Human_Internet @human_internet1

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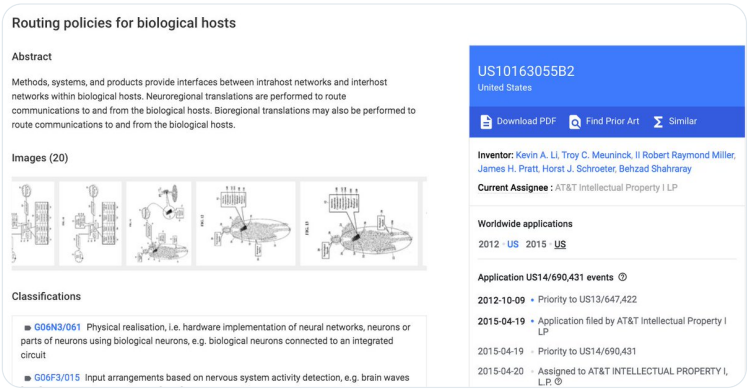
AT&T has patented the ability to address your brain / body / cells on the Internet. AT&T describes the ability to use a persons brain / thoughts to control aspects of another person over the Internet (i.e. thoughts, motor movements and control)

https://patents.google.com/patent/US10163055B2/en



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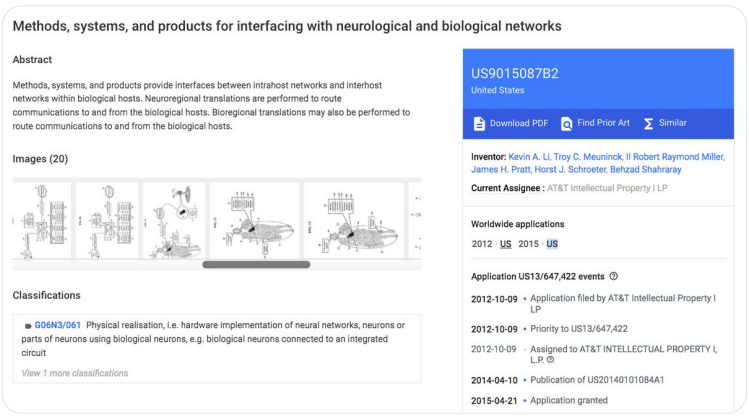
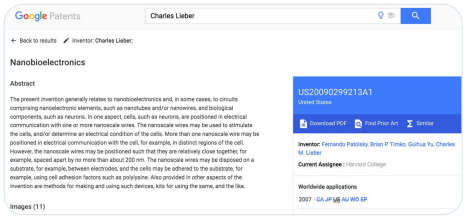


#Nanobioelectronics
#CharlesLieber - 2007 A.D.

https://patents.google.com/patent/US20090299213A1/en



EXAMPLE 1

[0082] The interface between nanoscale semiconductors and biological systems represents a powerful means for molecular-scale communication between these two distinct yet complementary components of information processing systems. This example illustrates the assembly and electrical properties of nanowire-based device arrays integrated with mammalian neurons. Discrete hybrid structures enable neuronal recording and stimulation at the axon, dendrite, or soma with high sensitivity and spatial resolution. Aligned arrays of these electronic nanostructures are used to measure the speed and shape evolution of action potentials as well as to interact with a single cell as multiple inputs and outputs. Additionally, we have demonstrated the assembly of hybrid n- and p-type structures enabling the generation of bipolar signals that could form the basis of logic gates and other integrated neuron-based computing structures. The flexible assembly of arrays of these structures creating tens of inputs or outputs to a single cell could prove useful for fundamental neurophysiological studies, real-time cellular interaction with chemical species, and the creation of hybrid cell/semiconductor computational networks.

EXAMPLE 2

[0083] This example illustrates the preparation of certain nanowire/neuron devices, according to one embodiment of the invention. FIG. 1A is a general schematic for the preparation and assembly of oriented p- and/or n-type silicon nanowires in an aligned neuron/nanodevice array, with interconnection into well-defined FET device array structures, patterning of polylysine as an adhesion and growth factor to define neuron cell growth with respect to the device elements, and neuron growth under standard conditions (discussed in detail below). This approach is flexible allowing for variations in the addressable nanowire device separations down to at least 100 nm and device array geometry, incorporation of electronically distinct p- and n-type elements in well-defined positions, and/or variation in the number and spatial location of the hybrid nanowire/neuron junctions or synapses with respect to the cell body and neurite projections. Moreover, new chips incorporating such changes can be rapidly prototyped in about 1 day (from blank substrate to stage of neuron growth), which is an advantage compared to traditional planar FET structures, and allows for the rapid exploration of new ideas (or new integrated hybrid structures).

[0101] These multi-nanowire/neuron arrays were characterized by simultaneous detection of the conductance output from nanowires following IC stimulation at the soma. FIG. 2B shows electrical responses measured from dendrite/nanowire devices (left traces, NW **6-9**) and axon / nanowire devices (right traces, NW **1-5**) after intracellular stimulation with a 15 ms, 0.5 nA current pulse. It was found that stimulation of action potential spikes in the soma yielded correlated conductance peaks in nanowire elements forming the nanowire/axon and nanowire/dendrite junctions (FIG. 2B). Qualitatively, these data demonstrate several key points. First, seven of the nine independently addressable nanowire/neurite junctions yielded reproducible conductance spikes correlated with IC stimulation. Higher yields of functioning elements have also been achieved (see below), although this about 80% yield still left three and four spatially-defined local detectors on the dendrite and axon, respectively. It is believed that this level of integration of hybrid electronic/biological synapses is unique to this work. Second, the conductance spikes recorded along the axon by elements **1-5** maintained sharp peak shape and relatively constant peak amplitude. In contrast, the conductance spikes measured by elements **6-9** along the dendrite exhibited noticeable broadening and reduced amplitude.

EXAMPLE 9

[0113] This approach can be readily extended to highly integrated systems that could open up opportunities in a number of areas. To demonstrate this idea a repeating structure was designed and fabricated (FIGS. 5A-5B) that had 50 addressable nanowire elements per neuron. This structure was chosen to show the capability of single cell hybrid structures at much higher density of nanoelectronics devices, but could be readily reconfigured, for example, into structures with different geometries, nanowire device spacings, and/or multiple cells. FIG. 5A is an optical image of a chip having six device arrays of 50 nanowire elements each and associated metal interconnects; FIG. 5B is an optical image corresponding to the area enclosed by the blue rectangle and showing two 50 nanowire element arrays. The rectangle highlights an area representative of the hybrid device array shown in FIG. 5C. The scale bars are 5 and 1 mm, respectively.

#NanoscaleSensors
#CharlesLieber - 2005 A.D.

https://patents.google.com/patent/US20060269927A1/en

[0095] A sensing element of the present invention can collect real time data and/or near-real time data, in some embodiments. The data may be used, for example, to monitor the reaction rate of a specific chemical or biological reaction. Physiological conditions or drug concentrations present in vivo may also produce a real time (or near-real time) signal that may be used to control a drug delivery system, in another embodiment of the invention. An example of near-real time data is a system in which multiple nanoscale wires are individually addressed, e.g., using a switching matrix. The switching matrix can address each wire on any suitable basis, for example, once per second, once every 100 milliseconds, once every 10 milliseconds, once every millisecond, once every 100 microseconds, once every 10 microseconds, once every microsecond, etc.

#Nanosensors and related technologies
#CharlesLieber - 2005 & 2015 A.D

https://patents.google.com/patent/US9102521B2/en
https://patents.google.com/patent/US9903862B2/en

The term "sample" refers to any cell, tissue, or fluid from a biological source (a "biological sample"), or any other medium, biological or non-biological, that can be evaluated in accordance with the invention including, such as serum or water. The sample may be contained in a fluid, e.g., in solution. A sample includes, but is not limited to, a biological sample drawn from an organism (e.g. a human, a non-human mammal, an invertebrate, a plant, a fungus, an algae, a bacteria, a virus, etc.), a sample drawn from food designed for human consumption, a sample including food designed for animal consumption such as livestock feed, milk, an organ donation sample, a sample of blood destined for a blood supply, a sample from a water supply, or the like.

A "sample suspected of containing" a particular component means a sample with respect to which the content of the component is unknown. "Sample" in this context includes naturally-occurring samples, such as physiological samples from humans or other animals, samples from food, livestock feed, etc. Typical samples taken from humans or other animals include tissue biopsies, cells, whole blood, serum or other blood fractions, urine, ocular fluid, saliva, or fluid or other samples from tonsils, lymph nodes, needle biopsies, etc.

A variety of sample sizes, for exposure of a sample to a nanoscale sensor of the invention, can be used in various embodiments. As examples, the sample size used in nanoscale sensors may be less than or equal to about 10 microliters, less than or equal to about 1 microliter, or less than or equal to about 0.1 microliter. The sample size may be as small as about 10 nanoliters, 1 nanoliter, or less, in certain instances. The nanoscale sensor also allows for unique accessibility to biological species and may be used for in vivo and/or in vitro applications. When used in vivo, in some case, the nanoscale sensor and corresponding method result in a minimally invasive procedure.

This invention was made with government support under Grant Nos. FA8650-06-C-7622, FA9550-05-1-0279, and N66001-04-1-8903 awarded by DARPA. The government has certain rights in the invention.

FIELD OF INVENTION

The present invention generally relates to nanotechnology and sub-microelectronic circuitry, as well as associated methods and devices, for example, nanoscale wire devices and methods for use in determining nucleic acids or other analytes suspected to be present in a sample (for example, their presence and/or dynamical information), e.g., at the single molecule level. For example, a nanoscale wire device can be used to detect single base mismatches within a nucleic acid (e.g., by determining association and/or dissociation rates). In some cases, the devices may include metal-semiconductor compounds, such as metal silicides.

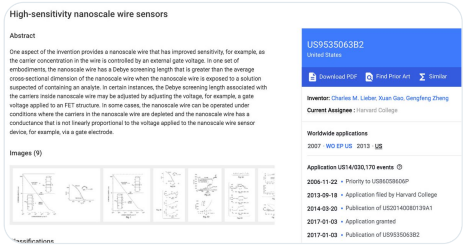
BACKGROUND

Interest in nanotechnology, in particular sub-microelectronic technologies such as semiconductor quantum dots and nanowires, has been motivated by the challenges of chemistry and physics at the nanoscale, and by the prospect of utilizing these structures in electronic and related devices. Nanoscopic articles might be well-suited for transport of charge carriers and excitons (e.g. electrons, electron pairs, etc.) and thus may be useful as building blocks in nanoscale electronics applications. Nanowires are well-suited for efficient transport of charge carriers and excitons, and thus are expected to be important building blocks for nanoscale electronics and optoelectronics.

