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Medical device for sensing and or stimulating tissue

Abstract

Devices, methods and systems for transmitting signals through a device located in a blood vessel of an animal for stimulating and/or sensing activity of media proximal to the devices. The media can include tissue and/or fluid. A method of controlling an apparatus in communication with a brain machine interface. The method can include measuring a first neural activity in a first neural area and measuring a second neural activity in a second neural area. The first neural activity can be associated with a first intent. The method can include creating and delivering, via the processor, one or more first control signals to the apparatus upon comparing the second neural activity with the first neural activity, and confirming, based on this comparison, that the second neural activity is associated with the first intent.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 16/683,077 filed Nov. 13, 2019, which is a continuation of U.S. patent application Ser. No. 16/054,657 filed Aug. 3, 2018 (now U.S. Pat. No. 10,512,555 issued Dec. 24, 2019), which claims priority to U.S. Provisional Application No. 62/540,997 filed Aug. 3, 2017 and to U.S. Provisional Application No. 62/545,875 filed Aug. 15, 2017, each of which is incorporated herein by reference in its entirety for all purposes.

TECHNICAL FIELD OF THE INVENTION
(1) The present invention relates to a medical device for implantation into a blood vessel of an animal.
BACKGROUND OF THE INVENTION
(2) Any discussion of document, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Australia or elsewhere on or before the priority date of the disclosure and broad consistory statements herein.
(3) In the United States alone, nearly two million people suffer from various neuromuscular disorders where control of limbs is severely impaired. In many of these patients, however, the portion of the brain responsible for movement remains intact, and it is disease and trauma to the spinal cord, nerves and muscles that limit mobility, function and independence. For these people, the ability to restore lost control at even a rudimentary level could lead to a greatly improved quality of life.

(4) At present, there are two primary options for restoring function. One option is to increase the capabilities of the remaining pathways, substituting paralyzed or amputated muscles with those under voluntary control. While this method has been highly successful for amputees by re-innervating forearm nerves into abdominal muscles which control a bionic arm, the restored function greatly depends on the site of damage or condition, with people paralyzed by brainstem or high cervical injuries only able to achieve minor functional improvement. A second option is to provide the brain with a new communication and control channel to convey messages to the external world. Currently, these brain controlled interfaces (BCIs) measure electroencephalographic or other electrophysiological activity via surgically implanted epidural, subdural, and intracortical electrodes. While cortical measurements performed with electrodes placed on the scalp enable non-invasive neuronal measurements, they require daily application and are prone to noise and movement related artefacts. Penetrating and non-penetrating intracranial electrodes, implanted after a craniotomy directly onto the surface of a cortical area, have much better signal to noise ratios (relative to scalp electrodes) and have been shown to enable rudimentary prosthetic hand operation. These methods, however, require invasive surgery and carry a relatively high risk of complication, which can involve infections and bleeding. Furthermore, craniotomies are limited in access to the central nervous system, with many motor and sensory cortex areas hidden and inaccessible within cortical folds. These approaches are restricted in position and cannot be relocated once implanted and are subject to signal deterioration due to glial scar formation surrounding penetrating electrodes.

(5) Thus, there remains a need to record and stimulate from cortical tissue in a method which is minimally invasive whilst also ensuring longevity and efficacy of recorded and induced signals.

(6) By using blood vessels as a conduit to the brain, the risks associated with craniotomies, and the invasive creation of a burr hole in the skull of the patient is removed whilst also removing current noise and movement related artefacts observed with non-invasive scalp electrodes. Despite the minimally invasive benefits provided by these types of procedures, it is preferable that thrombus formation caused by the blockage of blood flow through a vessel is prevented. It is also preferable that the electrical energy delivered to the electrodes be as efficient as possible, which will reduce the burden placed on the electrical circuitry. Optimization of wireless telemetry aimed to send power and data directly through the body to the implanted device, will enhance device functionality and negate the risk of infection caused through lead wires creating a direct passage between the vessel and the external environment. The ability to implant coils inside blood vessels will similarly reduce surgical risks associated with perforated vasculature.

(7) Thus, there remains a need to provide improved intravascular electrodes, telemetry circuitry and implantation positions that are capable of more efficiently transmitting and receiving electrical energy between vessels and external circuitry, while minimizing the occlusion of blood flow.

(8) It is generally desirable to overcome or ameliorate one or more of the above mentioned difficulties, or at least provide a useful alternative.

SUMMARY OF THE INVENTION

(9) According to the present invention, there is provided a medical device for implantation into a blood vessel of an animal, including: (a) a stent movable between a collapsed condition of use for insertion into said vessel and an expanded condition of use for resiliently bearing against a wall of said vessel; (b) one or more electrodes coupled to the stent for stimulating and/or sensing activity of media proximal to the device, wherein the media includes tissue and/or fluid. The term stent is meant to include any support structure that maintains, carries, supports or incorporates the one or more electrodes within the tissue and/or fluid. The term stent can include conventionally designed medical stents, alternatively, the term stent can include any mechanical framework or scaffolding that positions electrode elements within a body lumen, such as a vessel, and facilitates electrical coupling of the electrode element(s) to a lead or other conductive structure. In certain variations, portions of the support structure itself can function as electrodes.

(10) According to the present invention, there is also provided a method of recording of neural information or stimulation of neurons from the superior sagittal sinus or branching cortical veins of a patient using the above described device, including the steps of: (a) implanting the device in either the superior sagittal sinus or branching cortical veins; (b) receiving activity; and (c) generating data representing said activity; and (d) transmitting said data to a control unit.

(11) According to the present invention, there is also provided a method of for stimulation and recording neural information or stimulation of neurons from the visual cortex of a patient using the above-described device, including the steps of: (a) implanting the device in a vessel in the visual cortex of the patient; and (b) recording neural information associated with the vessel or stimulating neurons in accordance with received stimulation data.

(12) According to the present invention, there is also provided a system for controlling use of apparatus coupled to an animal or human, including: (a) the above-described device, said device being adapted for placement within a vessel of an animal or human to stimulate and/or sense the activity of media proximal to the device; (b) a control unit adapted for communication with the device; (c) apparatus coupleable to the animal or human, said apparatus adapted for in communication with the control unit, wherein the control unit is adapted to perform the steps of: (i) receiving data from the device representing activity of media proximal to the device; (ii)generating control signals for the apparatus; and (iii) sending said control signals to said apparatus.

(13) According to the present invention, there is also provided a control unit for controlling operation of apparatus coupled to an animal or a human, said control unit being adapted to perform the steps of: (a) receiving data from the above-described device, said data representing activity of media proximal to a vessel within which the device is placed; (b) generating control signals for controlling operation of the apparatus; and (c) sending said control signals to the apparatus.

(14) The present disclosure further includes a medical device for use within a tubular body having a lumen, the medical device comprising: a frame structure forming a plurality of struts, where the frame structure is moveable between a reduce profile and an expanded profile in which a diameter of the frame structure increases; where at least one of the plurality of struts forming the frame structure comprises an electrically conductive material on a support material, the electrically conductive material extending along at least a portion of the strut and being covered with a non-conductive material; at least one electrode formed by an opening in the non-conductive material on the portion of the strut; and a lead located at an end of the frame structure and configured to be in electrical communication with the electrically conductive portion, the lead extending from the frame structure.

(15) The medical device can further include a connector block configured to electrically couple the medical device to an external device, where the lead extends from the frame structure to the connector block.

(16) In another variation, the present disclosure includes a method of recording of neural information or stimulation of neurons a patient the method comprising: receiving a signal representative of neural activity from a device positioned in a vessel of the patient; generating data representing said activity using the signal; and transmitting said data to a control unit; generating a control signal from the control unit; and transmitting the control signal to an apparatus coupled to the patient.

(17) The present disclosure also includes a system for controlling an apparatus coupled to an animal or human. In one example, the system comprises a device adapted for placement within a vessel of the animal or human to stimulate and/or sense the activity of media proximal to the device; a control unit adapted for communication with the device, wherein the control unit is adapted to: (i) receive data from the device representing activity of media proximal to the device; (ii) generate a control signal; and (iii) transmit the control signal to said apparatus.

(18) The system can include an apparatus selected from or more of the following: an exoskeleton; a prosthetic limb; a wheelchair; a computer; and/or an electrical or electro-mechanical device.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Variations of the present invention are hereafter described, by way of non-limiting example only, with reference to the accompanying drawing. Like reference numerals in the drawings indicate identical or functionally similar features/elements throughout. All dimensions shown in the drawings are exemplary.

(2) FIG. **1** is a diagrammatic illustration of a system for controlling use of apparatus coupled to an animal or a human.

(3) FIG. **2**A is a diagrammatic illustration showing parts of the system shown in FIG. **1**.

(4) FIG. **2**B is a diagrammatic illustration showing of an additional variation of the system comprising two or more stents.

(5) FIG. **3** a diagrammatic illustration showing parts of the system shown in FIG. **1**.

(6) FIG. **4** is a diagrammatic illustration of a control unit of the system shown in FIG. **1**.

(7) FIG. **5**A is a diagrammatic illustration of a medical device of the system shown in FIG. **1**.

(8) FIG. **5**B is a cross-section view through the line A-A of the device shown in FIG. **5***a*.

(9) FIG. **5**C is a schematic diagram of a wireless chip.

(10) FIG. **5**D is a diagrammatic illustration of a medical device of the system shown in FIG. **1**.

(11) FIG. **6** is a diagrammatic illustration of a medical device located in a vessel.

(12) FIGS. **7**A to **7**E are diagrammatic illustrations of medical device of the system shown in FIG. **1**.

(13) FIG. **8**A is a diagrammatic illustration showing electrode mounting platforms of a medical device of the system shown in FIG. **1**.

