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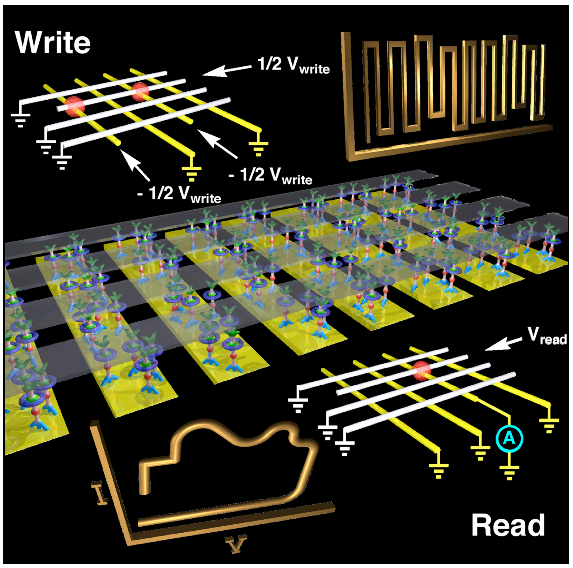
Nanoelectronics – Breaking the Memory Gridlock

A marriage between the tiniest of switches and densely packed architectures, based on crossbar arrays, is promising to change the way computers are assembled in the future. The secret lies in marrying two-way (binary) switches, composed of surfactant-like molecules that perform like a forest of little abacuses trapped between two electrode surfaces.

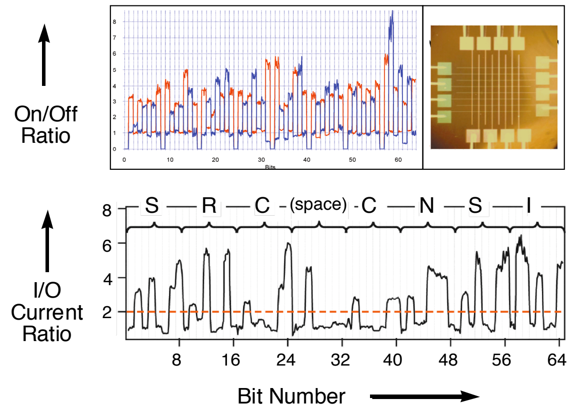


Box 1. Using molecules called rotaxanes, that are reminiscent of an abacus with one bead (blue), that can move between two positions (green and red) along a surfactant-like stalk terminated by a big oily end (green) and a big watery end (blue), the basis for a two-way switch operating according to a binary code (0s and 1s) has been established and incorporated into a crossbar circuit that can be operated as a rewritable 64-bit random access memory (RAM) circuit.

The bottom electrodes are composed of polysilicon, coated on their surface by native silicon dioxide on which the watery ends of the surfactant-like molecules are planted. In the working 8 x 8 crossbar memory circuit illustrated in Boxes 1 and 2, this bottom electrode is 100 nanometers wide. The top electrode is composed of a layer of titanium which is laid down as hot metal and so reacts to some extent with the oily ends of the surfactant-like molecules. A 5 nanometer layer of titanium is topped finally by a 10 nanometer layer of aluminum and it is 70 nanometers wide. The device (Box 1) is such that a collection of some 5000 molecules are trapped between the electrodes at each crosspoint.

The molecules are very special ones called rotaxanes from the Latin *rota* for wheel and *axis* for axle. Thus, they are constructed of a stalk encircled by a ring which can be induced to move mechanically between two sites, one (ring on green) which does not conduct much current and the other (ring on red) which conducts more current. These states correspond to the 0s and 1s of the binary code.

The 64-bit random access memory (RAM) circuit shown in Box 2 is based on an 8 x 8 cross-bar where 56 of the 64 bits work well – that is, 8 bits malfunction so-to-speak in this prototype device.



Box 2. A demonstration of point addressability within a 64-bit molecular switch crossbar circuit (inset) utilized as a random access memory (RAM) . The device was fabricated using surfactant-like, mechanically bistable rotaxanes and employed to store the acronyms SRC (Semiconductor Research Corporation) and the CNSI (California NanoSystems Institute). A character string of 0s and 1s that correspond to the standard ASCII characters for the indicated alphanumeric symbols was stored and then the entire memory was read out. For example, the letter "R" used in the SRC character string is stored as an eight-bit number "01010010." The red dashed line indicates the separation between 0s and 1s.

Using the binary code, this RAM circuit can be used to store information in its memory by a "Write" procedure which involves applying small voltages (± 2 volts) across the junctions between the electrodes in the crossbars. The memory can then be accessed by a "Read" procedure that allows a current to be measured with an ammeter when the same small voltage is applied.

The experiments herald the advent of a nanoelectronics where switches of molecular dimensions at around one square nanometer are no longer science fiction.

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