Nanoscale wires having selectively functionalized surfaces have been described in U.S. patent application Ser. No. 10/020,004, entitled "Nanosensors," filed Dec. 11, 2001, published as Publication No. 2002/0117659 on Aug. 29, 2002, and in corresponding International Patent Application Serial No. PCT/US01/48230, filed Dec. 11, 2001, published as International Patent Application Publication No. WO 02/48701 on Jun. 20, 2002 (each incorporated herein by reference). As described, functionalization of the nanoscale wire may permit interaction of the functionalized nanoscale wire with various entities, such as molecular entities, and the interaction induces a change in a property of the functionalized nanowire, which provides a mechanism for a nanoscale sensor device for detecting the presence or absence of an analyte suspected to be present in a sample.

High-sensitivity nanoscale wire sensors
#HARVARD 2013 A.D.

https://patents.google.com/patent/US9535063B2/en

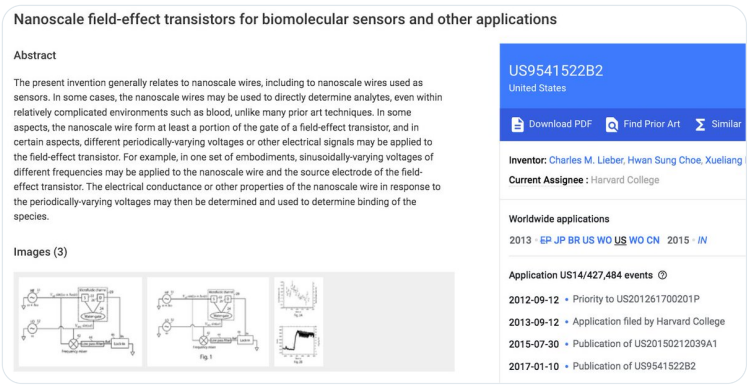


A variety of sample sizes, for exposure of a sample to a nanoscale sensor of the invention, can be used in various embodiments. As examples, the sample size used in nanoscale sensors may be less than or equal to about 10 microliters, less than or equal to about 1 microliter, or less than or equal to about 0.1 microliter. The sample size may be as small as about 10 nanoliters, 1 nanoliter, or less, in certain instances. The nanoscale sensor also allows for unique accessibility to biological species and may be used for in vivo and/or in vitro applications. When used in vivo, in some case, the nanoscale sensor and corresponding method result in a minimally invasive procedure.

Nanoscale field-effect transistors for biomolecular sensors and other applications
#HARVARD 2013 A.D.

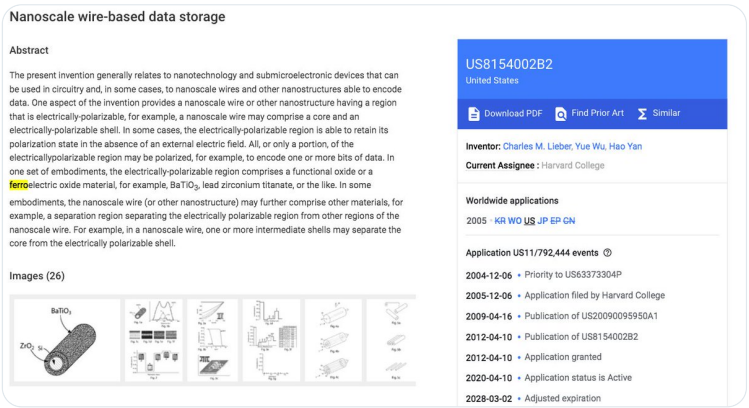
https://patents.google.com/patent/US9541522B2/en

https://en.wikipedia.org/wiki/Field-effect_transistor#Effect_of_gate_voltage_on_current



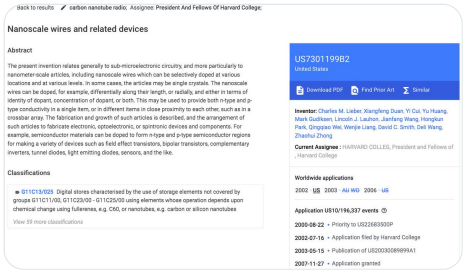
Nanoscale wire-based data storage
#HARVARD 2005 A.D.

https://patents.google.com/patent/US8154002B2/en



Nanoscale wires and related devices
#HARVARD - 2002 A.D.

https://patents.google.com/patent/US7301199B2/en



The term "sample" can be any cell, tissue, or fluid that can be derived from or originates from a biological source (a "biological sample"), or other similar media, biological or non-biological, and that can be evaluated in accordance with the invention, such as a bodily fluid, enviromental matter, water, or the like. A sample can include, but is not limited to, a biological sample drawn from an organism (e.g. a human, a non-human mammal, an invertebrate, a plant, a fungus, an algae, a bacteria, a virus, etc.); a sample drawn from food designed for human consumption, a sample including food designed for animal consumption such as livestock feed, milk; an organ donation sample, a sample of blood destined for a blood supply; a sample from a water supply, and the like. One example of a sample is a sample drawn from a human or animal to determine the presence or absence of a specific nucleic acid sequence.

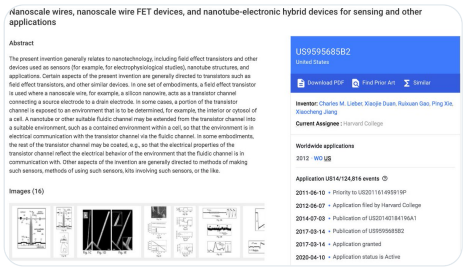
Electronic devices incorporating semiconductor nanoscale wires may be controlled, for example, using any input signal, such as an electrical, optical or a magnetic signal. The control may involve switching between two or more discrete states or may involve continuous control of nanoscale wire current, i.e., analog control. In addition to electrical signals, optical signals and magnetic signals, the devices may also be controlled in certain embodiments in response to biological and chemical species, for example, DNA, protein, metal ions. In a more general sense, these species may be charged or have a dipole moment. In other embodiments, the device may be switchable in response to mechanical stimuli, for example, mechanical stretching, vibration and bending. In yet other embodiments, the device may be switchable in response to temperature, pressure, or fluid movement, for example, the movement of an environmental gas or liquid.

A nanoscale sensor of the present invention may collect real time data in some embodiments. The real time data may be used, for example, to monitor the reaction rate of a specific chemical or biological reaction. Physiological conditions or drug concentrations present in vivo may also produce a real time signal that may be used to control a drug delivery system. For example, the present invention includes, in one aspect, an integrated system, comprising a nanoscale wire detector, a reader and a computer controlled response system. In this example, the nanoscale wire detector detects a change in the equilibrium of an analyte in the sample, feeding a signal to the computer controlled response system causing it to withhold or release a chemical or drug. This may be particularly useful as an implantable drug or chemical delivery system because of its small size and low energy requirements. Those of ordinary skill in the art will be aware of the parameters and requirements for constructing implantable devices, readers, and computer-controlled response systems suitable for use in connection with the present invention. That is, the knowledge of those of ordinary skill in the art, coupled with the disclosure herein of nanoscale wires as sensors, enables implantable devices, real-time measurement devices, integrated systems, and the like. Such systems may be made capable of monitoring one, or a plurality of physiological characteristics individually or simultaneously. Such physiological characteristics may include, for example, oxygen concentration, carbon dioxide concentration, glucose level, concentration of a particular drug, concentration of a particular drug by-product, or the like. Integrated physiological devices may be constructed to carry out a function depending upon a condition sensed by a sensor of the invention. For example, a nanoscale wire sensor of the invention may be constructed and arranged to detect glucose and, based upon the determined glucose level, may cause the release of insulin into a subject through an appropriate controller mechanism.

Nanoscale wires, nanoscale wire FET devices, and nanotube-electronic hybrid devices for sensing and other applications

#HARVARD 2012 A.D.

https://patents.google.com/patent/US9595685B2/en



in one set of embodiments, one or more reaction entities may be used to determine the analyte. The term "reaction entity" refers to any entity that can interact with an analyte in such a manner to cause a detectable change in a property of a nanoscale wire (e.g., one acting as a transistor channel in a field effect transistor). The reaction entity may enhance the interaction between the nanoscale wire and the analyte, or generate a new chemical species that has a higher affinity to the nanoscale wire, or to enrich the analyte around the nanoscale wire. The reaction entity can comprise a binding partner to which the analyte binds. The reaction entity, when a binding partner, can comprise a specific binding partner of the analyte. For example, the reaction entity may be a nucleic acid, an antibody, a sugar, a carbohydrate or a protein. The reaction entity also may be a polymer, catalyst, or a quantum dot. A reaction entity that is a catalyst can catalyze a reaction involving the analyte, resulting in a product that causes a detectable change in the nanoscale wire, e.g. via binding to an auxiliary binding partner of the product electrically coupled to the nanoscale wire.

The term "binding partner" refers to a molecule that can undergo binding with a particular analyte, or "binding partner" thereof, and includes specific, semi-specific, and non-specific binding partners as known to those of ordinary skill in the art. For example, Protein A is usually regarded as a "non-specific" or semi-specific binder. The term "specifically binds," when referring to a binding partner (e.g., protein, nucleic acid, antibody, etc.), refers to a reaction that is determinative of the presence and/or identity of one or other member of the binding pair in a mixture of heterogeneous molecules (e.g., proteins and other biologics). Thus, for example, in the case of a receptor/ligand binding pair the ligand would specifically and/or preferentially select its receptor from a complex mixture of molecules, or vice versa. An enzyme would specifically bind to its substrate, a nucleic acid would specifically bind to its complement, an antibody would specifically bind to its antigen. Other examples include, nucleic acids that specifically bind (hybridize) to their complement, antibodies specifically bind to their antigen, and the like. The binding may be by one or more of a variety of mechanisms including, but not limited to ionic interactions, and/or covalent interactions, and/or hydrophobic interactions, and/or van der Waals interactions, etc.

EXAMPLE 1

This example illustrates the development of intracellular electrical recording techniques capable of simultaneous multi-site recording with high spatial resolution and minimal invasiveness. This allows a network of electrogenic cells to be studied, for example, to understand signaling between the cells. In this example, a nanotube between the interior of living cell and the transistor channel of a field effect transistor (FET), such as a silicon nanowire FET, is demonstrated. A nanotube allows the cytosol of a cell to come into physical contact with the channel of the FET, thus allowing electrical coupling between the cell and FET to occur. The nanotube thus acts somewhat analogously to the gap junction in biological systems, through which various ions and molecules pass freely from one

cell to another, allowing for communication between the cells. In some cases, the cytosol may enter the nanotube and act as the gate electrode to the FET. Thus, potential changes within the cytosol, e.g., due to action potentials in electrogenic cells, may be determined as a conductance change within the FET.