(14) FIG. **8**B is a diagrammatic illustration showing placements of a medical device of the system shown in FIG. **1**.

(15) FIG. **9** shows diagrammatic illustrations of different electrode configurations.

(16) FIG. **10** shows diagrammatic illustrations of different electrode configurations.

(17) FIG. **11** is a diagrammatic illustration of a medical device of the system shown in FIG. **1**.

(18) FIG. **12** shows diagrammatic illustrations of different electrode configurations.

(19) FIG. **13***a* is a diagrammatic illustration showing wire attachments to an electrode.

(20) FIG. **13***b* is a diagrammatic illustration showing electrode lead wires wrapped around a shaft and covered in insulation forming a wire bundle or cable.

(21) FIGS. **13**C and **13**D illustrate variations of leads coupled to a device and, which are configured for repositioning of the lead or device.

(22) FIGS. **14** to **20** are diagrammatic illustrations showing different embodiments of the stent.

(23) FIGS. **21***a* to **21***c* are diagrammatic illustrations showing deployment of different embodiments of the device.

(24) FIGS. **21***d* and **21***e* show additional information regarding a helical lead **114**.

(25) FIGS. **22** to **24** are diagrammatic illustrations of a control unit of the system shown in FIG. **1**.

(26) FIGS. **25** and **26** are diagrammatic illustrations showing different stages of deployment of the device.

(27) FIGS. **27** and **28** are diagrammatic illustrations of control units having ground electrodes attached thereto.

(28) FIG. **29** is a diagrammatic illustration showing multiple vessels with multiple devices.

(29) FIG. **30** is a diagrammatic illustration showing a single vessel with multiple devices.

(30) FIG. **31** is a diagrammatic illustration of a wireless electrode system.

(31) FIG. **32** is a diagrammatic illustration of the system being used to record neural information or stimulation of neurons from the superior sagittal sinus (SSS) or branching cortical veins of a patient using the device.

(32) FIG. **33** shows an image reconstruction of a human brain (eyes facing left) demonstrating superior sagittal sinus and branching cortical veins near the motor cortex (red) and sensory cortex (yellow).

(33) FIG. **34** is a diagrammatic illustration showing a method for stimulation and recording neural information or stimulation of neurons from the visual cortex of a patient using the device.

(34) FIG. **35** is a diagrammatic illustration showing vessels and muscles in a human arm;

(35) FIG. **36** is an illustration of a human hand showing possible implant location to enable neural stimulation or measurement.

(36) FIG. **37** is a photo of a C-shaped ground electrode.

(37) FIGS. **38**A-**38**D illustrate examples of stents or scaffoldings having a plurality of electrodes disposed about the stent body.

(38) FIGS. **39**A-**39**C illustrate an example of integrated or embedded electrodes.

(39) FIGS. **40**A-**40**B show an example of a stent structure fabricated with dimensional variation to impart specific characteristics to the stent.

(40) FIGS. **41**A-**41**E illustrate a variation of a connector.

(41) FIG. **42** illustrates a variation of a stent electrically coupled to a control panel and a connector.

(42) FIGS. **43**A-**43**G illustrate various views of a variation of a connection panel.

(43) FIGS. **44**A-**44**D illustrate a variation of an overlay.

(44) FIGS. **45**A and **45**B illustrate a variation of an overlay.

(45) FIGS. **46**A-**46**F illustrate variations of stents having various electrode configurations.

(46) FIGS. **47**A-**47**F illustrate variations of stents having various electrode configurations.

(47) FIGS. **48**A-**48**D illustrate a variation of a stent.

(48) FIGS. **49**A-**49**C illustrate a variation of a stent.

(49) FIGS. **50**A-**50**C illustrate a variation of a stent.

(50) FIGS. **51**A and **51**B illustrate a variation of a stent.

(51) FIGS. **52**A-**52**C illustrate a variation of a stent.

(52) FIGS. **53**A-**53**D illustrate a variation of a stent.

(53) FIGS. **54**A and **54**B illustrate a variation of a stent.

(54) FIGS. **55**A and **55**B illustrate a variation of a stent.

(55) FIGS. **56**A-**56**D illustrate variations of stents having various electrode configurations.

(56) FIG. **57** illustrates a variation of a stent lattice structure.

(57) FIGS. **58**A-**58**D illustrate a variation of a stent.

(58) FIGS. **59**A-**59**C illustrate a telemetry unit lead having a snake and rung configuration.

(59) FIGS. **60**A-**60**D illustrate a variation of a system having a stent in communication with an external apparatus.

(60) FIGS. **61**A-**61**B illustrate cross sectional views of stent designs with open cross sections as well as cross sections with a first portion of the stent having a first radius and a second portion of the stent having a second radius.

(61) FIGS. **62**A-**62**B illustrate an improved electrode design with filleted edges that gradually taper to the strut.

(62) FIG. **63** illustrates a variation of a stent device with a stent shaft that has grooves or pockets to assist in joining the shaft to a lead.

(63) FIG. **64** illustrates a planar view of a variation of a stent device where the electrodes are specifically designed to limit the number of tracks per strut.

(64) FIG. **65** illustrates a variation of an implantable telemetry unit coupled to a connector via an extension lead arranged in a serpentine fashion.

(65) FIG. **66** illustrates a variation of an algorithm for processing neural signals from two or more neural areas.

(66) FIG. **67** illustrates a variation of an algorithm for processing neural signals from two or more neural areas.

(67) FIG. **68** illustrates a variation of an adaptive control algorithm.

(68) FIGS. **69**A-**69**E illustrate schematic variations of stent devices delivering stimulation to a target location.

(69) FIGS. **70**A-**70**H illustrate schematic variations of stent devices implanted in the brain in various locations delivering various types of stimulation to various target locations.

(70) FIGS. **70**I(*a*)-**70**I(*g*) illustrate schematic variations of stent devices implanted in vessels delivering various types of stimulation to various target locations.

(71) FIGS. **71**A and **71**B illustrate variations of stimulation heat maps.

DETAILED DESCRIPTION

(72) The system **10** shown in FIGS. **1** to **4** includes: 1) a medical device **100** designed for placement within a vessel **103** of an animal or human **110** to stimulate and/or sense the activity of media (tissue and fluids) proximal (adjacent or touching) to the device **100**, whether this be located inside or outside the vessel **103**; 2) a control unit **12** (also referred to as a connector block and telemetry system) adapted for communication with the device; 3) a communication conduit **14** for facilitating communications between the device **100** and the control unit **12**; and 4) apparatus **16** coupleable to the animal or human **110**, the apparatus **16** adapted for communication with the control unit.

(73) The control unit **12** can be adapted to perform the steps of: (a) receiving data from the device **100** representing activity of media proximal to the device **100**; (b) generating control signals for the apparatus **16**; and (c) sending the control signals to the apparatus **16**. In some variations, the system includes connector block (illustrated by element **12**) that functions as connector and acts as an extension of the communication conduit. In variations of the system, the control unit/connector block: is hermetically sealed and insulates the leads from the device to the control unit; can be inserted using zero-contact force attachments or attachments that do not require excessive force to insert (i.e., using balseal spring contacts); has a portion of the lead that is made from a stiffer silicone or similar material for handling and insertion into the connector. Variations of the device can include markers to identify portions of the leads that are stiffer (and can be handled) to distinguish from leads that cannot be handled. Such markers can include line-style markers, different colours or other indicators to clearly identify the regions. Variations of the connector block can have a fitting (e.g., clasp) such that multiple connectors can be inserted (i.e., two contact connectors (with 8 contacts each) for a 16 electrode Stentrode lead). The fitting can ensure securing of the contacts, alignment and prevention of water ingress

(74) When the medical device **100** is inserted adjacent to the motor cortex in the manner shown in FIGS. **2**A, **2**B, and **3**, the system **10** can be used, for example, to control operation of an exoskeleton, and/or an artificial limb in the manner shown in FIG. **1**.

(75) This device **100** is implanted into blood vessels **103**, from which, it will utilise electrodes mounted on a self-expanding member **101** to record or stimulate neighbouring tissue. Information is to be passed from or to the electrodes through the communication conduit **14**, inside of the blood vessel **103**, to a telemetry system **12** that, in turn, passes information (using wires or wirelessly) to or from an external apparatus **16**, which includes (but is not limited to) one or more of the following:

(76) (a) an exoskeleton; (b) wheelchair; (c) computer; and/or (d) other electrical or electro-mechanical device.

(77) As such, in one specific application, the implanted medical device **100** has the capability to enable a paralysed patient **110** to use their thoughts directly to command and control a gait aid such as an exoskeleton or robotic legs **16**.

(78) Other applications for the implantable medical device **100** include (but are not limited to): (a) detection and prevention of seizures; (b) detection and prevention of involuntary muscular or neural control (for example to alleviate symptoms associated with: (i) multiple sclerosis; (ii) muscular dystrophy; (iii) cerebral palsy; (iv) paralysis and (v) Parkinsons'; (c) detection and

therapeutic alleviation of neurological conditions, such as: (i) post-traumatic stress disorder; (ii) obsessive compulsive disorder; (iii) depression; and (iv) obesity; (d) direct brain control of computers and equipment, such as: (i) vehicles; (ii) wheelchairs; (iii) gait aids; robotic limbs; (e) direct input for sensory stimulation for: (i) blindness (connection to a camera); (ii) deafness (connection to microphone); (iiii) proprioception (connection to touch-sensitive robotic and computer systems); (f) internal assessment of personal health and wellbeing: (i) heart rate; (ii) respiration rate; (iii) temperature; (iv) environmental conditions; (v) blood sugar levels; and (vi) other biochemical and neurological markers; (g) internal communication (telepathy) between implanted groups of people utilising the device for information transmission, auditory, visual and proprioceptive feedback (for example, real time communication of what the implantee sees or hears); and (h) augmentation and optimisation of musculskeletal control and dexterity (for performance enhancement or rehabilitation).

