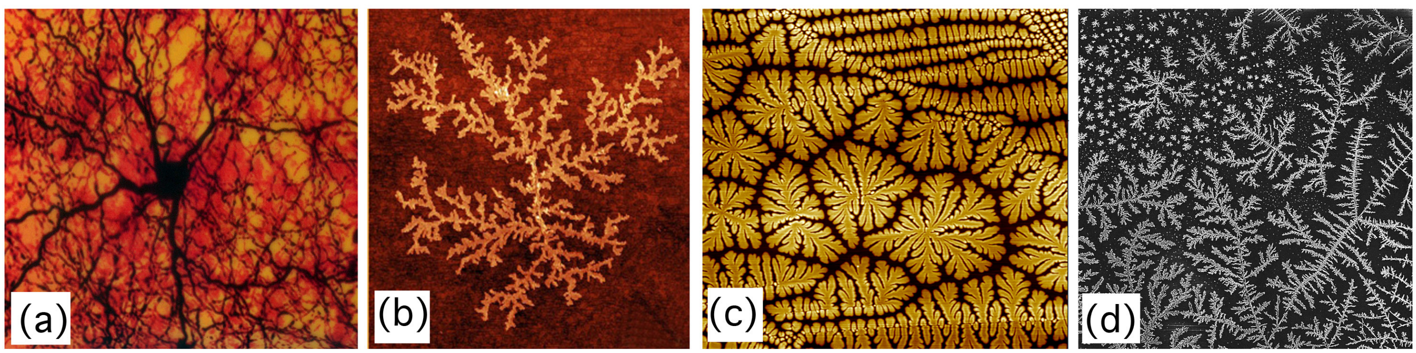
Richard Taylor

Professor of Physics, Psychology, and Art / Head, Department of Physics

- Home
- Research & Publications
- Research Team
- Media links: TV, Radio, Talks
- General Audience Articles

FEBRUARY 3, 2016 BY ANAE

Fractals in nanoelectronics, neural sensors and solar cells



(a) a fractal neuron, (b-d) fractal interconnects designed to stimulate and sense neuronal signals

Nanoelectronic devices approach one billionth of a meter in size (50,000 times smaller than a human hair). Smaller than today's commercial devices and made from purer materials, nano-devices are expected to revolutionize the technologies that underpin society.Ballistic nanoelectronic devices are made from materials so pure that the electrical current travels through the solid much like bullets fly through the air! Although impurities in the material are minimized in these devices, they have a profound effect on device performance. My research investigates how impurities induce chaos in the electricity by scattering the flow of electrons in the current. This chaotic scattering causes the electricity to flow along fractal patterns through the devices, much like a river splitting into fractal tributaries. Intriguingly, quantum mechanics allows the electrons to behave both like waves and particles, resulting in the highly topical phenomenon 'quantum chaos'.

My research of quantum chaos and the resulting fractal electricity is aimed at understanding the basic principles of electricity at the nano-scale and also how to exploit this novel behavior to produce faster and more powerful electronic devices.Given that electricity wants to flow along fractal pathways, we are building devices that connect together to form fractal shapes. These fractal circuits are constructed using two "self-assembly" growth processes: one process deposits gold nanoparticles onto tangled DNA strands, the other grows 'nanoflower' circuits from nanoclusters (see left image). Self-assembly represents an efficient and 'green' approach to constructing devices.

In addition to novel fractal transistors and sensors, we are developing fractals circuits for human implants and solar cells. In each case, we use the principle of biomimicry to exploit the functionality of nature's fractals to provide technological advances. The fractal circuits are ideal for bioeletronics because they mimic the neurons they are designed to stimulate and measure. They also replicate the light-harvesting properties of fractal trees for the solar cells. These two projects represent the most important targets for future physics research – safeguarding human health and the Earth's environment. For example, fractal electronics could address neurological disorders such as Parkinson's disease and depression, and also improve nerve connections to prosthetic limbs.

Selected Recent Publications And Media

Fractal implants for sensing and stimulating neuronal signals:

- Evolution of Retinal Neuron Fractality When Interfacing with Carbon Nanotube Electrodes. Bioengineering, 2024, 11(8), 823
- The Sensitivity of Neuron Arbor Geometry to the Fractal Properties of their Dendrites, Frontiers in Network Physiology 3, 10721815 (2023
- Comparison of fractal and grid electrodes for studying the effects of spatial confinement on dissociated retinal neuronal and glial behavior, Scientific Reports, 12, 15713 (2022)
- Investigating Fractal Analysis as a Diagnostic Tool That Probes the Connectivity of Hippocampal Neurons, Frontiers in Human Physiology, Frontiers in Physiology, Fractal Physiology (2022)
- Controlled assembly of retinal cells on fractal and Euclidean electrodes, PLOS ONE, 17(4):e0265685 (2022)
- Investigation of Fractal Carbon Nanotube Networks for Biophilic Neural Sensing Applications, Nanomaterials, 11, 636 (2021)
- Fractal analysis of time-series data sets: Methods and Challenges. Chapter to "Fractal Analysis" IntechOpen, 2019
- How neurons exploit fractal geometry to optimize their network connectivity. Nature: Scientific Reports 11, 2332 (2021), DOI: 10.1038/s41598-021-81421-2
- Physical guidance of Cultured Retinal Neurons Using Zig-zag Surface Patterns, American Journal of Biomedical Science and Research, 11, 219, (2020), DOI: 10.34297/AJBSR.2020.11.001629
- Modelling the Improved Visual Acuity Using Photodiode Based Retinal Implants Featuring Fractal Electrodes, *Frontiers in Neuroscience*, 12 (277), 1-14, doi: 10.3389/fnins.2018.00277, (2018)
- Fractal Electrodes as a Generic Interface for Stimulating Neurons, Nature: Scientific Reports, vol. 7, 6717 (2017), DOI:10.1038/s41598-017-06762-3
- "Artificial Vision: Vision of Beauty" Feature Article Physics World 22 (May 2011)
- "Fractal Electronics as a Generic Interface to Neurons", chapter in "The Fractal Geometry of the Brain", Springer, 2016