Unlike other potentiometric techniques, the nanotube can be miniaturized without substantial loss of signal amplitude. In this example, a full amplitude intracellular action potential from embryonic chicken cardiomyocyte cell was determined using a FET device having a single nanotube having an inner diameter of 50 nm and an outer diameter of 50 nm to 100 nm at the top, i.e., where the nanotube contacts the cytosol. These sizes were chosen in this example since decreasing nanotube inner diameters generally increases the electrical resistance of cytosol inside. For instance, a 1.5 micrometer long nanotube may have a limit on its inner diameter of about 2 nm at a bandwidth of 3 kHz. The nanotubes used in this example also illustrate minimal invasiveness and/or highly localized electrical detection. The detection is also generally repeatable, as illustrated by repeated intracellular recordings at the same position on a cardiomyocyte cell. In some cases, the FET channel may be chosen to have a diameter that is about the same as the I.D. of the nanotube at its tip. It was found that, in certain cases, increasing the width of the FET channel does not increase sensitivity of the device, but does increase the conductance background which might lead to higher noise levels and/or lower signal-to-noise ratios

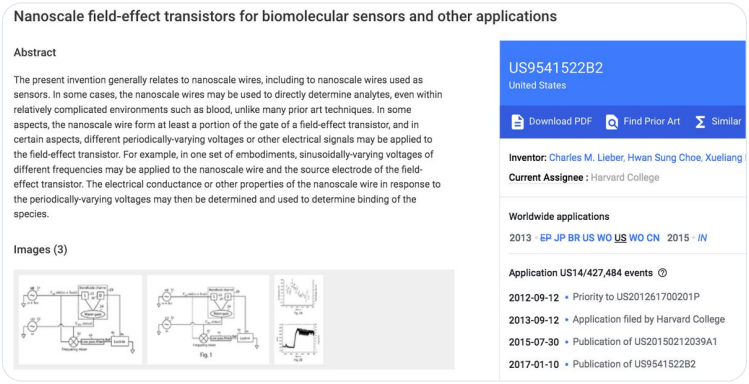
In biological systems, certain passages are created between cells and are commonly used for cell-to-cell communication. An example is a gap junction, which is formed from a protein. Gap junctions are often used to transmit action potentials in cardiac myocyte systems. Ions and/or small molecules are able to move through the gap junction between cells without significant external leakage, thereby allowing fast, efficient, and synchronizable coupling between cells. The devices used in this example are similar in concept, allowing coupling between a cell and an electronic device, thereby allowing similar fast, efficient, and/or synchronizable coupling between a cell and an electronic device.

To study the electrical behavior of a cell, in this example, the channel of the FET (connecting a source electrode to a drain electrode) is positioned to be in contact with the intracellular cytosol of the cell, but the electrodes themselves are not contacted with the cell, thereby minimizing the invasiveness of the FET. The FET in this example also allows for high spatial resolution multiplexing intracellular recording. However, instead of directly putting the FET channel inside the cell, a nanotube is used between the cell and the FET channel.

Nanoscale field-effect transistors for biomolecular sensors and other applications
#HARVARD 2013 A.D.

https://patents.google.com/patent/US9541522B2/en

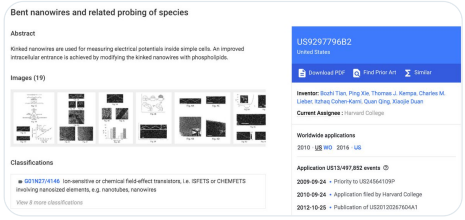
https://en.wikipedia.org/wiki/Field-effect_transistor#Effect_of_gate_voltage_on_current



Bent nanowires and related probing of species

#HARVARD - 2010A.D.

https://patents.google.com/patent/US9297796B2/en



In some embodiments, the nanoscale object may used to be communicate electrically with a cell. For example, the nanoscale object may be used to transmit a current to the cell. In some embodiments, the transmitting a current to a cell may induce an action potential.

In some cases, the nanoscale object may be used to determine electrical activity in a cell. Advantageously, the nanoscale object may be used in certain embodiments in place of a patch clamp and/or voltage clamp. In some embodiments, the nanoscale object may be used to determine electric activity in a cell using field effect. Also advantageously, it is believed that the nanoscale objects are less disruptive to cells because of the small size of the nanoscale objects and/or surface functionalization of the nanoscale objects, at least in some cases.

In some embodiments, the nanoscale object may transmit and/or receive a current greater than 0.1 picoamps, greater than 1 picoamp, greater than 10 picoamps, greater than 100 picoamps, greater than 1 nanoamp, greater than 10 nanoamps, greater than 100 nanoamps, greater than 1 microamp, greater than 10 microamps, greater than 100 microamps, or even more. In some embodiments, the nanoscale object transmit a current between 0.1 picoamps and 100 microamps, between 0.1 picoamps and 100 picoamps, between 10 picoamps and 10 nanoamps, between 1 nanoamp and 1 microamp, or between 100 nanoamps and 100 microamps.

In some cases, the nanoscale object may be capable of detecting an electric potential, e.g., the nanoscale object may be, or include, a field effect transistor (FET). In some embodiments, the nanoscale object may be a two terminal FET device. In some cases, the nanoscale object may detect an electric potential of greater than 0.1 microvolts, greater than 1 microvolt, greater than 10 microvolts, greater than 100 microvolts, greater than 1 millivolt, greater than 10 millivolts, greater than 100 millivolts, greater than 1 volt, or even greater. In some embodiments, the nanoscale object may detect an electric potential between 0.1 microvolts and 1 volt, between 0.1 microvolts and 100 microvolts, between 10 microvolts and 10 millivolts, or between 1 millivolt and 1 volt. In the case of a FET

device, the nanoscale object may, in some embodiments, perform as a gate in the transistor. The nanoscale object may allow an increase or decrease in the flow of current between the source and drain of the transistor in response to a threshold electrical potential. The threshold electrical potential may be within any of the voltage ranges listed above. In some embodiments, the nanoscale object can detect the electrical potential intracellularly by being in contact with the cytosol.

In some embodiments, the nanoscale object may used to be communicate electrically with a cell. For example, the nanoscale object may be used to transmit a current to the cell. In some embodiments, the transmitting a current to a cell may induce an action potential.

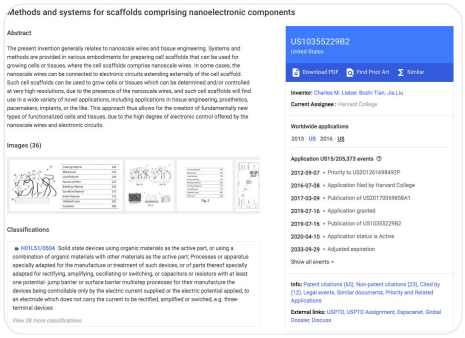
Nanoscale objects of the invention can be used to probe biological materials, such as cells, using a variety of techniques. U.S. Pat. No. 7,301,199, issued Nov. 27, 2007 to Lieber, et al., and U.S. patent number 7,129,554, issued Oct. 31, 2006 to Lieber, et al., both incorporated herein by reference, describe techniques for making and using nanoscale objects, including arranging nanoscale objects in devices for determination of various species. Some of those techniques can be useful for probing biological species such as cells in accordance with the present invention.

A nanoscale object in contact with a lipid bilayer may be used to communicate electrically, e.g., for determination of some aspect of the lipid bilayer or a related cell. For example, the nanoscale object may be capable of sending and/or receiving an electrical current, and/or passing an electrical current through the nanowire that

Methods and systems for scaffolds comprising nanoelectronic components

#HARVARD - 2013 & 2016 A.D.

https://patents.google.com/patent/US9786850B2/en
https://patents.google.com/patent/US10355229B2/en


Methods and systems for scaffolds comprising nanoelectronic components

Abstract

The present invention generally relates to nanoscale wires and tissue engineering. Systems and methods are provided in various embodiments for preparing cell scaffolds that can be used for growing cells or tissues, where the cell scaffolds comprise nanoscale wires. In some cases, the nanoscale wires can be connected to electronic circuits extending externally of the cell scaffold. Such cell scaffolds can be used to grow cells or tissues which can be determined and/or controlled at very high resolutions, due to the presence of the nanoscale wires, and such cell scaffolds will find use in a wide variety of novel applications, including applications in tissue engineering, prosthetics, pacemakers, implants, or the like. This approach thus allows for the creation of fundamentally new types of functionalized cells and tissues, due to the high degree of electronic control offered by the nanoscale wires and electronic circuits.

Images (36)

Classifications

US10355229B2
United States
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Inventor: Charles M. Lieber, Bozhi Tian, Jia Liu
Current Assignee : Harvard College
Worldwide applications
2013 · US · 2016 · US
Application US15/205,373 events
2012-09-07 · Priority to US201261698492P
2016-07-08 · Application filed by Harvard College
2017-03-09 · Publication of US20170069858A1
2019-07-16 · Application granted
2019-07-16 · Publication of US10355229B2
2020-04-10 · Application status is Active
2033-09-29 · Adjusted expiration
Show all events

In one set of embodiments, a cell scaffold may not be present within a biological tissue (e.g., an implanted tissue), or may have been present but may have partially or completely degraded, e.g., such that it no longer functions as a cell scaffold. Thus, for example, in one embodiment, the present invention is directed to a biological tissue comprising nanoscale wires such as semiconductor nanowires or any other nanoscale wire describe herein. In some cases, at least some of the nanoscale wires form a portion of an electrical circuit that extends externally of the tissue. The biological tissue may also comprise conductive pathways, such metal leads, within the biological tissue, e.g., connecting nanoscale wires or other electrical components. In addition, in some cases, some or all of the conductive pathways can also be connected to an external electrical system, such as a computer or a transmitter, e.g., a radio transmitter, a wireless transmitter, etc. Thus, in another set of embodiments, the present invention is generally directed to a biological tissue comprising nanoscale wires and/or conductive pathways (e.g., forming an electrical network such as is discussed herein), not necessarily limited to a cell scaffold. The tissue may be present in vitro or an in vivo, e.g., implanted into a subject, such as a human subject, the tissues may be autologous, homologous, or heterologous with the subject.

In some embodiments, cells or tissues can be interfaced with the nanoscale wires or other electrical components (within the cell scaffold, and/or after degradation of the cell scaffold) to such a degree that they form a substantially unitary structure where cells present within the biological tissue may require electrically communications with the nanoscale wires in order to function, or to communicate with each other. For example, cardiac or muscle cells within a tissue may not be able to beat or contract, or may not be able to beat or contract in a regular fashion, without stimuli from the nanoscale wires, or without using the nanoscale wires to communicate. As another example, nerve cells within the tissue may form axons and/or dendrites with the nanoscale wires, e.g., in order to transmit and/or receive electronic signals from other nerve cells and/or from the nanoscale wires. In such fashion, an electrically unitary structure may be generated, i.e., a "cyborg" tissue can be created whose biological functioning depends not only on the cells or tissues, but on the electronic components as well, e.g., such that the distinction between the biological and electronic systems becomes blurred.

