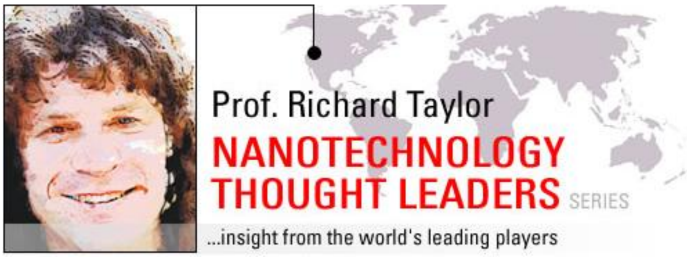

Fractals in Nano-Devices

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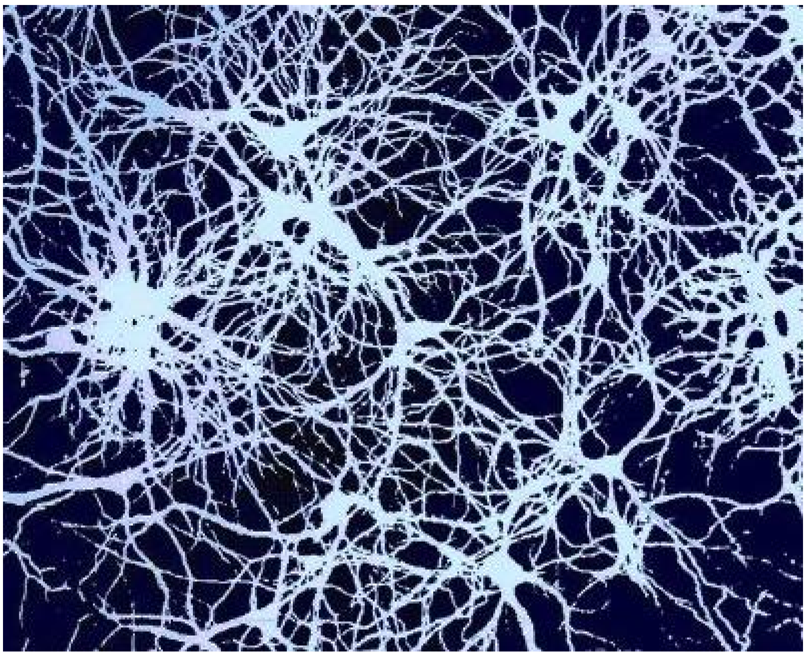
Date Added: Oct 1, 2009

Future nano-devices are expected to underpin many of the technologies that society relies on, ranging from household electronics to medical implants. One of the great challenges of bringing this promising future into reality lies in developing practical methods for constructing these highly intricate structures: How will we assemble electronic circuits that feature many more components than today's commercial circuits and where each component approaches the atomic scale?

Fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole.

'Self-assembly' holds great promise as a technique for building commercial nano-circuits. Adopting this approach, the nano-engineer allows the circuit to build itself by exploiting natural growth processes. Self-assembly offers two striking advantages. Not only is it more efficient at assembling vast numbers of components compared to traditional fabrication techniques, this fundamentally 'green' technique constructs circuits by the addition of material rather than the wasteful removal of material that lies at the heart of previous 'top-down' fabrication techniques.



Computers modeled on the brain's fractal geometry could possess large circuit connectivity and the associated computing power

One of the remarkable consequences of harnessing natural growth processes is that the resulting circuits exhibit natural patterns rather than the smooth, straight lines that form the framework of today's commercial circuit designs. In particular, many self-assembly processes generate fractal patterns. Fractals are shapes that repeat at many magnifications and are prevalent throughout nature, appearing in natural environments[1], biological systems and human physiology[2].