(79) FIG. **2**B illustrates a two-stent **101** system. For purposes of illustration, the stents are positioned in a single vessel. However, the stents can be configured such that they can be positioned in separate vessels. The stents **101** can be joined by non-conductive material to form a power receiver and transmitting antenna. Alternatively, the stents can be coupled by one or more wires or conductive elements. Moreover, the system can include active electronics between the stents **101**.

(80) The devices described herein can be positioned in any number of areas of brain structures depending upon the desired outcome. For example, as discussed in Teplitzky, Benjamin A., et al. "Computational modeling of an endovascular approach to deep brain stimulation." *Journal of Neural Engineering* 11.2 (2014): 026011.stents can be positioned as follows: Internal capsule for depression and obsessive compulsive disorder (OCD); thalamus for epilepsy (E), Parkinsons' Disease, essential tremor, Tourette syndrome, consciousness disorder, chronic pain, obsessive compulsive behavior; fornix for Alzheimer's disease; globus pallidus internus for dystonia, depression, Tourette syndrome; hippocampus for epilepsy; hypothalamus for obesity, anorexia mentosa; inferior thalamic pduncle for depression and obsessive compulsive disorder; lateral habenula for depression, obesity, anorexia mentosa; nucleus accumbens for depression, obsessive compulsive disorder, addiction, obesity, anorexia mentosa; periaqueductal/periventricular for chronic pain; subgenal cingulate white matter for depression; subthalamic nucleus for Parkinson's Disease, dystonia, depression, obsessive compulsive disorder, epilepsy; and ventral capsule for obsessive compulsive disorder.

(81) 1. Medical Device

(82) As shown in FIGS. **5**a, **5**b, **5**d and **6**, the medical device **100** generally includes: a. a collapsible and expandable stent **101**; b. a plurality of electrodes **131** coupled to the stent **101**; c. electrode lead wires **141** electrically coupled to electrodes **131**; d. an olive **112** coupled to the stent **101** by an olive wire **114** for preventing perforation of vessels during implantation; e. implanted chips; f. contacts **151** couple to the lead wires **141** to enable communication between the device **100** to the control unit **12**; and g. a stent shaft **121** is used to deploy the device **100**.

(83) Electrode lead wires **141** can be electrically connected to at least one electrode and will be wound around the stent strut lattice **108** such that mechanical compression and extension is not interfered with. Electrode wires **141** may be wound around the stent shaft **121**, thread through a stylet shaft or may form part of the stent shaft directly. Lead wires **141** will form connections with electrode contacts **151** on the opposite end of the stent shaft to the stent, whereby electrical contact a connector block mechanism **12** enables the connection path with external equipment **16**, which included but is not limited to computers, wheelchairs, exoskeletons, robotic prosthesis, cameras, vehicles and other electrical stimulation, diagnostic and measurement hardware and software.

(84) The term electrode **131** is used in this specification to refer to any electrical conductor used to make contact with media in and/or around a blood vessel **103**.

(85) A detailed description of the operation of each of these components is set out below.

(86) The Stent

(87) The stent **101** includes a plurality of struts **108** coupled together with strut crosslinks **109**.

(88) In the arrangement shown in FIG. **7***a*, the device **100** includes nine electrodes coupled to the stent **101** in a linear pattern. As shown, the stent **101** appears flat. The top of the stent **101** may be directly joined to the bottom of the stent **101** or will curve around to meet (without permanent attachment) the bottom of the stent **101**.

(89) Alternatively, the device **100** includes a stent with any suitable number of electrodes **131** arranged in any suitable configuration. For example, the electrodes can be configured as follows: the sinusoidal arrangement of electrodes **131** shown in FIG. **7***b*; the spiral arrangement of electrodes **131** shown in FIG. **7***c* to enable 360 degree contact of an electrode to the vessel wall once deployed; the reduced amplitude sinusoidal arrangement of electrodes **131** shown in FIG. **7***d* for increased coverage whilst still ensuring only one stent is at each vertical segment; and the dense arrangement of electrodes shown in FIG. **7***e* for increased coverage. The stent **101** is laser cut or woven in a manner such that there is additional material or markers where the electrodes **131** are to be placed to assist with attachment of electrodes and uniformity of electrode locations. For example, if a stent **101** was fabricated by laser cutting material away from a cylindrical tube (original form of stent), and, for example, electrodes are to be located at 5 mm intervals on the one axis, then electrode mounting platforms **107**, **108** can be created by not cutting these areas from the tube. Similarly, if the stent is made by wire wrapping, then additional material **107**, **108** can be welded or attached to the stent wires providing a platform on which to attach the electrodes. Alternatively, stents can be manufactured using thin-film technology, whereby material (Nitinol and or platinum and or other materials or combinations of) is deposited in specific locations to grow or build a stent structure and/or electrode array

(90) Electrodes

(91) As particularly shown in FIG. **8***a*, the device **100** includes electrode placements **107** coupled to strut crosslinks **109**. The placements **107** are used to coupled the electrodes **131** to the stent. An alternative embodiment of the placements **106** is shown in FIG. **8***b*. In this embodiment, the placements are circular.

(92) As shown, the electrodes **131** are located on or at the stent crosslinks **109**. Locating the electrodes in these positions allows for changes in shape of the stent **101** (i.e expanding and collapsing) without significantly affecting the integrity of the electrodes. Alternatively, may also be located in between the stent strut crosslinks (not depicted).

(93) FIG. **9** depicts different electrode geometries which include but are not limited to: flat discs **161**; cylinders or rings **162**; half-cylinders or rings **163**; spheres, domes or hemispheres **164**; hyperbolic parabaloids **165**; and double electrodes or electrodes whereby they are longer along one axis **166**.

(94) As shown in FIG. **10**, the electrodes **131** can include shape memory material and hence the electrodes **131** may be uninsulated sections of the device **100**. As shown, the electrode **131** inside a patient and the vessel **104** is unobstructed. After activation of shape memory, the electrode **131** conforms to better fit the vessel wall **103**.

(95) To enhance contact and functionality of the device **100**, electrodes **131** include the attachment of additional material (shape memory alloy or other conducting material) through soldering, welding, chemical deposition and other attachment methods to the stent **101** including but not limited to: directly on or between the stent struts **108**; to lead wires **14** passing from the electrodes **131** to wireless telemetry links or circuitry; and directly to an olive **112** placed on the distal aspect of the device **100** to or stent shafts.

(96) To further enhance the device **100** performance, there may be one or more electrodes **131** per wire strand **141** and there may be one or more strands **141** utilised per device **100**. These strands **141** may be grouped to form a bundle **144**, which may be woven in alternate sinusoidal paths around the stent struts **108** in the manner shown in FIG. **11**. Similarly, there may be one or more

wires **141** designated to each electrode **131** and hence there may be one or more electrodes **131** per device **100**. Thus, multiple electrodes **131** may be used simultaneously.

(97) To optimise the ability of the electrodes **131** to stimulate or record from medium (including but not limited to neural tissue, vascular tissue, blood, bone, muscle, cerebrospinal fluid), the electrodes **131** may be positioned at pre-determined intervals based on the diameter of the target vessel **103** to allow each of the electrodes **131** to be in contact with the vessel **103** in the same orientation (ie, all electrodes facing to and in contact with the left vessel wall upon deposition). Electrodes **131** may be mounted such that recordings or stimulation can be directed to all 360 degrees of the vessel simultaneously. Similarly, to enhance the recording and stimulation parameters of the electrodes **131**, the electrode sizes may be varied, with larger electrodes **131** used to assess greater areas of neighbouring medium with smaller electrodes **131** utilised for localisation specificity.

(98) Alternatively, the electrodes **131** are made from electrically conductive material and attached to one or more stents, which form the device **100** and allow for multiple positions. In this embodiment, the electrodes **131** are made from common electrically active materials such as platinum, platinum-iridium, nickel-cobalt alloys, or gold, and may be attached by soldering, welding, chemical deposition and other attachment methods to one or more lead wires **141**, which may be directly attached to the shape memory shaft(s). The electrodes **131** can be one or more exposed sections on the insulated lead wire **141** and the electrode lead wires may be wrapped around one or more shape memory backbones. There may be one or more electrodes and lead wires wrapped around a single shape memory backbone, and, where multiple shape memory backbones are used in the one device, the backbones may have different initial insertion and secondary deposition positions. Thus, they may be used for targeting multiple vessels simultaneously.

(99) As shown in FIG. **12**, the electrodes **131** can be designed such that they are carriers of substances **134** and solutions such as therapeutic drugs, including but not limited to anti-thrombogenic, and materials. In this embodiment, the electrodes **131** are designed to release the drugs, either passively through diffusion or through control by an implanted electrical clock or manually through electrical stimulation of the electrodes **131**. In this embodiment, the electrodes **131** are made from materials that have portions of the electrodes **131** that are not electrically conductive.

(100) The drug **134** can be released into the vessel **104** upon timed, natural, electrical or otherwise activation, or into the vessel wall **103**.

(101) In variations of the device, an insulation layer between the nitinol substrate and the electrodes (e.g., platinum, silicone oxide) comprises a silicone carbide or other insulation material. Alternatively, a layer of silicone carbide can be provided to prevent the degradation and erosion of the silicone oxide layer.

(102) Electrode Wires

(103) The electrode wires **141** are electrically coupled to respective electrodes in the manner shown in FIG. **13***a*. As shown, the electrical attachment **135** and the back face of the electrode is covered in a non-conductive substance **136**.

(104) The lead wires **141** can be wrapped around the stent **101** and along a shaft **121**.

