modules of various sizes one day may dramatically reduce the cost of generating electricity from the sun