In some embodiments, cells or tissues can be interfaced with the nanoscale wire or other electrical components (within the cell scaffold, and/or after degradation the cell scaffold) to such a degree that they form a substantially unitary structure where cells present within the biological tissue may require electrically communications with the nanoscale wires in order to function, or to communicate with each other. For example, cardiac or muscle cells within a tissue may not be able to beat or contract, or may not be able to beat or contract in a regular fashion without stimuli from the nanoscale wires, or without using the nanoscale wires to communicate. As another example, nerve cells within the tissue may form axons and/or dendrites with the nanoscale wires, e.g., in order to transmit and/or receive electronic signals from other nerve cells and/or from the nanoscale wires. In such fashion, an electrically unitary structure may be generated, i.e., a "cyborg" tissue can be created whose biological functioning depends not only on the cells or tissues, but on the electronic components as well, e.g., such that the distinction between the biological and electronic systems becomes blurred.

In another set of embodiments, the biological tissue may be one that contains sufficient nanoscale wires that a property, such as a chemical or an electrical property, can be determined at a relatively high resolution, and/or in three dimensions within the biological tissue, e.g., due to the placement of nanoscale wires within the tissue that can be used as sensors. For example, one or more nanoscale wires may be present within an electronic circuit as a component of a field effect transistor. In addition, in certain embodiments, such determinations may be transmitted and/or recorded, e.g., for later use and or analysis.

Thus, for example, a property such as a chemical property and/or an electrical property can be determined at a resolution of less than about 2 mm, less than about 1 mm, less than about 500 micrometers, less than about 300 micrometers, less than about 100 micrometers, less than about 50 micrometers, less than about 30 micrometers, or less than about 10 micrometers, etc., e.g., due to the average separation between a nanoscale wire and its nearest neighboring nanoscale wire. In addition, as mentioned, the property may be determined within the tissue in 3 dimensions in some instances, in contrast with many other techniques where only a surface of the biological tissue can be studied. Accordingly, very high resolution and/or 3-dimensional mappings of the property of the biological tissue can be obtained in some embodiments. Any suitable tissue may be studied, e.g., cardiac tissue, vascular tissue, muscle, cartilage, bone, liver tissue, pancreatic tissue, bladder tissue, airway tissues, bone marrow tissue, or the like.

In addition, in some cases, such properties can be determined and/or recorded as a function of time. Thus, for example, such properties can be determined at a time resolution of less than about 1 min, less than about 30 s, less than about 15 s, less than about 10 s, less than about 5 s, less than about 3 s, less than about 1 s, less than about 500 ms, less than about 300 ms, less than about 100 ms, less than about 50 ms, less than about 30 ms, less than about 10 ms, less than about 5 ms, less than about 3 ms, less than about 1 ms, etc.

Methods and systems for scaffolds comprising nanoelectronic components

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In yet another set of embodiments, the biological tissue, and/or portions of the biological tissue, may be electrically stimulated using nanoscale wires present within the tissue. For example, all, or a subset of the electrically active nanoscale wires may be electrically stimulated, e.g., by using an external electrical system, such as a computer. Thus, for example, a single nanoscale wire, a group of nanoscale wires, or substantially all of the nanoscale wires can be electrically stimulated, depending on the particular application. In some cases, such nanoscale wires can be stimulated in a particular pattern, e.g., to cause cardiac or muscle cells to contract or beat in a particular pattern (for example, as part of a prosthetic or a pacemaker), to cause the firing of neurons with a particular pattern, to monitor the status of an implanted tissue within a subject, or the like.

In yet another set of embodiments, the biological tissue, and/or portions of the biological tissue, may be electrically stimulated using nanoscale wires present within the tissue. For example, all, or a subset of the electrically active nanoscale wires may be electrically stimulated, e.g., by using an external electrical system, such as a computer. Thus, for example, a single nanoscale wire, a group of nanoscale wires, or substantially all of the nanoscale wires can be electrically stimulated, depending on the particular application. In some cases, such nanoscale wires can be stimulated in a particular pattern, e.g., to cause cardiac or muscle cells to contract or beat in a particular pattern (for example, as part of a prosthetic or a pacemaker), to cause the firing of neurons with a particular pattern, to monitor the status of an implanted tissue within a subject, or the like.

In addition, in some cases, cells are plated or seeded on the cell scaffold and allowed to grow. For example, the cells may be plated on the cell scaffold in vitro, and/or the cell scaffold may be exposed or even submerged within a suitable cell growth medium. Such media are widely available commercially. In some embodiments, the cell scaffold can be subsequently implanted in vivo into a subject, e.g., upon the growth of suitable from the cells. In other cases, the cell scaffold can directly be used in an in vivo setting, i.e., without needing plating of cells, and/or without formation of tissues before implantation.

In addition, the cell scaffold can be interfaced in some embodiments with one or more electronics, e.g., an external electrical system such as a computer or a transmitter (for instance, a radio transmitter, a wireless transmitter, etc.). In some cases, electronic testing of the cell scaffold may be performed, e.g., before or after implantation into a subject. For instance, one or more of the metal leads may be connected to an external electrical circuit, e.g., to electronically interrogate or otherwise determine the electronic state or one or more of the nanoscale wires within the cell scaffold. Such determinations may be performed quantitatively and/or qualitatively, depending on the application, and can involve all, or only a subset, of the nanoscale wires contained within the cell scaffold, e.g., as discussed herein.

In addition, in some cases, cells are plated or seeded on the cell scaffold and allowed to grow. For example, the cells may be plated on the cell scaffold in vitro, and/or the cell scaffold may be exposed or even submerged within a suitable cell growth medium. Such media are widely available commercially. In some embodiments, the cell scaffold can be subsequently implanted in vivo into a subject, e.g., upon the growth of suitable from the cells. In other cases, the cell scaffold can directly be used in an in vivo setting, i.e., without needing plating of cells, and/or without formation of tissues before implantation.

In addition, the cell scaffold can be interfaced in some embodiments with one or more electronics, e.g., an external electrical system such as a computer or a transmitter (for instance, a radio transmitter, a wireless transmitter, etc.). In some cases, electronic testing of the cell scaffold may be performed, e.g., before or after implantation into a subject. For instance, one or more of the metal leads may be connected to an external electrical circuit, e.g., to electronically interrogate or otherwise determine the electronic state or one or more of the nanoscale wires within the cell scaffold. Such determinations may be performed quantitatively and/or qualitatively, depending on the application, and can involve all, or only a subset, of the nanoscale wires contained within the cell scaffold, e.g., as discussed herein.

Routing policies for biological hosts

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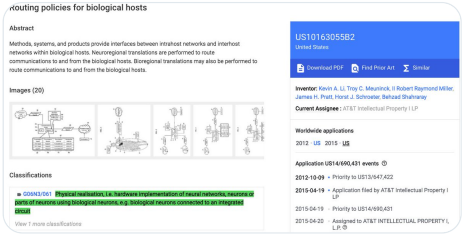
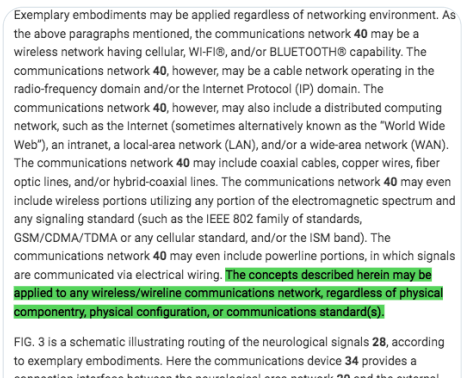


Exemplary embodiments thus provide the interface **32** between the different networks. The communications device **34** may receive the neurological signals **28** from the neurological area network **20** in the woman's brain. The communications device **34** may then forward or route those neurological signals **28** to the external communications network **40**. The woman's neurological signals **28** may thus be transmitted and sent into a cellular data network and/or a WI-FI® network for routing to some distant destination for analysis. The woman's communications device **34** may also receive signals from the external communications network **40** that are destined for her neurological area network **20**. The communications device **34**, likewise, may receive the biological signals **30** from the body area network **22** and send those biological signals **30** into the external communications network **40**. The woman's communications device **34** may also receive signals from the external communications network **40** that are destined for her body area network **22**. Exemplary embodiments thus provide the interface **32** between the neurological area network **20** in the woman's brain, the body area network **22** in the woman's body, and the external communications network **40**.

Exemplary embodiments also describe nested communications. The neurological area network **20**, the body area network **22**, and the external communications network **40** may have a nested arrangement based on frequency. Science has shown that the human brain processes the neurological signals **28** at an extremely high frequency. Indeed, the brain's frequency may be much too high for economical transmission into the external communications network **40**. The biological signals **30** in the body area network **22** are a lower frequency, but the biological signals **30** may still be of too high frequency for the external communications network **40**. The woman's communications device **34**, then, may transform the neurological signals **28** and/or the biological signals **30** to be compatible with the external communications network **40** (which later paragraphs will explain).

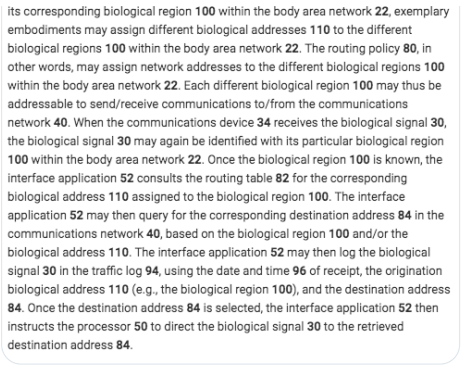
FIG. 7 thus illustrates bioregional translations. Each biological signal **30** may be received from, or identified with, a different biological region **100** within the body area network **22**. Some biological signals **30** may originate from, or be identified with, an arm, while others are identified with a leg. Granularity may even be finer, thus identifying biological signals **30** from a hand, finger, toe, or even a cell. Regardless, when the communications device **34** receives the biological signal **30**, the biological signal **30** may be identified with, or contain information identifying, the biological region **100** within the body area network **22**. The interface application **52** queries the routing policy **80** for the corresponding destination address **84** in the communications network **40**, based on the biological region **100**. Once the destination address **84** is selected, the interface application **52** then instructs the processor **50** to direct the biological signal **30** to the retrieved destination address **84**.

FIG. 8 is another schematic illustrating bioregional translations, according to exemplary embodiments. Because the biological signal **30** may be associated with



Exemplary embodiments may be applied regardless of networking environment. As the above paragraphs mentioned, the communications network **40** may be a wireless network having cellular, WI-FI®, and/or BLUETOOTH® capability. The communications network **40**, however, may be a cable network operating in the radio-frequency domain and/or the Internet Protocol (IP) domain. The communications network **40**, however, may also include a distributed computing network, such as the Internet (sometimes alternatively known as the "World Wide Web"), an intranet, a local-area network (LAN), and/or a wide-area network (WAN). The communications network **40** may include coaxial cables, copper wires, fiber optic lines, and/or hybrid-coaxial lines. The communications network **40** may even include wireless portions utilizing any portion of the electromagnetic spectrum and any signaling standard (such as the IEEE 802 family of standards, GSM/CDMA/TDMA or any cellular standard, and/or the ISM band). The communications network **40** may even include powerline portions, in which signals are communicated via electrical wiring. The concepts described herein may be applied to any wireless/wireline communications network, regardless of physical componentry, physical configuration, or communications standard(s).