(105) As shown in FIGS. **5***a*, **5***b* and **13***b*, the electrode lead wires **141** are wrapped around the shaft **121** and covered in insulation **122** forming a wire bundle or cable. A sleeve **153** wraps around the wire bundle at the location of the contact **151**, whereby at least one wire **141** is wrapped around the sleeve **153** and connected to the contact **151** at a connection weld point **152**. The over-molding **154** ensures a uniform diameter is present between contacts.

(106) The sleeve **153** covers the wire bundle **142** with an exposed section of wire **141** attached **152** to a contact **151**.

(107) Distal electrodes and/or markers and/or buffers are also depicted **112** attached via a wire **114** to the stent **101**. The shaft **121** is attached at the end of the stent at the attachment/detachment zone

115 and is shown passing through the sleeve **142** and electrode contacts **151** to exit behind past the connector securement point **155**.

(108) The lead wires **141** shown to be inside the sleeve **142** where they are wrapped around the shaft **121** where they make electrical contact at a contact weld **152** to the electrode contacts **151**. An overcoat **154** is shown to ensure uniform diameter of the device between the contacts. The shaft **121** may be detached at the detachment zone **115** and removed following deployment in a vessel.

(109) As shown in FIG. **13***b*, lead wires **141** are connected to electrode contacts **151**. Electrode lead wires **141** are initially wrapped around a shaft **121** covered in insulation **122** forming a wire bundle or cable. A sleeve **153** is placed around the wire bundle at the location of the contact, whereby at least one wire **141** is wrapped around the sleeve and connected to the contact **151** at a connection weld point **152**. Over-molding **154** may be used to ensure a uniform diameter is present between contacts.

(110) As particularly shown in FIG. **5***b*, the stent shaft **121** is coated in an insulative layer **122**, has a plurality of wires **141** that are insulated **143** and grouped in an insulated bundle **142** wrapped around it. A sleeve **153** covers the wire bundle **142** with an exposed section of wire **141** attached **152** to a contact **141**.

(111) The wires **141** are made from electrically conductive materials including but not limited to Platinum, Platinum/Tungsten, Stainless Steel, Nitinol, Platinum/Iridium, Nickel-Cobalt Alloys, or other conductive and biocompatible materials.

(112) The wires **141** are between 10 um and 100 um thick (diameter), stranded cable or monofilament, and connect the electrodes **131** to the contacts **151**. Alternatively, the wires **141** connect the electrode **131** to wireless circuitry retained on the stent or shaft.

(113) The wires **141** are insulated with non-conductive material (ie, Teflon or polyimide). The wires **141** are wrapped around the stent struts in a sinusoidal pattern as shown in FIG. **11**. Alternatively, the wires **141** are wrapped in a helical tube or wire bundle or cable, with the wire or bundle between 300 um and 2 mm in diameter (thickness)

(114) The wires **141** are connected to contacts **151** using wire wrapping, conductive epoxy, welding, or other electrically conductive adhesion or connection means.

(115) FIG. **13**C illustrates a variation of a lead **114** coupled to a device **100**. In some circumstances, there may be a need retract the device for repositioning of the device after a sub optimal placement. FIG. **13**C illustrates one variation of a lead **114** having a threaded screw terminal **202** that connects the existing lead to an extension lead **206**. The lead include a female threaded portion **202**, which mates with a male portion **204** on the extension lead. Placement of the threaded portion on the interior of the lead reduces the risk that the male portion damages the spring contacts that the device **100** lead fits into after the extension lead has been removed.

(116) FIG. **13**D illustrates an alternative to the screw terminal design shown in FIG. **13**C. In this variation, the lead **114** includes a locking mechanism **208**. A variation of the locking mechanism can be based on pressure, where pressure on a selected portion of the lead would enable a latch **208** to open or close. Benefits of this would be to reduce the likelihood of any twisting of the device during delivery to detach the prematurely. In this variation, the latch **210** on the extension **206** locks into the lead **114**. When an area on the extension is pushed (red arrows) the latch **210** releases from the lead **114** and can be either pushed into the lead (to attach) or be pulled from the lead (to release). Multiple latches would be placed around the circumference of the extension **114** lead, although one is shown here for purposes of illustration.

(117) Olive

(118) In the embodiment shown in FIG. **5***a*, the device **100** includes an olive **112** mounted at the distal tip to reduce risk of perforation and to improve device **100** safety during the implantation and deposition phase. In this arrangement, the olive **112** is directly connected to the front of the device **100** and act as a buffer, which is the first aspect of the device that comes in contact with the deployment catheter or the vessel during deployment. The olive **112** can additionally be used as a

radiopaque distal marker. The olive **112** can be configured and attached to the stent **101** in many different forms including, but not limited to, the following:

(119) i. Flexible Cord

(120) As shown in FIG. **5***a*, the olive **112** is placed at a distance from the front of the stent **101**, connecting with the stent **101** via a flexible cord **114**.

(121) ii. Spring Olive

(122) FIG. **14** depicts an olive placed on the distal end of a stent **101** whereby the olive is comprised of a buffer which may or may not be electrically active and function as an electrode **112** connected to the stent **101** by a flexible spring or helically wound wire **111**.

(123) iii. Multiple Olives

(124) FIG. **15** depicts a plurality of olives placed on the distal end of a stent **101** whereby the olive is comprised of a plurality of buffers which may or may not be electrically active and function as an electrode **113**.

(125) iv. Short Olive

(126) FIG. **16** depicts an olive placed on the distal end of a stent **101** whereby the olive is connected directly to the end of the stent which may or may not be electrically active and function as an electrode **112**.

(127) v. Shaped Wire Olive

(128) FIG. **17** depicts an olive placed on the distal end of a stent **101** whereby the olive is a flexible wire which may or may not be electrically active and function as an electrode and may or may not be shaped as a shepherds crook **114**.

(129) vi. Wire Olive

(130) FIG. **18** depicts an olive placed on the distal end of a stent **101** whereby the olive is comprised of a buffer which may or may not be electrically active and function as an electrode **112** connected to the stent **101** by a flexible wire **114**.

(131) vii. Olive with Detachment Zone

(132) FIG. **19** depicts an olive placed on the distal end of a stent **101** whereby the olive is comprised of a buffer which may or may not be electrically active and function as an electrode **112** connected to the stent **101** by a flexible wire **114**. This figure further depicts a shaft **121** that is connected to the stent **101** via an attachment and/or detachment zone **115**.

(133) FIG. **20** further depicts the shaft **121** that is detached from the stent **101** via the attachment and/or detachment zone **115**.

(134) The flexible wire **114** includes but is not limited to electrically conductive and electrically insulating wires, springs, helical leads and tubes which may have a buffer at the front. Alternatively, the buffer is electrically conductive and acts as an electrode, comprising all the features of stent-mounted electrodes.

(135) Implanted Chips

(136) Implanted electrical circuitry (chips) can be used to control the stimulation and measurement of the electrodes **131**. The chip can be implanted in place of an electrode (or elsewhere mounted on the stent), where the chip has the capacity to transmit the signals. The chip includes circuitry for: (a) signal amplification; (b) signal multiplexing; and (c) transmission of power and data.

(137) The electrodes **131** are attached to one or more electrical chips (whereby the chip is defined as the electrical circuitry as well as the substrate which the chip is built on). Miniaturised chips are mounted on the stent **101** in a similar manner and position to the electrodes **131**.

(138) Alternatively, these chips may be attached at a distance from the neural recording or stimulation site such as the neck or pectoral region, or the chip may connect directly to external hardware, such as current sources, recording equipment or prostheses.

(139) The chips can include circuitry for stimulation of neural tissue (current and/or voltage sources, batteries and/or capacitors or charge/energy storing components and switch matrices, etc) and circuitry for the recording of neural activity (amplifiers, power sources, switch matrices, etc)

and blood composition (such as pH meters, salts and saline composition, glucose etc).

(140) Further, chips may have circuitry required for the transmission of power and data through telemetry coils and self-monitoring hardware such as thermal sensors.

(141) The depiction of the wireless chip **195** shown in FIG. **5***c*, whereby the microprocessor **191** is shown as well as other components **193** (eg, capacitors, multiplexors, clocks, wireless transmitters, receivers etc). This depiction has two coils that can be used for transmission and receiving of both power and data, shown as a large coil **192** and a small coil **194**.

(142) The chip itself may contain a telemetry coil for the transmitting and receiving power and data and may contain a magnet to enable alignment with adjacent chips and telemetry coils or may be attached to shape memory alloys or other materials in which the telemetry coils are comprised.

(143) The chip can be flexible, and may be pre-curved to the diameter of the vessel to allow for the deposition of the chip within a vessel. Thus, the chip may contain shape memory alloys or polymers to conform the chip to the curvature of the vessel during the deposition phase. The chip may also be mounted on a bioabsorbable or biodegradable substrate to allow for integration within a vessel. Multiple chips may be used simultaneously.

(144) f. Contacts

(145) As particularly shown in FIGS. **5***a* and **5***b*, electrode contacts **151** are required to enable connection of the device **100** to external equipment in the situation where wireless circuitry is not employed. The electrode contacts **151** can be made from materials similar to those used by the electrodes and will be of similar diameters. The contacts **151** are electrically insulated from each other and will be connected to the electrode lead wires **141** by (but not limited to) conductive epoxy, laser or resistance welding, soldering, crimping and/or wire wrapping.

(146) The contacts **151** are platinum rings or rings of other conductive, biocompatible materials. The contacts can be made from or contain magnetic materials (ie, Neodinium).

(147) The contacts **151** can be: (a) between 500 um and 2 mm in diameter; (b) between 500 um and 5 mm in length; and (c) between 10 um and 100 um in thickness.

(148) The contacts **151** are shaped as discs, tubes, parabaloids or other shapes similar to those used for the electrodes **131**.

