Smarter Computers

Future Information Processing Technology from Nanotechnology

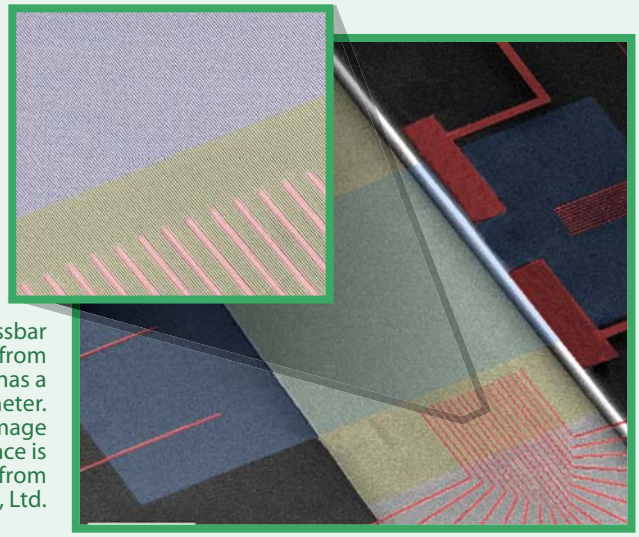
Interested Agencies: DOD, DOE, DOT, FDA, NASA, NIH, NIST, NSF

Computers and other advanced electronic systems are at the foundation of our Nation's technological and economic strength. Complex natural phenomena such as climate patterns are modeled using advanced computers. Airplanes and car engines are designed with sophisticated information technology systems. Three-dimensional diagnostic images of human organs are constructed by computers coupled to imaging technologies.

Complementary metal-oxide semiconductor field-effect transistor (CMOS-FET) technology is the engine that propels modern computers and electronics. Historically, CMOS-FETs have gotten smaller, year after year. This has meant that more components can be fit onto a computer chip, one reason why computers and other electronic systems have gotten ever more powerful over time. As individual circuit components approach nanoscale dimensions, however, conventional electronic devices become unreliable and waste too much power, both of which will eventually limit the ability to miniaturize.

Nanotechnology offers new approaches for continuing improvements in information technology. One of the most anticipated developments will be discovery of a replacement for the logic switch around which today's computers are designed, that is, the CMOS-FET. Ideally, future nanotechnology-enabled logic switches will provide increased performance while using significantly less electrical power, will be integrable with existing fabrication processes, and will lead to computers with much higher component densities.

Controlling the structure of matter at the nanoscale will enable future electronic devices that will operate more efficiently at much lower power than existing devices and systems. Graphene, a flat sheet-like molecule made of carbon atoms, offers an example. Electrons can travel great distances in sheets of graphene, resulting in less waste heat. Moreover, depending on how a graphene sheet is oriented, it can act either as a conductor or a semiconductor, two essential components in an electronic circuit. These characteristics offer the potential advantage of being able to create energy-efficient, multicomponent devices from a single sheet of graphene. There are numerous other areas where nanotechnology can contribute to the continued improvement of information technology systems. These include the use of nanostructured materials for better thermal management and superior dielectric properties.



Scanning electron microscope images of a nanowire crossbar memory circuit, in which the memory elements are made from overlaying silicon and titanium nanowires. This circuit has a memory element density of 100 billion bits per square centimeter. Lower right: Image of entire circuit. Upper left: Magnified image of nanowire crossbar memory junctions. Wire-to-wire distance is approximately 33 nm. Reproduced by permission from *Nature*, © 2007 Macmillan Publishers, Ltd.