FIG. 3 is a schematic illustrating routing of the neurological signals **28**, according to exemplary embodiments. Here the communications device **34** provides a



its corresponding biological region **100** within the body area network **22**, exemplary embodiments may assign different biological addresses **110** to the different biological regions **100** within the body area network **22**. The routing policy **80**, in other words, may assign network addresses to the different biological regions **100** within the body area network **22**. Each different biological region **100** may thus be addressable to send/receive communications to/from the communications network **40**. When the communications device **34** receives the biological signal **30**, the biological signal **30** may again be identified with its particular biological region **100** within the body area network **22**. Once the biological region **100** is known, the interface application **52** consults the routing table **82** for the corresponding biological address **110** assigned to the biological region **100**. The interface application **52** may then query for the corresponding destination address **84** in the communications network **40**, based on the biological region **100** and/or the biological address **110**. The interface application **52** may then log the biological signal **30** in the traffic log **94**, using the date and time **96** of receipt, the origination biological address **110** (e.g., the biological region **100**), and the destination address **84**. Once the destination address **84** is selected, the interface application **52** then instructs the processor **50** to direct the biological signal **30** to the retrieved destination address **84**.

"In more simple terms, one person's brain may control another person's body and vice-versa"

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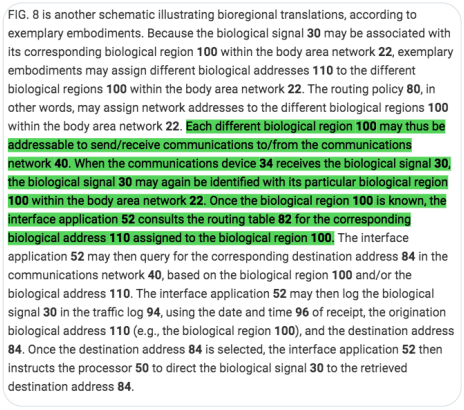
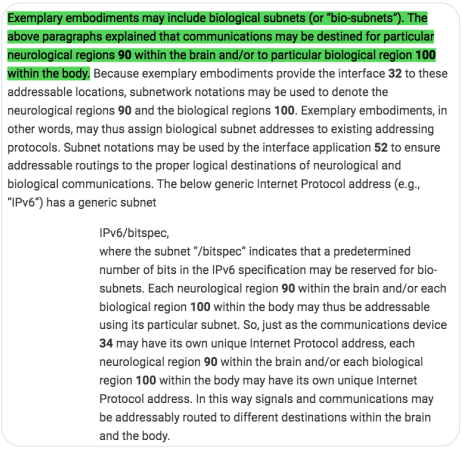


FIG. 8 is another schematic illustrating bioregional translations, according to exemplary embodiments. Because the biological signal **30** may be associated with its corresponding biological region **100** within the body area network **22**, exemplary embodiments may assign different biological addresses **110** to the different biological regions **100** within the body area network **22**. The routing policy **80**, in other words, may assign network addresses to the different biological regions **100** within the body area network **22**. Each different biological region **100** may thus be addressable to send/receive communications to/from the communications network **40**. When the communications device **34** receives the biological signal **30**, the biological signal **30** may again be identified with its particular biological region **100** within the body area network **22**. Once the biological region **100** is known, the interface application **52** consults the routing table **82** for the corresponding biological address **110** assigned to the biological region **100**. The interface application **52** may then query for the corresponding destination address **84** in the communications network **40**, based on the biological region **100** and/or the biological address **110**. The interface application **52** may then log the biological signal **30** in the traffic log **94**, using the date and time **96** of receipt, the origination biological address **110** (e.g., the biological region **100**), and the destination address **84**. Once the destination address **84** is selected, the interface application **52** then instructs the processor **50** to direct the biological signal **30** to the retrieved destination address **84**.



Exemplary embodiments may include biological subnets (or "bio-subnets"). The above paragraphs explained that communications may be destined for particular neurological regions **90** within the brain and/or to particular biological region **100** within the body. Because exemplary embodiments provide the interface **32** to these addressable locations, subnetwork notations may be used to denote the neurological regions **90** and the biological regions **100**. Exemplary embodiments, in other words, may thus assign biological subnet addresses to existing addressing protocols. Subnet notations may be used by the interface application **52** to ensure addressable routings to the proper logical destinations of neurological and biological communications. The below generic Internet Protocol address (e.g., "IPv6") has a generic subnet

> IPv6/bitspec,
> where the subnet "/bitspec" indicates that a predetermined number of bits in the IPv6 specification may be reserved for bio-subnets. Each neurological region **90** within the brain and/or each biological region **100** within the body may thus be addressable using its particular subnet. So, just as the communications device **34** may have its own unique Internet Protocol address, each neurological region **90** within the brain and/or each biological region **100** within the body may have its own unique Internet Protocol address. In this way signals and communications may be addressably routed to different destinations within the brain and the body.

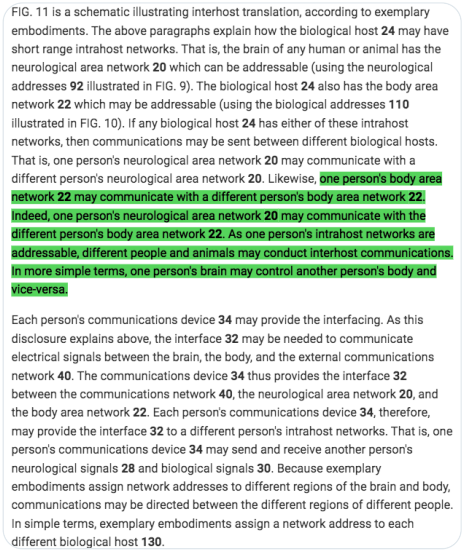
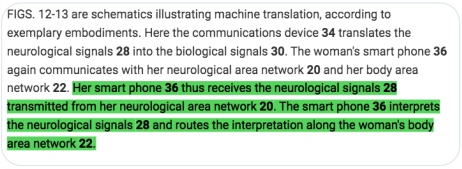


FIG. 11 is a schematic illustrating interhost translation, according to exemplary embodiments. The above paragraphs explain how the biological host **24** may have short range intrahost networks. That is, the brain of any human or animal has the neurological area network **20** which can be addressable (using the neurological addresses **92** illustrated in FIG. 9). The biological host **24** also has the body area network **22** which may be addressable (using the biological addresses **110** illustrated in FIG. 10). If any biological host **24** has either of these intrahost networks, then communications may be sent between different biological hosts. That is, one person's neurological area network **20** may communicate with a different person's neurological area network **20**. Likewise, one person's body area network **22** may communicate with a different person's body area network **22**. Indeed, one person's neurological area network **20** may communicate with the different person's body area network **22**. As one person's intrahost networks are addressable, different people and animals may conduct interhost communications. In more simple terms, one person's brain may control another person's body and vice-versa.

Each person's communications device **34** may provide the interfacing. As this disclosure explains above, the interface **32** may be needed to communicate electrical signals between the brain, the body, and the external communications network **40**. The communications device **34** thus provides the interface **32** between the communications network **40**, the neurological area network **20**, and the body area network **22**. Each person's communications device **34**, therefore, may provide the interface **32** to a different person's intrahost networks. That is, one person's communications device **34** may send and receive another person's neurological signals **28** and biological signals **30**. Because exemplary embodiments assign network addresses to different regions of the brain and body, communications may be directed between the different regions of different people. In simple terms, exemplary embodiments assign a network address to each different biological host **130**.



FIGS. 12-13 are schematics illustrating machine translation, according to exemplary embodiments. Here the communications device **34** translates the neurological signals **28** into the biological signals **30**. The woman's smart phone **36** again communicates with her neurological area network **20** and her body area network **22**. Her smart phone **36** thus receives the neurological signals **28** transmitted from her neurological area network **20**. The smart phone **36** interprets the neurological signals **28** and routes the interpretation along the woman's body area network **22**.

Methods, systems, and products for interfacing with neurological and biological networks

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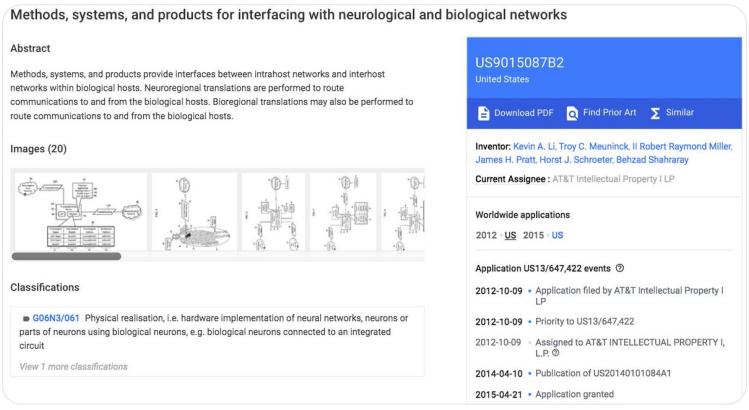

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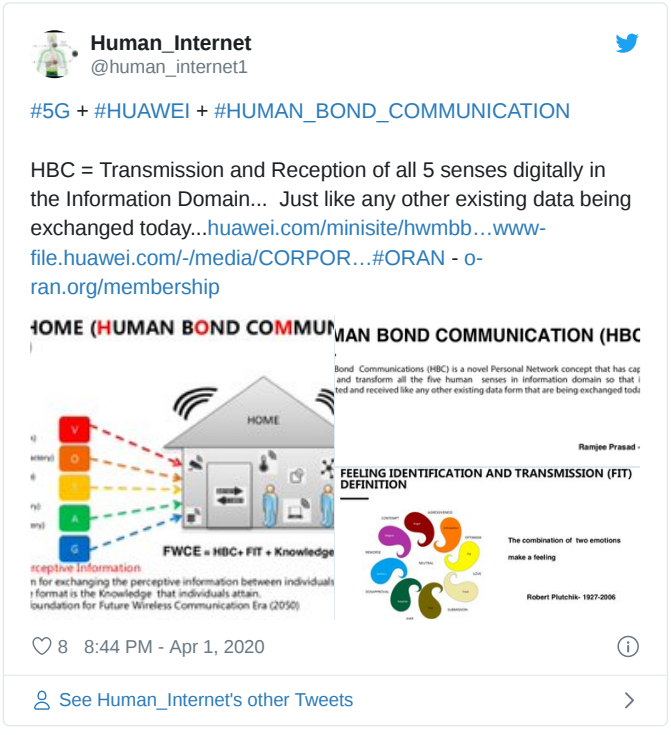

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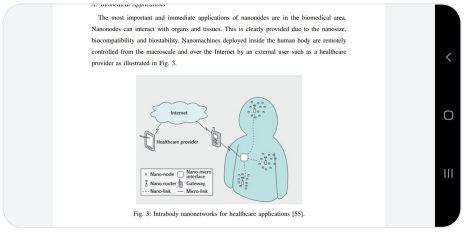
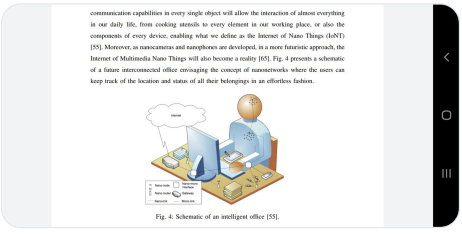


The most important and immediate applications of nanonodes are in the biomedical area. Nanonodes can interact with organs and tissues. This is clearly provided due to the nanosize, biocompatibility and biostability. Nanomachines deployed inside the human body are remotely controlled from the macroscale and over the Internet by an external user such as a healthcare provider as illustrated in Fig. 3.