(149) The contacts are placed over non-conducting sleeve (including but not limited to a silicone tube, heat shrink, polymer coating) to assist with electrical insulation of other lead wires and electrode and stent wire, and to assist in retaining shape tubular shape whilst allowing some flexibility.

(150) The contacts **151** can have a contact to contact separation of between 100 um and 10 mm, for example, between 1.0 mm and 3.0 mm (e.g., 2 mm or 2.46 mm). Other contact separation dimensions, more or less, as well as other ranges, narrower or wider, are also appreciated.

(151) The contacts **151** are formed through wire wrapping of the wires **141**.

(152) At least one contact **151** can be a dummy connector (including but not limited to a metal ring, magnetic ring, plastic tube). A dummy connector in this instance is a connector that is not in electrical contact with an electrode, instead, the purpose is to enable a connection or securing point (ie, through a screw terminal) to the device in a desired location and such that the contacts (connected to electrodes) are not damaged.

(153) The contacts **151** are separated by a non-conductive sleeve (including but not limited to a silicone tube, heat shrink, polymer coating) to reduce electrical noise and prevent contact between superficial lead wires **141**.

(154) g. Shaft

(155) As shown in FIG. **21***a*, to enable deployment, a flexible shaft **121** is connected to the device **100**. In the example shown in FIG. **21***a*, the shaft **121** is connected at the distal end of the device **100** such that it acts to pull the device **100** from the front.

(156) In the alternate embodiment shown in FIG. **21***b*, the shaft **121** is attached to the proximal end of the device **100** such that the shaft **121** pushes the device **100** from the back of the stent **101**. In

this embodiment, medical device **100** includes a plurality of electrodes **131** mounted to a stent **101** with electrode lead wires **141** wrapped around the stent **101** and the shaft **121** and covered in a sleeve **142**. Distal electrodes and/or markers and/or buffers are also depicted **113** as is the stent detachment zone **105**.

(157) The further embodiment shown in FIG. **21**_c_ includes a double tapered stent **101** with mounted electrodes **131** and a stent shaft **121** attached to the stent **101** at the stent attachment/detachment zone **105**. Another attachment/detachment zone **115** at the front of the stent **101** connects the stent **101** to the olive wire **114** and a stylet sleeve **124**, through which, a removable stylet **123** is placed. Electrode wires **141** are shown as wrapped around the outside of the stylet sleeve **123** or as being fed through the centre.

(158) There may be a plurality of wires, with both pushing and pulling abilities. The stent shafts **121** may be implanted permanently or may be designed to be detached and removed. In this embodiment, the attachment/detachment zone will be located at the junction of the stent shaft **121** and the stent **101**. Detachment methods include, but are not limited to, electrochemical detachment, mechanical detachment and thermo-electrical detachment.

(159) The stent shaft **121** can be used as a backbone for electrode lead wires **141**, assisting the stability of the electrode lead wires **141** as they traverse from the electrodes **131** to the electrode contacts. In this embodiment, the electrode wires **141** are in a polymer **142**, (including but not limited to shrink wrap, heat shrink, parylene, silicone, Teflon, etc) to provide additional mechanical support, assist in water retention and to enable coatings to be deposited onto the stent shaft where wires are present.

(160) The stent shaft **121** may be a stylet that is removed following implantation and deposition of the device **100**. In this embodiment, the stent shaft **121** may be a cylindrical tube such that the stylet **123** can be fed through the centre of the tube **121**.

(161) The wires **141** can be thread through the middle of a stylet sleeve.

(162) The wires **141** can be wrapped around the stent shaft or stylet sleeve.

(163) In a further embodiment, the electrode wires **141** that connect the electrodes **131** to the contacts **152** are wrapped in a wire bundle **144** and wrapped around an internal lumen tubing **145** in a helical form such that there is an internal lumen **147** whereby a removable stylet **148** can be thread during insertion and removed following deployment. This embodiment enabled removability of the stylet **148** and flexibility of the wire bundle **144** that is over coated in an external tubing **146**.

(164) FIGS. **21**_d_ and **21**_e_ show additional information regarding a helical lead **114**. As depicted, the helical **114** lead includes wire bundle **144** wrapped around an internal lumen tube **145**. Through the internal lumen **147**, a removable stylet **148** can be thread during delivery and removed following device placement

(165) Control Unit

(166) The control unit **12** shown in FIG. **2** is a wireless controller, relaying information and power through the skin wirelessly.

(167) The connector block **12** in FIGS. **22**, **23**, and **24** are passive devices (ie, no circuitry). Essentially, it functions as an intermediate connection between the device **100** and external equipment. The device **100** is inserted into the connector block **12** whereby the device **100** contacts make electrical contact with internal contacts contained within the connector block **12**. These internal contacts of the connector block **12** then form a thicker wire bundle which passes through the skin (the rest of the connector block is implanted) and can be connected to external equipment.

(168) Essentially, as we are limited in space (the entire device must pass through a catheter as the catheter needs to be removed over the device after implantation) the connector block enables attachment of larger items to the thin device **100**.

(169) The embodiments shown in FIGS. **22**, **23** and **24** are the same, although only FIG. **24** shows the wire that goes through the skin.

(170) The control unit **12** shown in FIG. **22** is shaped to receive and make electrical connection

with the lead **14**. The control unit include contacts rings mounted on the inside. Here, the connector block **12** is secured and ensured water-tight through attachment of silicone and/or sutures at the grooved end.

(171) The wireless system that is implanted on the stent directly is essentially the same (although a miniaturised version) of the wireless system **12** in FIG. **2**.

(172) As shown in FIG. **23**, the electrode lead **14** is inserted and a silicone gasket is used to make a watertight seal following

(173) FIG. **24** depicts a connector block whereby the electrode lead **14** is thread through the connection opening **172** whereby the contacts connect with the electrically conductive connectors **175** inside the connector block body **173**. Separation and electrical insulation and water-tightness is increased through silicone (or otherwise) separators **174**. Contacts **175** are welded (or otherwise) to connector block wires **179** that may form a silicone or otherwise **181** encased bundle **181** to terminate at a wireless or direct electrical connection port **183**.

(174) Method of Using the System

(175) The device **100** is movable between an insertion position shown in FIG. **25** and the deposition or scaffolding position shown in FIG. **26**.

(176) In the insertion position, the device **100** is contracted and thus thin enough to be threaded through the vasculature pathway from within a catheter from an entry point (ie, the jugular vein) to a deposition point (eg, the motor cortex).

(177) When arranged in the deposition or scaffolding position, the device **100** is in an expanded condition where scaffold electrodes mounted on the outside of the stent **101** as pressed against the vessel wall. This expanded position anchors the device **100** in its location within the vessel **103**. Further, this deposition position is designed such that it has a minimal effect on blood flow integrity through the vessel **103** in which the device **100** is deposited. The scaffolding position may be synonymous to a spring, coil or helical strand, whereby the device **100** is in contact with the vessel wall only, reducing the effect on blood flow. Electrodes **131** may also be mounted on the inside of the stent **101** such that information from fluid flowing through the expanded stent **101** can be measured. For a stent **101** to be removed or relocated, additional shafts (other than that used for initial deployment) are required. These are explained in the context of this invention, with both single tapered and double tapered designs used.

(178) To enable the device **100** to be arranged in multiple positions, the material used is such that multiple states are possible. These materials include, but are not limited to, Nitinol and other shape memory alloys and polymers. Further, to enhance the long term biocompatibility of the device **100**, the polymers may be bioabsorbable or biodegradable, with a time of degradation similar to the time in which fibrosis occurs over the device **100**. Hence, the electrodes **131** (which preferably are not designed to degrade, and may be made from Nitinol, shape memory alloys, conductive polymers, other non-shape memory alloys and inert and biocompatible metals such as platinum, iridium, stainless steel and gold) will be all that remains of the initial device **100** and will become embed inside the blood vessel **103**, further enhancing the stability of the device **100** at the location of deposition

(179) Device in Blood Vessel (After Deployment)

(180) FIG. **6** depicts a medical device **100** in the expanded or deposition or scaffolding position. The device **100** includes a stent **101**, distal olives and/or proximity markers **112**, a wire **114** attaching the stent **101** to the olive **112**, a plurality of electrodes **131**, and an attachment/detachment zone **115** whereby the shaft is connected to the stent **101** having been deployed in a blood vessel **104**. Stent **101** mounted electrodes **131** are in direct apposition with the vessel wall **131** and are depicted as not interruptive of blood flow to any vessel (both the vessel the device is deployed in and other connected vessels). Here, the olive **112** can be used to direct the medical device into the desired vessel **104**.

(181) Device in Blood Vessel Pre-Deployment

(182) FIG. **25** depicts a medical device **100** during implantation (surgical deployment phase) as it is being thread through vessels **104** inside a catheter **102**. The stent **101**, electrodes **131**, stent detachment zone **105** and stent distal markers/electrodes/buffers **113** are shown, as are the vessel walls **103**. Here, the catheter **102** is being used to select and direct the device into the desired vessel **104**.

(183) Device In Blood Vessel After Deployment

(184) FIG. **26** depicts a medical device **100** in the expanded or deposition or scaffolding position comprising a stent **101**, distal olives and/or proximity markers **113**, a plurality of electrodes **131**, lead wires **141** and a stent detachment zone **105** being deployed in a blood vessel **104** through a deposition catheter **102**. Stent **101** mounted electrodes **131** are in direct apposition with the vessel wall **103** and are depicted as not interruptive of blood flow to any vessel (both the vessel the device is deployed in and other connected vessels).

(185) Ground Electrode

(186) The system can include a ground electrode **167**, configured in the manner shown in FIG. **27**, which is used to assist and improve the quality of the recorded signals or to provide an electrical return path for stimulation applications. Here the ground electrode may be placed on the connector block provided it is implanted. Ground electrode **167** can be directly attached to the outside of the wireless controller **12**.