- Artificial Retinas Project. Richard Taylor, head of the Artificial Retinas Project, discusses project research. Movie produced by Matt Alpert.
- Artificial Retinas Project Radio (mp3 file)

Fractal Solar Cells:

- "Fractal Solar Panels: Optimizing Aesthetic and Electrical performances", *PLOS ONE,* 15(3):e0229945 (2020)
- "Effect of Fractal Silver Electrodes on Charge Collection and Light Distribution in Semiconducting Organic Polymer Films", Journal of Materials Chemistry, 2014, 2, 16608-16616

Fractal Nano Circuits:

- "Fractal Electronic Circuits Self-Assembled From SB Atomic Clusters" *Nanotechnology* 22 365304 (2011)
- "Toward Chaotic Electron Transport in Bismuth nanocluster wires" Proc. APS meeting (2009)
- "Coulomb Blockade in DNA-templated, Quasi-1D Nanoparticle Arrays" (in preparation)

Film-Boiling Liquids:

- "Self-Propelled Film-boiling Liquids" *Physical Review Letters* 96 154502 (2006)

Ballistic Optical Devices:

- "An Optical Demonstration of Fractal Geometry" *The Bridges Proceedings* Tarquin books 349 (2010)
- "Electromagnetic Wave Chaos in Gradient Refractive Index Optical Cavities" *Physical Review Letters* 86 5466 (2001)
- "Effects of Geometric Wave Chaos on the Electromagnetic Eigenmodes of Gradient-index Optical Cavity" *Physical Review E* 64 026203 (2001)

Ballistic Electronic Devices:

- "Is it the Boundaries or Disorder that Dominates Electron Transport in Semiconductor 'Billiards'?" Fortschr. Phys. 61, 332 (2013)
- "Probing the Sensitivity of Electron Wave Interference to Scattering-Induced Disorder in Solid-state Devices" Physical Review B 85 195319 (2012)
- "The Impact of Small-Angle Scattering on Ballistic Transport In Quantum Dots" Physical Review Letters 108 196807 (2012)
- "Field-oriented Dependence of the Zeeman Spin Splitting in GaInAs Quantum Point Contacts" *Physical Review* B 81 041303 (2010)
- "Investigation of Electron Wave Hybridization in GaInAs/InP Arrays" *Applied Physics Letters* 95 182105-1-3 (2009)

- "Enhanced Zeeman Splitting in GaInAs Quantum Point Contacts" *Applied Physics Letters* 93 012105 (2008)
- "Confinement Properties of a GaInAs/InP Quantum Point Contact" *Physical Review* B 77 155309 (2008)
- "A Unified Model of Electron Quantum Interference For Ballistic and Diffusive Semiconductor Devices" *Physical Review* B 73 195318-1-7 (2006)
- "Experimental Investigation of the Breakdown of the Onsager-Casimir Relations" *Physical Review* Letters 96 116801 (2006)
- "Symmetry of Magnetoconductance Fluctuations of Quantum Dots in the Nonlinear Response Regime" *Physical Review B* 73 235321(2006)
- "Symmetry of Two Terminal Nonlinear Electric Conductance" *Physical Review Letters* 92 046803-1 (2004)
- "Three Key Questions on Fractal Conductance Fluctuations: Dynamics, Quantization and Coherence" *Physical Review* B 70 085302 (2004)
- "A Review of Fractal Conductance Fluctuations in Ballistic Semiconductor Devices" Invited chapter to the book *Electron Transport in Quantum Dots* Kluwer Academic/Plenum (2003)
- "The Dependence of Fractal Conductance Fluctuations on Soft-wall Profile in a Double-layer Billiard" *Applied Physics Letters* 80 4381 (2002)
- "Reversible Quantum Brownian Heat Engines for Electrons" *Physical Review Letters* 89 116801 (2002)
- "The Evolution of Fractal Patterns during a Classical-Quantum Transition" *Physical Review Letters* 87 036802 (2001)

Bookmark the permalink.

← Fractals in psychology and art

Fractal Retinal Implants →

Contact Information

Department of Physics
University of Oregon
Eugene, OR 97403-1274, U.S.A.
Tel: +1-541-346-4741
Email: rpt@uoregon.edu

Bookmarks

Dr. Taylor's CV

Dr. Taylor's Google Scholar page

Materials Science Institute

Department of Physics

Search …