Fig. 3: Intrabody nanonetworks for healthcare applications [55].



communication capabilities in every single object will allow the interaction of almost everything in our daily life, from cooking utensils to every element in our working place, or also the components of every device, enabling what we define as the Internet of Nano Things (IoNT) [55]. Moreover, as nanocameras and nanophones are developed, in a more futuristic approach, the Internet of Multimedia Nano Things will also become a reality [65]. Fig. 4 presents a schematic of a future interconnected office envisaging the concept of nanonetworks where the users can keep track of the location and status of all their belongings in an effortless fashion.

Fig. 4: Schematic of an intelligent office [55].

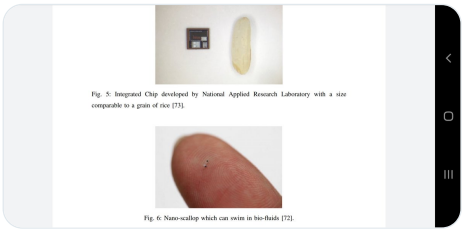


Fig. 5: Integrated Chip developed by National Applied Research Laboratory with a size comparable to a grain of rice [73].

Fig. 6: Nano-scallop which can swim in bio-fluids [72].

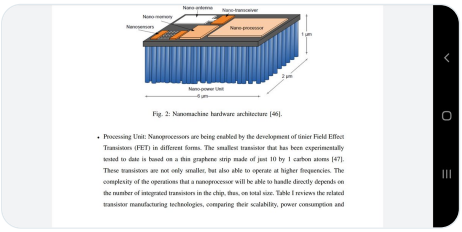


Fig. 2: Nanomachine hardware architecture [46].

- Processing Unit: Nanoprocessors are being enabled by the development of tinier Field Effect Transistors (FET) in different forms. The smallest transistor that has been experimentally tested to date is based on a thin graphene strip made of just 10 by 1 carbon atoms [47]. These transistors are not only smaller, but also able to operate at higher frequencies. The complexity of the operations that a nanoprocessor will be able to handle directly depends on the number of integrated transistors in the chip, thus, on total size. Table I reviews the related transistor manufacturing technologies, comparing their scalability, power consumption and

Nanoscale Optical Communication

Opto-Acoustic / Thermo-Acoustic conversions to perform cellular signaling... inside the

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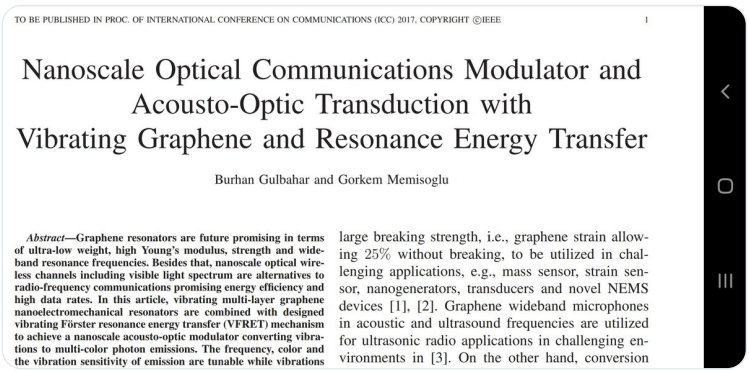

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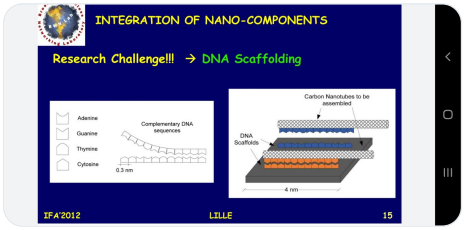
Nanoscale Optical Communications Modulator and Acousto-Optic Transduction with Vibrating Graphene and Resonance Energy Transfer

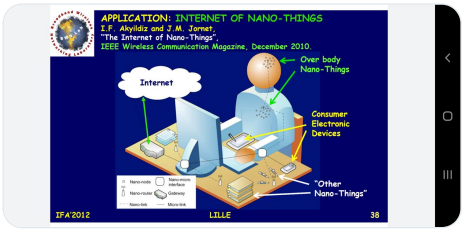
Burhan Gulbahar and Gorkem Memisoglu

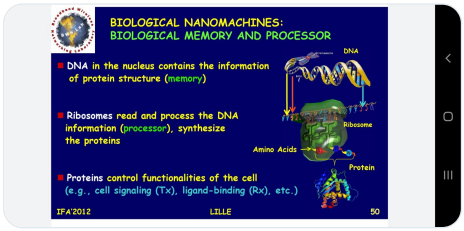
Abstract—**Graphene resonators are future promising in terms of ultra-low weight, high Young's modulus, strength and wide-band resonance frequencies. Besides that, nanoscale optical wireless channels including visible light spectrum are alternatives to radio-frequency communications promising energy efficiency and high data rates. In this article, vibrating multi-layer graphene nanoelectromechanical resonators are combined with designed vibrating Förster resonance energy transfer (VFRET) mechanism to achieve a nanoscale acousto-optic modulator converting vibrations to multi-color photon emissions. The frequency, color and the vibration sensitivity of emission are tunable while vibrations**

large breaking strength, i.e., graphene strain allowing 25% without breaking, to be utilized in challenging applications, e.g., mass sensor, strain sensor, nanogenerators, transducers and novel NEMS devices [1], [2]. Graphene wideband microphones in acoustic and ultrasound frequencies are utilized for ultrasonic radio applications in challenging environments in [3]. On the other hand, conversion

http://researchers.lille.inria.fr/~mitton/documents/LilleAkyildiz.pdf

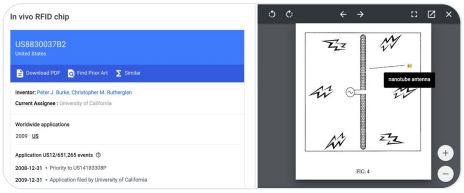


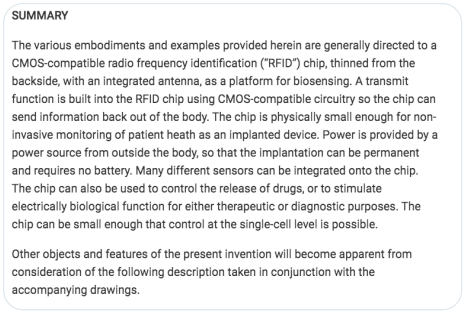




In vivo RFID chip
https://patents.google.com/patent/US8830037B2/en

NANO RFID CHIP





SUMMARY

The various embodiments and examples provided herein are generally directed to a CMOS-compatible radio frequency identification ("RFID") chip, thinned from the backside, with an integrated antenna, as a platform for biosensing. A transmit function is built into the RFID chip using CMOS-compatible circuitry so the chip can send information back out of the body. The chip is physically small enough for non-invasive monitoring of patient heath as an implanted device. Power is provided by a power source from outside the body, so that the implantation can be permanent and requires no battery. Many different sensors can be integrated onto the chip. The chip can also be used to control the release of drugs, or to stimulate electrically biological function for either therapeutic or diagnostic purposes. The chip can be small enough that control at the single-cell level is possible.

Other objects and features of the present invention will become apparent from consideration of the following description taken in conjunction with the accompanying drawings.

Fully-functional Radio From A Single Carbon Nanotube Created
2007 A.D.
https://www.sciencedaily.com/releases/2007/10/071031135307.htm

"With such a small receiver or transmitter, you could put a tracking collar on a bacterium."

Music and Voice Reception

Self Assembly

> “A single carbon nanotube molecule serves simultaneously as all essential components of a radio — antenna, tunable band-pass filter, amplifier, and demodulator,” said physicist Alex Zettl, who led the invention of the nanotube radio. “Using carrier waves in the commercially relevant 40-400 MHz range and both frequency and amplitude modulation (FM and AM), we were able to demonstrate successful music and voice reception.”
>
> Given that the nanotube radio essentially assembles itself and can be easily tuned to a desired frequency band after fabrication, Zettl believes that nanoradios will be relatively easy to mass-produce. Potential applications, in addition to incredibly tiny radio receivers, include a new generation of wireless communication devices and monitors. Nanotube radio technology could prove especially valuable for biological and medical applications.
>
> “The entire radio would easily fit inside a living cell, and this small size allows it to safely interact with biological systems,” Zettl said. “One can envision interfaces with brain or muscle functions, or radio-controlled devices moving through the bloodstream.”

Triggered Self-Assembly of Nanoparticles In Vivo

https://patents.google.com/patent/US20090246142A1/en

Cosmetics?

Lotion, Deodorant, Shampoo, Perfume, Makeup

Vaccines?

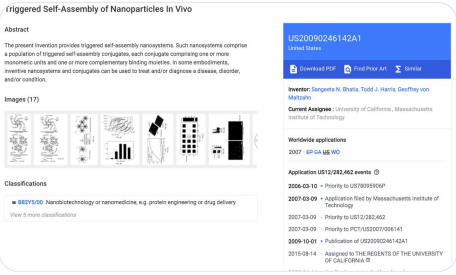
#BillGatesIsEvil

Inhalants?

Vape / Cigarettes / Stratospheric Aerosol injections

Self Assembling "Triggers"

"...Any form of Radiation"


Triggered Self-Assembly of Nanoparticles In Vivo

Abstract

The present invention provides triggered self-assembly nanosystems. Such nanosystems comprise a population of triggered self-assembly conjugates, each conjugate comprising one or more monomeric units and one or more complementary binding moieties. In some embodiments, inventive nanosystems and conjugates can be used to treat and/or diagnose a disease, disorder, and/or condition.