(187) An alternative embodiment of the ground electrode **167** is shown in FIG. **28**. Ground electrode **167** on the outside of the controller **12**.

(188) The platinum C-shaped ground electrode **167** shown in FIG. **37** is embed in silicone **181** with a red helical lead wire **141** that is attached to a standard electrical terminal **169**. Dacron mesh is used to assist secure the electrode and wire to tissue.

(189) FIG. **29** shows a vessel with multiple devices **100** inserted in different vessels **104** to access different areas.

(190) FIG. **30** shows a single vessel **104** with multiple devices **100** implanted to cover a larger area.

(191) FIG. **31** a wireless electrode system **1000** showing electrodes mounted on a stent **101** within a blood vessel **104** overlying the motor cortex in a human that are picking up neural information and relaying this information to a wireless transmitter **1002** located on the stent **101**. Note the stent **101** has been deployed and the stylet has been removed (ie, only the stent **101**, electrodes, electrode wires and wireless system **1002** remains). The information is wirelessly transmitted through the skull to a wireless received **1004** placed on the head, which in turn, decodes and transmits the acquired neural information to a prosthetic limb **16**.

(192) As shown in FIG. **32**, the device **100** can be used to record neural information or stimulation of neurons from the superior sagittal sinus (SSS) or branching cortical veins of a patient using the device **100**, including the steps of: (a) implanting the device in either the superior sagittal sinus or branching cortical veins; (b) receiving activity; and (c) generating data representing said activity; and (d) transmitting said data to a control unit. Stent **101** implanted in SSS over motor cortex acquiring (i.e. receives) signals that are fed through the wire to external equipment **12**.

(193) FIG. **33** shows an image reconstruction of a human brain (eyes facing left) demonstrating superior sagittal sinus and branching cortical veins near the motor cortex (red) and sensory cortex (yellow)

(194) FIG. **34** shows a method of for stimulation and recording neural information or stimulation of neurons from the visual cortex of a patient using the device **100**, including the steps of: (a) implanting the device in a vessel in the visual cortex of the patient; and (b) recording neural information associated with the vessel or stimulating neurons in accordance with received stimulation data.

(195) As particularly shown in FIG. **35**, the device **100** is delivered through a vessel **104** deposited in a muscle for direct muscular stimulation or recording.

(196) The device **100** can be delivered through a vessel adjacent to a peripheral nerve (such as

shown in FIG. **35**) for stimulation or recording.

(197) The device is delivered through a vessel adjacent to a sympathetic or parasympathetic nerve for stimulation or ablation

(198) As shown in FIG. **36**, one example of a peripheral nerve (the median nerve in this example) showing possible implant location to enable neural stimulation or measurement.

(199) FIG. **38**A illustrates another example of a stent or scaffolding **101** having a plurality of electrodes **131** disposed about the stent **101** body. For purposes of illustration, the stent **101** is shown without any connecting structure that electrically couples the electrodes to leads or other such structure that allows electrical communication between the electrodes and control unit as described above. In the illustrated variation, the electrodes **131** are dispersed about the body of the stent **101** and are located at the joining or apex of joining struts **108**. In such a configuration, where instead of having cells shaped like diamonds, the cells are shaped like a 'V'. This configuration can enhance the apposition between the electrodes **131** and the tissue or vessel wall.

(200) FIG. **38**A also illustrates a variation of a stent **101** that can be fabricated where stent structure comprises an integrated conductive layer that extends through a portion or more of the stent strut **108** and where the electrode **131** is formed through an exposed portion of the integrated conductive layer. Such a stent configuration, as described in detail below, permits a stent **101** electrode **131** assembly, which embeds electrodes and conductive electrode tracks into the stent lattice or strut itself. Such a construction reduces or eliminates the requirement to use fixation methods (i.e., adhesives, glues, fasteners, welds, etc.) to mount electrodes to the body of the stent. Such a construction further reduces or eliminates the need to further weld or electrically connect electrodes to wires. Another benefit is that conventional wire-connected-electrodes require accommodation of the wires about the stent struts and through the body of the stent.

(201) FIG. **38**B illustrates a stent structure **101** with integrated electrodes **131**, where the stent structure is coupled to a shaft **121** at a distal end **146**. The shaft, as described herein, can electrically couple the electrodes **131** to one or more control units (not shown) as described herein. In one example, the shaft **121** can comprise a guidewire, push wire other tubular structure that contains wires or conductive members extending therein and are coupled to the conductive layer of the stent at the distal end **146**. Alternatively, FIGS. **38**C and **38**D shows a variation of stents **101** that can be fabricated such that the shaft **121** is part of or integral with the stent structure, where the conductive layer extends through a portion or all of the stent to the shaft **121**. Such a construction further eliminates the need for joining the shaft to the stent structure at the working end of the stent. Instead, the joining of the stent structure (forming the shaft) to a discrete shaft can be moved proximally along the device. Such a construction allows the working end of the stent and shaft to remain flexible. The stent structures shown in FIGS. **38**C and **38**D can also include an optional reinforced section **62** as discussed above. FIG. **38**C further illustrates a hollow shaft **121**, which allows insertion of a stylet **123** therethrough to assist in positioning of the device or permits coupling of wires or other conductive members therethrough. Furthermore, the shaft **121** can include any number of features **119** that improve flexibility or pushability of the shaft through the vasculature.

(202) The electrical connection of the electrodes **131** to leads extending through the device can be accomplished by the construction of one or more connection pads (similar in construction to the electrodes described below) where the size of the pads ensures sufficient contact with the wire/lead, the type of pads ensures robustness and reduces track fatigue when crimped and attached. The section containing the pads can be compressed into a tube at, for example, distal section **146** to enable insertion of a cable **121**.

(203) In certain variations, the connection pads should be able to feed through the catheter. Furthermore, the connection pads **132** can include one or more holes or openings that enable visual confirmation that the pads are aligned with contacts on the lead. These holes/openings also enables direct/laser welding or adhesion of the contact leads (inside tube **121**) and the contact pads (on the

inside of the tube spanning through the hole to the outside)

(204) In one example, a coaxial-octofilar cable (i.e. an inner cable with 8 wires positioned inside an outer cable having 8 wires) is used to enhance fatigue resistance and to ensure that wires can fit within constraints (i.e., can be inserted through a sufficiently small catheter, and can have an internal stylet as required).

(205) FIGS. **39**A-**39**C illustrate one example of a stent structure **101** constructed with an embedded electrode and conductive path. FIG. **39**A illustrates an example of a stent structure **101** in a planar configuration with electrodes **138** in a linear arrangement for purposes of illustration only. Clearly, any configuration of electrodes is within the scope of this disclosure. Specifically, in those variations of stent structures useful for neurological applications, the stent structure can comprise a diameter that is traditionally greater than existing neurological stents. Such increased diameter can be useful due to the stent structure being permanently implanted and while requiring apposition of electrodes against the vessel/tissue wall. Moreover, in some variations, the length of such stent structures can include lengths up to and greater than 20 mm to accommodate desired placement along the human motor cortex. For example, variations of the device require a stent structure that is sufficiently long enough to cover the motor cortex and peripheral cortical areas. Such lengths are not typically required for existing interventional devices aimed at restoring flow or addressing aneurysms or other medical conditions. In addition, in certain variations, the electrical path between certain electrodes can be isolated. In such a case, the electrically conductive material **50** can be omitted from certain stent struts to form a pattern that allows an electrode to have an electrical conduction path to a contact pad or other conductive element but the electrical conduction path is electrically isolated from a second electrode having its own second electrically conductive path.

(206) Placement of the electrodes in a specific pattern (e.g., a corkscrew configuration or a configuration of three linear (or corkscrew oriented) lines that are oriented 120 degrees from each other) can ensure a deployed electrode orientation that directs electrodes towards the brain. Once implanted, orientation is not possible surgically (i.e., the device will be implanted and will be difficult if not impossible to rotate). Therefore, variations of the device will be desirable to have an electrode pattern that will face towards the desired regions of the brain upon delivery.

(207) Electrode sizing should be of a sufficient size to ensure high quality recordings and give large enough charge injection limits (the amount of current that can be passed through the electrodes during stimulation without damaging the electrodes which in turn may damage tissue). The size should also be sufficient to allow delivery via a catheter system.

(208) FIGS. **39**B and **39**C illustrates a cross-sectional view of the stent structure of FIG. **39**A taken along line **39**B-**39**B to further illustrate one variation of a manufacturing technique of using MEMS (microelectrical mechanical systems) technology to deposit and structure thin film devices to fabricate a stent structure with electrodes and a conductive path embedded into the stent lattice or struts. The spacing of the struts in FIGS. **39**B and **39**C are compressed for illustrative purposes only.

(209) As discussed above, embedding the electrode and conductive path presents advantages in the mechanical performance of the device. Furthermore, embedding of electrodes provides the ability to increase the number of electrodes mounted on the structure give that the conductive paths (30-50 μm×200-500 nm) can be smaller than traditional electrode wires (50-100 μm).

(210) Manufacture of thin-film stents can be performed by depositing Nitinol or other superelastic and shape memory materials (or other materials for deposition of electrodes and contacts (including but not limited to gold, platinum, iridium oxide) through magnetron sputtering in a specific pattern (**56**) using a sacrificial layer (**58**) as a preliminary support structure. Removal of the support structure (**54**) enables the thin film to be further structured using UV-lithography and structures can be designed with thicknesses corresponding with radial force required to secure the electrodes against a vessel wall.

