Nanotechnology Highlight:
Carbon Nanotube Single-Electron Memory

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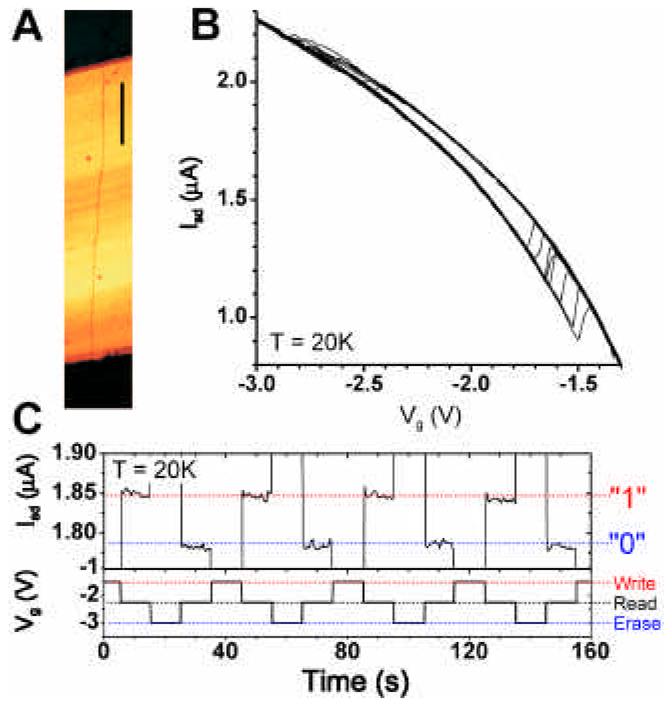
Carbon nanotubes - nanometer-diameter wires of pure carbon - are now being considered as candidates for new electronic technologies in which the individual components will be assembled into complex structures form the "bottom up". But many questions remain: What sort of devices should be made? Will they operate on principles similar to existing electronic devices, or will new principles become important?

Researchers at the University of Maryland have used carbon nanotubes to create a new type of memory device, which is capable of storing information as a single electronic charge[1]. A single-charge memory greatly reduces the energy required to write and erase the memory, and increases device uniformity, since the charge is a discrete quantity. The memory takes advantage of the unique properties of nanotubes: the high mobility (more than ten times greater than silicon[2]) nanotube transistor leads to high charge sensitivity, and the narrow nanotube channel insures that conductance changes at one point are felt by the entire device.

The nanotube memory works by storing charges in the silicon dioxide dielectric between the semiconducting nanotube and gate electrode. The charges shift the turn-on voltage of the nanotube transistor, and thus change the current through the device. Single electrons could be reproducibly written, read and erased at temperatures up to 100 Kelvin. The researchers found that the while the nanotube transistor is easily sensitive enough to detect single charges at room temperature, the charges did not stay put long enough in the oxide; this could be improved with by tailoring the charge storage site using nanocrystals or specially-designed dielectric layers. The nanotube transistor's room temperature charge sensitivity should find a wide range of applications, from observing charge dynamics in dielectrics to detecting charged biomolecules in solution.



Nanotube single-electron memory
An atomic force micrograph of the device is shown in (A); the nanotube is the thin, nearly vertical dark line; the dark blocks at top and bottom are the source and drain electrodes (scale bar 1 micron). The conducting silicon substrate beneath 500 nm of silicon dioxide acts as the gate (not shown). The current I_{sd} as a function of gate voltage V_g is shown in (B). The gate voltage is swept back and forth eight times. The two branches of the curve correspond to a difference of one electron stored in the dielectric. The operation of the memory is shown in (C). The memory state is read at -2.25 volts on the gate, and written (erased) with momentary pulses to -1.5 V (-3 V). A current of over 50 nA is switched by the single stored electron.

References

1. M. S. Fuhrer, B. M. Kim, T. Dürkop, and T. Brintlinger, *Nano Letters* **2**, 755 (2002).
2. P. L. McEuen, M. S. Fuhrer, H. Park, *IEEE Transactions on Nanotechnology*, **1**, 78 (2002).