Images (17)

Classifications

B82Y5/00 Nanobiotechnology or nanomedicine, e.g. protein engineering or drug delivery

View 5 more classifications

US20090246142A1

United States

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Inventor: Sangeeta N. Bhatia, Todd J. Harris, Geoffrey von Maltzahn

Current Assignee : University of California , Massachusetts Institute of Technology

Worldwide applications

2007 · EP CA US WO

Application US12/282,462 events

2006-03-10 · Priority to US78095906P

2007-03-09 · Application filed by Massachusetts Institute of Technology

2007-03-09 · Priority to US12/282,462

2007-03-09 · Priority to PCT/US2007/006141

2008-10-01 · Publication of US20090246142A1

2015-08-14 · Assigned to THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

[0251] Formulations suitable for topical administration include, but are not limited to, liquid and/or semi liquid preparations such as liniments, lotions, oil in water and/or water in oil emulsions such as creams, ointments and/or pastes, and/or solutions and/or suspensions. Topically-administrable formulations may, for example, comprise from about 1% to about 10% (w/w) active ingredient, although the concentration of the active ingredient may be as high as the solubility limit of the active ingredient in the solvent. Formulations for topical administration may further comprise one or more of the additional ingredients described herein.

[0249] Dosage forms for topical and/or transdermal administration of a compound of this invention may include ointments, pastes, creams, lotions, gels, powders, solutions, sprays, inhalants and/or patches. Generally, the active ingredient is admixed under sterile conditions with a pharmaceutically acceptable carrier and/or any needed preservatives and/or buffers as may be required. Additionally, the present invention contemplates the use of transdermal patches, which often have the added advantage of providing controlled delivery of a compound to the body. Such dosage forms may be prepared, for example, by dissolving and/or dispensing the compound in the proper medium. Alternatively or additionally, the rate may be controlled by either providing a rate controlling membrane and/or by dispersing the compound in a polymer matrix and/or gel.

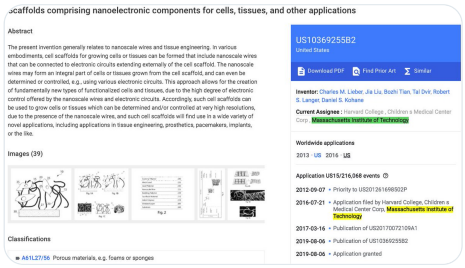
[0186] TSACs are designed with specific and tunable self-assembling properties and are modified to avoid interacting with themselves, their complement, and non-specific biological materials until they are triggered by an external stimuli. This method provides methods of avoiding non-specific interactions of TSACs with proteins of the serum, extracellular matrix, or cell membranes. This method provides methods of avoiding uptake by the reticulo-endothelial system (RES) before activation at the target site.

[0187] Versatility in the mechanism for triggering self-assembly makes this method applicable over a broad range of diagnostic and/or therapeutic applications. For instance, activation by proteases enables targeting to sites of protease upregulation in cancer, thrombosis, atherosclerosis, arthritis, wound healing and the like. Similarly, diseased tissue having low pH and/or hypoxic tissue could be used to trigger self-assembly. Alternatively, self-assembly may be triggered by any form of radiation (e.g., heat, radiofrequency (RF), light, ultrasound, x-ray, etc.)

Scaffolds comprising nanoelectronic components for cells, tissues, and other applications

https://patents.google.com/patent/US10369255B2/en

#MIT #CharlesLieber #Harvard
&
https://www.bizapedia.com/us/the-childrens-medical-center-corporation.html



In addition, in some cases, cells are plated or seeded on the cell scaffold and allowed to grow. For example, the cells may be plated on the cell scaffold in vitro, and/or the cell scaffold may be exposed or even submerged within a suitable cell growth medium. Such media are widely available commercially. In some embodiments, the cell scaffold can be subsequently implanted in vivo into a subject, e.g., upon the growth of suitable from the cells. In other cases, the cell scaffold can directly be used in an in vivo setting, i.e., without needing plating of cells, and/or without formation of tissues before implantation.

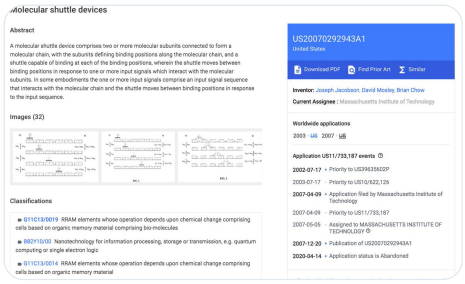
In addition, the cell scaffold can be interfaced in some embodiments with one or more electronics, e.g., an external electrical system such as a computer or a transmitter (for instance, a radio transmitter, a wireless transmitter, etc.). In some cases, electronic testing of the cell scaffold may be performed, e.g., before or after implantation into a subject. For instance, one or more of the metal leads may be connected to an external electrical circuit, e.g., to electronically interrogate or otherwise determine the electronic state or one or more of the nanoscale wires within the cell scaffold. Such determinations may be performed quantitatively and/or qualitatively, depending on the application, and can involve all, or only a subset, of the nanoscale wires contained within the cell scaffold, e.g., as discussed herein.

In some embodiments, cells or tissues can be interfaced with the nanoscale wires or other electrical components (within the cell scaffold, and/or after degradation of the cell scaffold) to such a degree that they form a substantially unitary structure where cells present within the biological tissue may require electrically communications with the nanoscale wires in order to function, or to communicate with each other. For example, cardiac or muscle cells within a tissue may not be able to beat or contract, or may not be able to beat or contract in a regular fashion, without stimuli from the nanoscale wires, or without using the nanoscale wires to communicate. As another example, nerve cells within the tissue may form axons and/or dendrites with the nanoscale wires, e.g., in order to transmit and/or receive electronic signals from other nerve cells and/or from the nanoscale wires. In such fashion, an electrically unitary structure may be generated, i.e., a "cyborg" tissue can be created whose biological functioning depends not only on the cells or tissues, but on the electronic components as well, e.g., such that the distinction between the biological and electronic systems becomes blurred.

Molecular shuttle devices
#MIT - 2003 A.D.

Controlled sub-cellular construction / assembly / expression(s)

https://patents.google.com/patent/US20070292943A1/en



SUMMARY

[0004] The invention features molecular scale devices that may be used as bi-stable switches, bi-directional molecular assembly lines, and molecular memory devices. The devices are composed of molecular subunits and shuttles that move between the subunits. As used herein the term "molecular" is used to indicate that the components which make us the devices are truly molecular-scale components. These molecular components are characterized by the fact they may be produced by chemical means, rather than by lithographic means.

[0005] One aspect of the invention provides a molecular shuttle device that includes two or more molecular subunits connected to form a molecular chain, the subunits defining binding positions along the molecular chain, and at least one shuttle capable of translating along the chain by means of sequentially breaking and forming bonds between the subunits and the shuttle. Thus, in one embodiment, the shuttle is a translatable ligand capable of translating along the chain by means of sequentially breaking and forming bonds between the subunits and the shuttle. As discussed in greater detail below, the breaking or formation of the bonds may be mediated by external input signals.

[0006] One aspect of the invention provides molecular devices and systems used to move shuttles along a molecular chain composed of connected molecular subunits which define binding positions for the shuttle along the chain. The shuttles move from one binding position to another in response to one or more input signals. The shuttles are capable of binding to any binding position along the chain and may move bi-directionally along the chain. That is, the shuttle may move forward or backward along the chain in response to an appropriate input signal or series of input signals.

[0044] By exposing a chain of subunits having a shuttle bound thereto to an appropriate series of input signal sequence, the shuttle may be induced to move from position to positions along the chain. Depending on the exact sequence of the input signals, this motion may be uni- or bi-directional. The shuttle may also change direction as it travels along a chain. This is illustrated in FIGS. 1 and 2 which show schematic diagrams of a shuttle stepping along the subunits of a molecular chain in response to a

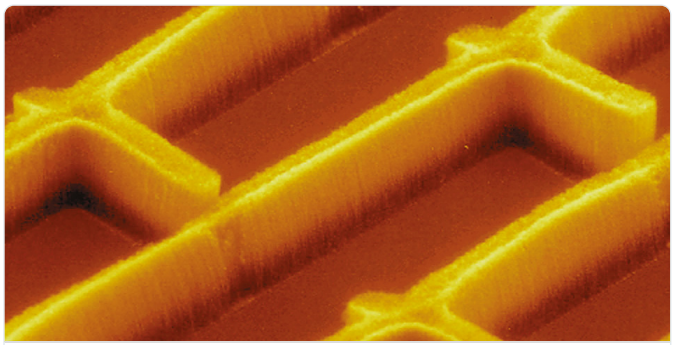
[0057] Remote electronic control over the hybridization behaviour of DNA molecules, by inductive coupling of a radio-frequency magnetic field to a metal nanocrystal covalently linked to DNA is described in Nature, Vol. 415, pp. 152-155 (2002), the entire disclosure of which is incorporated herein by reference.

stepping along the subunits of a molecular chain in response to a sequence of input signals.

[0045] FIG. 1 illustrates a general approach toward untethered molecular shuttle devices, such as switches and molecular assembly lines. In FIG. 1A, input frequencies (i.e., signals) selectively "turn on" attractive intermolecular forces between the shuttle and successive subunits along the chain. In the absence of an input, there is no binding affinity between the shuttle and any of the subunits. Therefore, applying a specific input frequency moves the shuttle to the nearest affected position. However, the utility of such a system is limited because it is not bi-stable, since the input must be present in order for the shuttle to remain bound. The system is also limited by diffusion of the shuttle into solution. For example, if the shuttle is at position **1**, it is biased toward position **2** by first breaking the non-covalent bonding between the shuttle and subunit **1**. The shuttle then diffuses into solution. Applying the input frequency v_2 (corresponding to the quantized energy value hv_2) increases the binding affinity between the shuttle and position **2**, and thus moves of the shuttle toward position **2**. Furthermore, diffusion in solution biases the shuttle toward position **2** over the more distant position **2'**, where the binding affinity is equal to that in position **2**.

[0046] As shown in FIG. 1A, the shuttle can then be moved from position **2** back to position **1** or moved forward to position **3** by applying input signals of frequency v_1 or v_3, respectively. The system is therefore bi-directional. Furthermore, the shuttle can be moved between any two positions along the chain by applying a series of input signals having the correct pulse/frequency sequence.

Multi-Wall Carbon Nanotubes
2000 A.D. (20 years ago)



Multiwall carbon nanotubes – Physics World
The unique mechanical and electronic properties of multiwall nanotubes are proving to be a rich source of new physics and could also lead to new applications in materials and devices

https://physicsworld.com/a/multiwall-carbon-nanotubes/

https://www.researchgate.net/publication/273352790_Performance_and_analysis_of_temperature_dependent_multi-walled_carbon_nanotubes_as_global_interconnects_at_different_technology_nodes

6 Conclusion

This paper shows the applicability of MWCNTs as an interconnect candidate in future design of integrated circuit even at moderate to high temperature range. A complete temperature dependent equivalent distributed circuit model of MWCNT bundle has been presented. The influence of temperature on MWCNT is examined. SPICE simulation is used to compare the performance of MWCNT interconnect in terms of delay, power and PDP for 32, 22 and 16 nm technology nodes at global interconnects (1 mm interconnects length). The results shows that the rise in temperature affects the performance of MWCNT interconnect. The results of MWCNT are also compared with copper interconnect and shows that MWCNT is not only the better candidate than copper as interconnect at moderate temperature but also gives the better performance at moderate to high temperature as future VLSI interconnects.