(211) Electrical insulation of electrodes is achieved by RF sputtering and deposition of a non-conductive layer (**52**) (eg, SiO) onto the thin-film structure (**54**). Electrodes and electrode tracks (**50**) are sputter deposited onto the non-conductive layer (using conductive and biomedically acceptable materials including gold, Pt, Ti, NiTi, PtIr), with an additional non-conductive layer deposited over the conductive track for further electrical isolation and insulation. As shown, conducting path **50** is left exposed to form the electrode **138** (similarly, a contact pad area can remain exposed). Finally, the sacrificial layer **56** and substrate are removed leaving the stent structure **101** as shown in FIG. **39**C.

(212) In certain variations where the base structure **54** comprises superelastic and shape-memory materials (i.e. Nitinol), the stent structure **101** can be annealed in a high vacuum chamber to avoid oxidation during the annealing process. During heat treatment, the amorphous Nitinol structure **54** crystallizes to obtain superelasticity and can be simultaneously shape set into a cylindrical or other shape as desired. The structure **101** can then be heat treated.

(213) FIG. **40**A, which is a partial sectional view of taken along lines **40**A-**40**A of FIG. **41**B, illustrate an additional variation of a stent structure **101** fabricated via MEMS technology where one or more stent struts **108** can be dimensionally altered to impart desired structural or other aspects to the stent structure **101**. For example, in the illustrated variation, certain stent struts **108** are dimensionally altered such that the support material **60** comprises a greater thickness than adjacent stent structures **108**. However, such dimensional variation is not limited to thickness but can also include width, shape, etc.

(214) FIG. **40**B illustrates the stent structure **101** resulting from the dimensionally altered struts resulting in a sinusoidal section **62** of the stent structure **101** that comprises a greater stiffness (resulting from the increased thickness). Such a configuration allowing the stent device to be pushed through a catheter rather than conventional requirements to be unsheathed (where the sheath is pulled back over the stent). Conventional stents are made from a thin lattice of Nitinol diamonds or cells. This sinusoidal section **62** can function like a backbone and gives forward pushing strength to the device without restricting super-elasticity and the ability for the stent to compress and expand. Clearly, any number of variations of dimensionally altered strut sections are within the scope of this disclosure.

(215) FIGS. **41**A-**41**E illustrate various aspects of a variation of a connector **200** that can be in electrical communication with a stent (e.g., stent **101**) and a receptacle (e.g., control unit **12**). For purposes of illustration, the connector **200** is shown isolated from the stent **101** and the receptacle **12**. As described above, the connector **200** can allow electrical communication between the electrodes and the control unit.

(216) FIG. **41**A illustrates that the connector **200** can have a dual-octofiler cable (also referred to as a coaxial-octofiler cable). The dual-octofiler cable can have a first coil **201** (e.g., inner coil) and a second coil **202** (e.g., outer coil). The first and second coils **201**, **202** can each have 8 wires **141**. Other numbers of wires, more or less, are also appreciated. The first coil **201** can be positioned within a lumen of the second coil **202**. The first coil can be positioned within a lumen of an internal tubing **145**. The first and/or second coils **201**, **202** can be positioned within a lumen of an external tubing **146**. The first and second coils **201**, **202** can be wound coils. The first and second coils **201**, **202** can be helical coils. For example, the first coil **201** can be wrapped along an inner surface of the internal tube **145** and the second coil **202** can be wrapped along an outer surface of the internal tube **145**. As described above, the dual-octofiler configuration can be used to enhance fatigue resistance and to ensure that wires can fit within constraints (i.e., can be inserted through a sufficiently small catheter, and can have an internal stylet as required).

(217) An insulator (e.g., polyurethane) can cover one or more wires **141** of the coils **201**, **202** (i.e., the wires **141** can be insulated). An insulator (e.g., polyurethane) can be positioned between the first and second coils **201**, **202**. For example, the internal tube **145** can be an insulator that can be positioned between the first and second coils **201**, **202**. An insulator (e.g., polyurethane) can cover

the first and/or second coils **201**, **202** (i.e., the first and second coils **201**, **202** can be insulated).

(218) The first coil **201** can have a length that is less than, greater than, or equal to the length of the second coil **202**. For example, the first coil **201** can be longer than the second coil **202**. The first coil **201** can have a diameter that is less than, greater than, or equal to the diameter of the second coil **202**. The first and/or second coils **201**, **202** can each have one or more diameters. For example, the first coil **201** can have two diameters and the second coil **202** can have one diameter. The first coil **201** can have a first diameter and a second diameter. The first diameter can correspond to where the first coil **201** is positioned within the second coil **202** and the second diameter can correspond to where the first coil **201** is not positioned within the second coil **202** (e.g., where it extends past the first coil **201**). Other arrangements are also appreciated.

(219) Although not shown in FIG. **41**A, the external shaft **146** can comprise contacts **151** and separators **174** (e.g., insulators). The separators **174** can be positioned next to contacts **151** to keep the contacts **151** electrically insulated from one another. The wires **141** of the first and second coils **201**, **202** can be electrically connected to the contacts **151**. For example, the 8 wires **141** of the first coil **201** and the 8 wires **141** of the second coil **202** can each be electrically coupled to a corresponding contact **151**.

(220) The first coil **201** can allow a stylet **148** (not shown) to travel through it. For example, the first coil **201** can define a lumen that allows a stylet **148** to pass through the first coil **201**. The inner surface of the first coil **201** can be insulated and/or not insulated.

(221) The first and second coils **201**, **202** can have a wound section and an unwound section. For example, the first and second coils **201**, **202** can transition from a wound section to an unwound section. The wound section have helical wires and the unwound section can have straight, curved (e.g., have one or more bends), and/or angled (e.g., have one or more bends) wires. The wound and unwound sections can be flexible and/or rigid. For example, the wound section can be flexible and the unwound section can be rigid.

(222) The first and second coils **201**, **202** can have a helical section and a non-helical section. For example, the first and second coils **201**, **202** can transition from a helical section (e.g., where the wires **141** define a helix) to a non-helical section (e.g., where the wires **141** do not define a helix). For example, the wires **141** in the non-helical section can be unwound to no longer form a coil. The wires **141** in the non-helical section can be straight, curved (e.g., have one or more bends), and/or angled (e.g., have one or more bends). The helical and non-helical sections can be flexible and/or rigid. For example, the helical section can be flexible and the non-helical section can be rigid.

(223) The first and second coils **201**, **202** can each have one or more channels. For example, the first and second coils **201**, **202** can each have 8 channels. Other numbers of channels, more or less, are also appreciated (e.g., 9 to 16 channels, or more). Other numbers of coils are also appreciated, for example, 3 or more coils. For example, it will be appreciated that another coil can be positioned within the lumen of the first coil **201** and/or on the outside of the second coil **202**.

(224) FIG. **41**B illustrates a cross-sectional view of the connector **200** shown in FIG. **41**A taken along the line **41**A-**41**A to further illustrate the first and second coils **201**, **202** of the dual-octofiler coil configuration. FIG. **41**B also illustrates that the first coil **201** can step-up **203** in diameter to match or otherwise approach the diameter of the second coil **202**. The step-up **203** can occur somewhere along the length of the first coil **201** and somewhere along the length of the second coil **202**. For example, the first coil **201** can step-up **203** at about the midpoint of the first coil **201** and at an end of the second coil **202** (e.g., a terminal end). The first coil **201** can step-up **203** to contact the leads **151**, for example, so that uniformly sized leads **151** can be used. The first coil **201** can step-up **203** to attach to the leads **151**. However, it will be appreciated that the leads **151** can have one or more sizes. With or without the step-up **203**, the receptacle **12** can have a step in it so that the contacts **175** of the receptacle **12** can make contact with the contacts **151** in contact with the first coil **201**. The various components of the dual octofilar cable can have the various dimensions shown (in inches).

(225) FIG. **41**C illustrates another perspective view of the connector **200** of FIG. **41**A, but with the outer shaft **146** made transparent for purposes of illustration. As described above, the second coil **202** can be wrapped around the inner shaft **145** and the first coil **201** can have a step-up **203**. FIG. **41**C illustrates that the 8 wires **141** of the first and second coils **201**, **202** can have terminal ends **207**. As shown, the wires **141** of the second coil **202** can terminate first, followed by the wires **141** of the first coil **201**. The terminal ends **207** of the second coil **202** can attach to the first 8 leads **151** of the connector **200** and the terminal ends **207** of the first coil **201** can attach to the second 8 leads **151** of the connector **200**. The first 8 leads **151** can be closer to a first end **210**a of the connector **200** and the second 8 leads **151** can be closer to a second end **210**b of the connector **200**. Any connection sequence is appreciated, including, for example, connecting from proximal to distal (e.g., from first end **210**a to second end **210**b) as shown, from distal to proximal, alternating, etc. The terminal ends **207** can be electrically coupled to contacts **151** as described above (e.g., by welding). The terminal ends **207** can be exposed to the contacts **151** to establish an electrical path between the leads **151** and the electrodes **131**, **138**.

(226) FIG. **41**C also illustrates that the helix angle of the second coil **202** can change, for example, at position **204**. The helix angle of the second coil **202** can increase or decrease. For example, the helix angle can increase near where the second coil **202** makes contact with the first contact **151**. Other numbers of changes in the helix angle of the second coil **202**, more or less, are also appreciated (e.g., including zero change to two or more changes).

(227) FIG. **41**D illustrates another perspective view of the connector **200** of FIG. **41**A, but with the inner and outer shafts **145**, **146** made transparent for purposes of illustration. FIG. **41**D illustrates that the helix angle of the first coil **201** can change, for example, at position **205**. The helix angle of the first coil **201** can increase or decrease. For example, the helix angle can increase near where the last terminal end **207** of the second coil **202** makes electrical contact with an eighth contact **151**. Other numbers of changes in the helix angle of the first coil **16**, more or less, are also appreciated (e.g., including zero change to two or more changes).