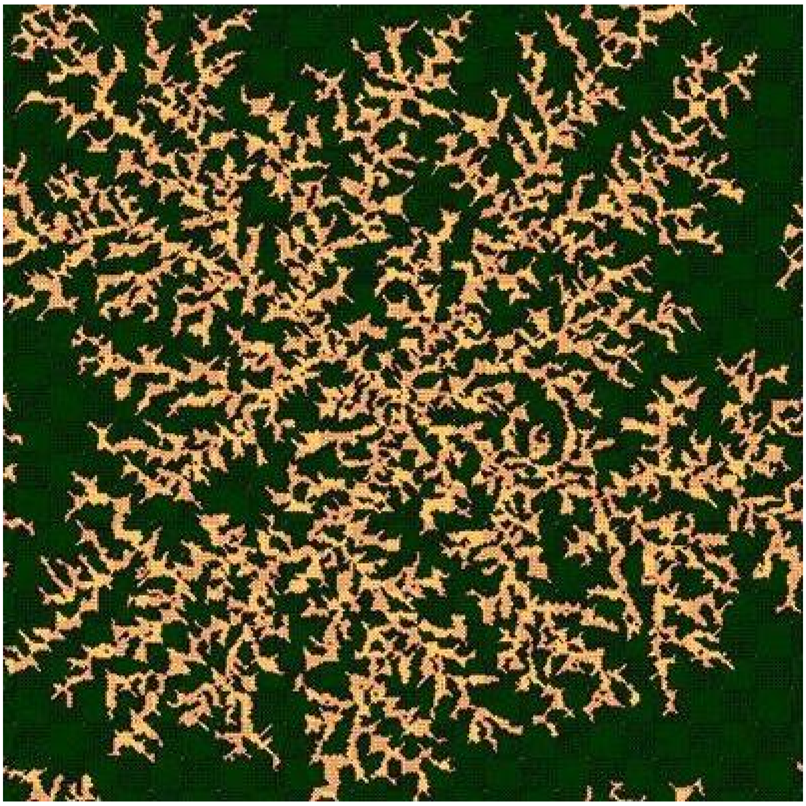
Nature uses fractals frequently because they possess a number of highly desirable properties. Topping this list is the fact that the repeating shapes build objects with huge surface areas. Nature exploits this property for example in trees, where the large surface area of the tree canopy ensures an unprecedented ability to absorb sunlight. The same approach could equally be employed to great effect by designing novel solar cell structures based on fractal shapes.

Solar cells modeled on a tree's fractal geometry could capture vast amounts of sunlight

Another consequence of large surface areas is that two merging patterns connect together very efficiently. For example, the dendritic structure of the neurons in the human brain exploits this fractal connectivity to produce enhanced information processing. The same connectivity could equally be exploited for future commercial computers by using artificial fractal electrical circuits.

This philosophy of learning from nature's successes may well revolutionize many fields within nanotechnology. Although some electronics applications already exploit fractal geometry (cell phone antennae being a famous example), many fields lie at the start of this exciting journey, with many discoveries and challenges lying ahead.

Prof. Taylor's investigations focuses on two families of electronic device in which millions of metallic nano-particles (each approximately 50 nanometers across) are self-assembled into fractal circuits. In the first family of device, the particles merge together to form 'nanoflowers'[3] using a growth process called diffusion-limited aggregation. In the second family, the nano-particles are attached to DNA strands[4] which assemble to form a fractal circuit. In both cases, the self-assembly process generates a tree-like pattern similar to one shown in the illustration.



Simulation of the self-assembled fractal electronic circuits

These projects are driven by the potential to tune the growth conditions so that the fractal characteristics of the circuits match those found for example in the neural structure of the human brain. Imagine a future where computers operate like our own minds and, ultimately, where fractal circuits may act as implants to be inserted into specific regions of the brain, restoring or enhancing a patient's mental functionality. Such goals represent the exceptional promise of nanotechnology - where researchers from a diverse range of disciplines work together to improve the basic quality of human life.

Reference

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3. S.A. Scott and S.A. Brown, Journal of European Physics 39 433 (2006).
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