BRITANNICA

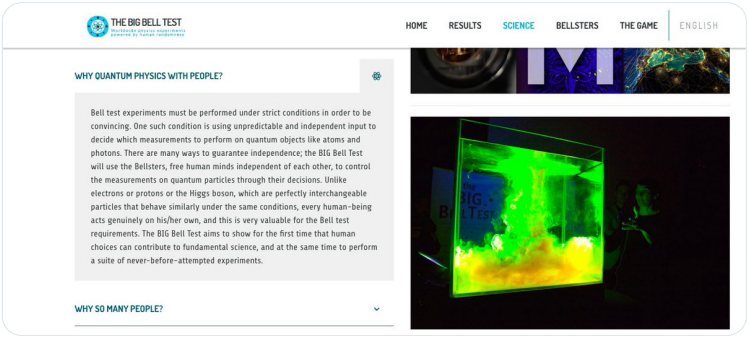
Phonon | physics

Phonon, in condensed-matter physics, a unit of vibrational energy that arises from oscillating atoms within a crystal. Any solid crystal, such as ordinary table salt (sodium chloride), consists of at…

https://www.britannica.com/science/phonon

https://www.calculateme.com/temperature/kelvin-to-fahrenheit/310

thebigbelltest.org



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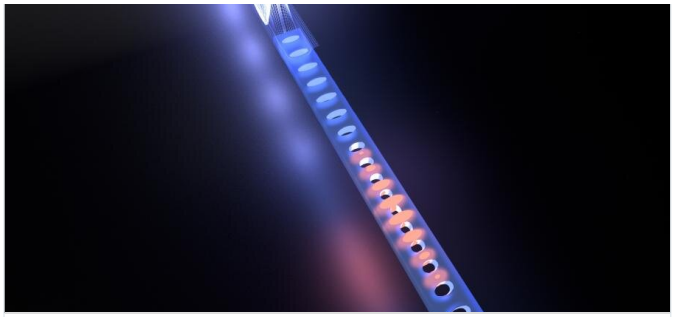

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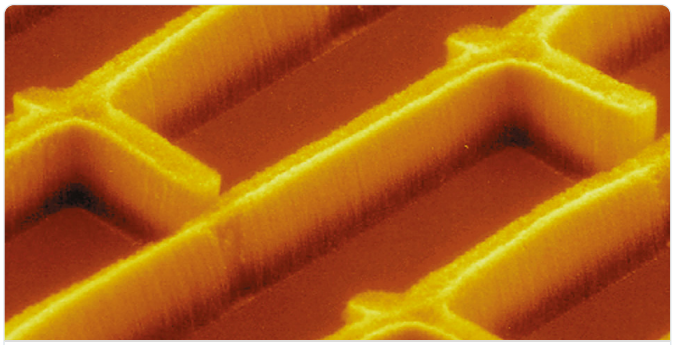
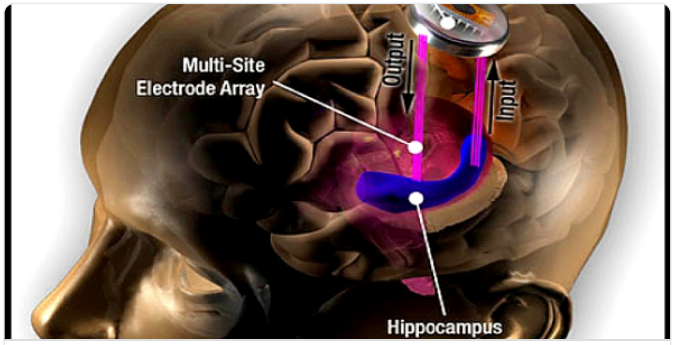
Nano Tech ---> Future of VLSI Connections (Room Temp)



Multiwall carbon nanotubes – Physics World
The unique mechanical and electronic properties of multiwall nanotubes are proving to be a rich source of new physics and could also lead to new applications in materials and devices

https://physicsworld.com/a/multiwall-carbon-nanotubes/

https://en.wikipedia.org/wiki/Very_Large_Scale_Integration
ADD:
A Field Programmable Neural Array
http://hasler.ece.gatech.edu/Published_papers/Neuron_papers/HMM_dendrite/FPNA_2006.pdf
Here is additional info for consideration
https://en.wikipedia.org/wiki/Neuromorphic_engineering
VLSI NEURAL INTERFACE



Neural codes for memory implants

(Medical Xpress)—The ability to short-circuit debilitating tremors in disease states with implantable stimulators is nothing short of remarkable. The same can be said for cochlear prosthetics which r…

https://medicalxpress.com/news/2013-04-neural-codes-memory-implants.html

Towards molecular computers that operate in a biological environment

http://bwn.ece.gatech.edu/nanos/papers/Towards_molecular_computers_that_operate_in_a_biological_environment.pdf

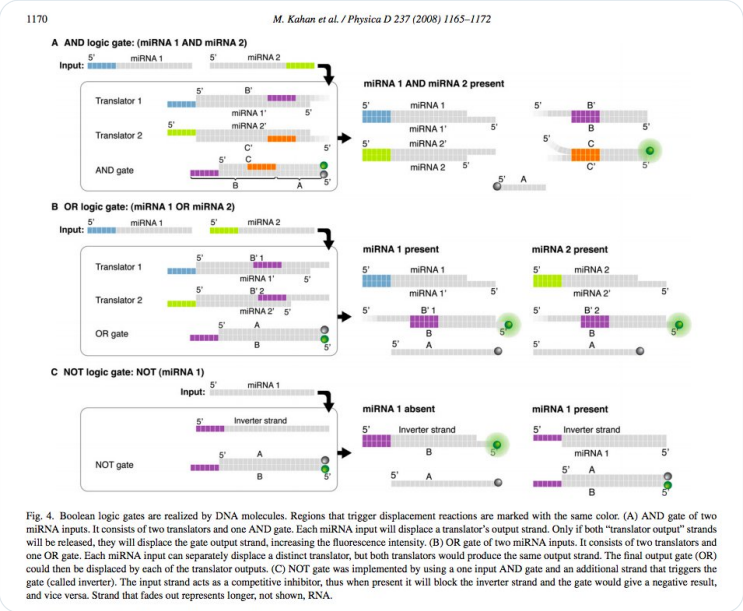


Fig. 4. Boolean logic gates are realized by DNA molecules. Regions that trigger displacement reactions are marked with the same color. (A) AND gate of two miRNA inputs. It consists of two translators and one AND gate. Each miRNA input will displace a translator's output strand. Only if both "translator output" strands will be released, they will displace the gate output strand, increasing the fluorescence intensity. (B) OR gate of two miRNA inputs. It consists of two translators and one OR gate. Each miRNA input can separately displace a distinct translator, but both translators would produce the same output strand. The final output gate (OR) could then be displaced by each of the translator outputs. (C) NOT gate was implemented by using a one input AND gate and an additional strand that triggers the gate (called inverter). The input strand acts as a competitive inhibitor, thus when present it will block the inverter strand and the gate would give a negative result, and vice versa. Strand that fades out represents longer, not shown, RNA.

Electromagnetic wireless nanosensor networks

http://bwn.ece.gatech.edu/surveys/wnsn10.pdf

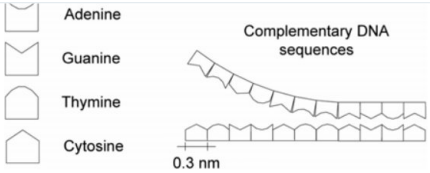


Fig. 8. DNA nucleotides and two complementary sequences being *glued*.

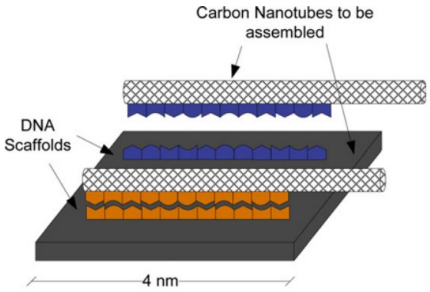
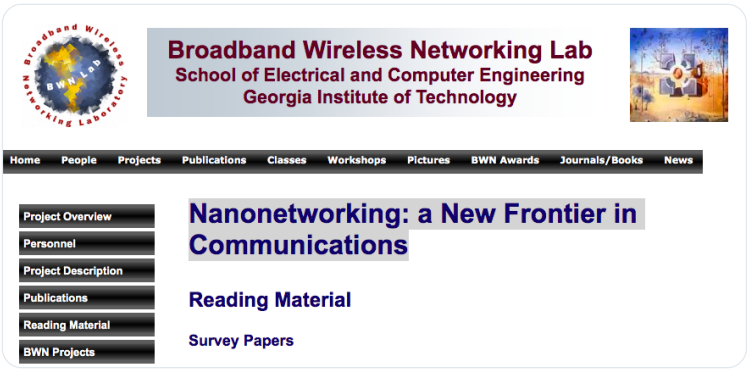


Fig. 9. Two carbon nanotubes precisely connected over a silicon substrate by means of DNA scaffolding.

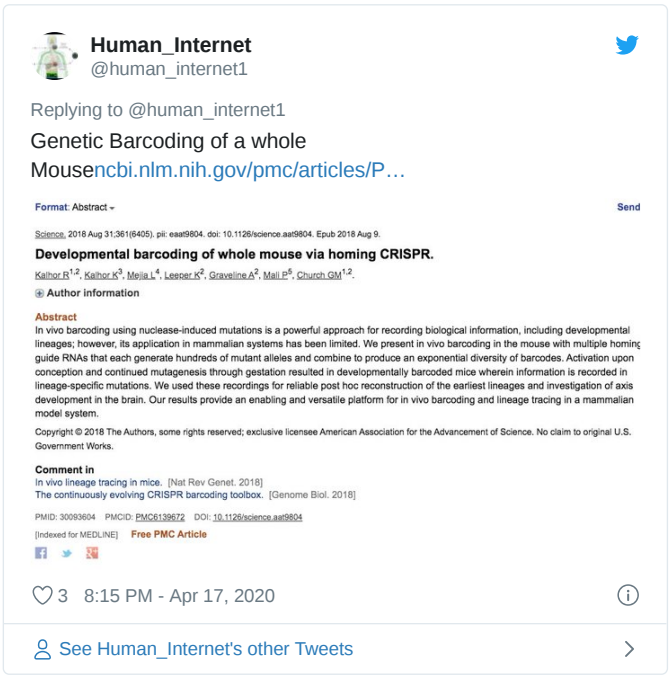
http://bwn.ece.gatech.edu/nanos/paperlist.html



#Quantum #Communications: From #Space to the #Nano

https://dl.acm.org/doi/10.1145/3345312.3345498

Future Internet Systems / Applications. #5G and beyond



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