(228) FIG. **41**E illustrates the connector **200** of FIG. **41**A with the leads **151** and separators **174** shown. The leads and separators **151**, **174** can be positioned relative to one another in an alternating pattern. As described above, each wire **141** of the first and second coils **201**, **202** terminate on a contact **151**. The wires/filars **141** are exposed and attached (e.g., welded) to the inner surface (e.g., inner diameter) of the leads **151**.

(229) The connector **200** can be inserted into and/or attached to a receptacle **12** as described above. The connector **200** can be plugged into a receptacle **12** as described above. FIG. **41**E illustrates that the connector **200** can have a retention member **206** (e.g., retention ring **206**) that can engage with and/or attach to the receptacle **12**. To accomplish this, the retention member **206** can form a ring or a ring-like structure, although other shapes are also appreciated. For example, the receptacle **12** can be screwed onto the retention member **206**. The retention member **206** can have internal and/or external screw threads. For example, the retention member **206** can comprise a set screw. The retention member **206** can have a longer longitudinal dimension than one of the contacts **151**.

(230) The retention member **206** can be rigid to provide the connector **200** with structural support before, during and after implantation. Other parts of the connector **200** can be flexible so that the connector **200** can navigate or otherwise conform to the tortuosity of a blood vessel. For example, the portion of the connector **200** that is between the retention member **206** and the second end **210**b of the connector **200** can be flexible (this portion is also referred to here as the lead body). The lead body of the connector **200** can flex 90 degrees around a 6 mm radius. Other angles and radii, more or less, are also appreciated. The connector **200** (e.g., the second end **210**b of the connector **200**) can flex 45 degrees around a radius of 0.5 mm. Other angles and radii, more or less, are also appreciated. The connector **200** can be looped around a 1 cm radius. Other loop radii, more or less, are also appreciated.

(231) In the lead body portion of the connector **200**, the coils **201**, **202** can be allowed to float such

that they are not embedded in insulation. The coils **201**, **202** can be embedded in insulation within the retention member **206** and/or within the lead body portion. The separators **174** can be over-molded to ensure a uniform diameter is present between contacts.

(232) FIG. **41**E illustrates that the lead wires **141** can extend beyond the first end **210**a of the connector **200**. The lead wires **141** that extend beyond the first end **210**a of the connector **200** can be unwound (e.g., uncoiled) such that each wire **141** can individually connect to a connection panel (e.g., connection panel **220** described below), or otherwise connect to the connection panel in one or more bundles **144** of wires **141**. For example, the lead wires **141** can transition from coiled configurations into 16 tailed ends that can connect to the connection panel. The 16 tailed ends can be straight and/or curved. The connection panel can electrically couple the connector **200** to the electrodes **131**, **138**. For example, FIG. **41**E illustrates that the first and second coils **201**, **202** can be unwound and grouped into three bundles **144** of lead wires **141**. Other numbers of bundles, more or less, are also appreciated. Wires from the first and second coil **201**, **202** can be bundled with first coil **201** wires **141** and/or with second coil **202** wires **141**. It is appreciated that individual wires **141** and one or more bundles of wires **144** can extend from the connector **200** to connect with the connection panel. The wires **141** can unwind/uncoil over some dimension within the retention member **206** and/or over some dimension within the rest of the connector **200**. The wires **141** and/or bundles **144** that extend from the connector toward the stent **101** can be rigid and/or flexible.

(233) The wires **141** can be directly connected to the stent **101**, for example, with laser welding. For example, the wires **141** can be directly connected to pads on the stent **101**. The wires **141** can be indirectly connected to the stent **101**, for example, with wire bonding. For example, the wires **141** can be indirectly connected to pads on the stent **101** via connection to intermediate pads. The pads on the stent **101** can be wire bonded to the intermediate pads, for example, with jumper wires.

(234) FIG. **42** illustrates that the connector **200** of FIGS. **41**A-**41**E can be electrically coupled to the electrodes **131**, **138** of the stent **101** via a connection panel **220**. FIG. **42** illustrates that the wires **141** of the connector **200** can be indirectly connected to the stent **101** via the connection panel **220**. The connection panel **220** can have a first panel (e.g., an overlay) and a second panel (e.g., a stentrode panel) electrically coupled together. The first and second panels can each have one or more connection pads. The pads can be made of platinum or other conductive materials. The wires **141** of the connector **200** can be electrically connected to one or more pads of the first panel and the conductive paths (also referred to as electrode tracks) of the stent **101** can be electrically connected to one or more pads of the second panel. One or more jumpers can be used to electrically connect the first panel to the second panel. For example, one or more jumpers can be used to electrically connect the first panel pads to the second panel pads. The one or more jumpers can electrically connect the pads of the first panel to the pads of the second panel, thereby electrically connecting the leads **151** of the connector **200** to the electrodes **131**, **138** of the stent **101**. Attaching the wires/filars **141** to the first panel can advantageously provide a more stable and reliable connection than directly attaching the wires/filars **141** to the stentrode pads (e.g., to the second panel pads). The first and/or second panels can be attached to the connector **200**, for example, by welding or other attachment method. The first and second panels can each have 16 pads. Other numbers of pads, more or less, are also appreciated (e.g., 1 pad to 32 or more pads). An insulating material (e.g., epoxy) can cover the connection panel **220**.

(235) More than one connection panel **220** can be used. For example, two connection panels **220** can be used. The use of two connection panels **220** can advantageously make connections easier and give more space for wire management relative to the use of only one connection panel **220** since not all 16 wires **141** are connected to the same area when two connection panels are used. The use of multiple connection panels can help provide structural support to the connection panel region when the stentrode is being pushed out of the delivery system. For example, the use of multiple connection panels can help distribute the force/axial load that is applied when the system is pushed through a delivery system (e.g., a catheter). The use of multiple connection panels is also

advantageous from a processing and fatigue resistance standpoint.

(236) The one or more connection panels **220** can be aligned with a backbone of the stent **101**. For example, the one or more connection panels **220** can be aligned with struts **108**, thicker struts **108**, and/or with a reinforced section **62**.

(237) The transition from the dual coils **201**, **202** to the leads **141** extending toward the panel **220** can include unwinding/uncoiling the first and second coils **201**, **202** as described above.

(238) The connector **200** (also referred to as an endovascular implantable lead) can be configured to transmit neural interface sensor data to an implantable telemetry unit (e.g., control unit **12**). The dual-octofiler coils **201**, **202** can advantageously withstand long term repetitive movement and trauma due to neck movements, among other movements. The use of dual-octofiler coils **201**, **202** can advantageously reduce noise due to muscle artifacts.

(239) The pads on the stent can be connected to the conductors in the lead body by a variety of methods including but not limited to resistance welding, laser welding (each involving direct contact between the pads on the Stentrode and the lead), and/or wire bonding (connection between the Stentrode and the lead via an intermediate pad).

(240) FIGS. **43**A-**43**F illustrate various views of a variation of a portion of a connection panel **220**. As shown, the connection panel **220** can have a first panel **222** (e.g., an overlay) attached to a portion of the stent **101**, for example, a second panel **224**. The second panel **224** can be a connection paddle. The second panel **224** can be integrated with or attached to the stent **101**. The second panel **224** can have multiple pads (not shown) and multiple electrode tracks **236**. The electrode tracks **236** can be electrically connected to the pads of the second panel **224**. The first panel **222** can have multiple pads **226** and multiple openings **228** (also referred to as windows or holes). The pads can be made of platinum or other conductive materials. The openings **228** can be aligned with or otherwise placed over the pads on the stent **101**. The first panel **222** can have the same number or a different number of pads **226** and openings **228**. For example, the first panel **222** can have 16 pads **226** and 16 openings **228**, although other numbers of pads and openings, more or less, are also appreciated (e.g., 1 to 32 or more pads and openings). As another example, the first panel **222** can have more pads **226** than openings **228**. As yet another example, the first panel **222** can have fewer pads **226** than openings **228**. The stent **101** can have the same number or a different number of pads as the number of openings **228** in the first panel **222**. For example, the stent **101** can have 16 pads and the first panel **222** can have 16 openings **228**. As another example, the stent **101** can have 16 pads and the first panel **222** can have fewer than 16 openings **228** (e.g., 4 or 8 openings).

(241) FIGS. **43**A and **43**B illustrate that the windows **228** can have a reduced cross-sectional area relative to the cross-sectional area of the pads **226**. This can advantageously increase/optimize the operating space on the first panel **222** for wire management. The pads and windows **226**, **228** can be arranged in various patterns to increase/optimize the operating space on the first panel for wire management. The pattern shown in FIGS. **43**A and **43**B is non-limiting, as any suitable pattern of pads and windows **226**, **228** is appreciated. FIG. **43**G illustrates a variation of the pads and openings **226**, **228**. The pads **226** can have, for example, a pad first dimension and a pad second dimension. The pad first dimension can be a pad length and the pad second dimension can be a pad width. The pad first dimension can be greater than, less than or the same as the pad second dimension. For example, FIG. **43**G illustrates that the pad first dimension can be greater than the pad second dimension. The pad first dimension can be, for example, about 0.05 mm to about 1.00 mm, less than 10.00 mm, including every 0.01 mm increment within these ranges (e.g., 0.50 mm). The pad second dimension can be, for example, about 0.04 mm to about 1.00 mm, less than 10.00 mm, including every 0.01 mm increment within these ranges (e.g., 0.13 mm). The openings **228** can have, for example, an opening first dimension and an opening second dimension. The opening first dimension can be an opening length and the opening second dimension can be an opening width. The opening first dimension can be greater than, less than or the same as the opening second

dimension. For example, FIG. **43**G illustrates that the opening first dimension can be greater than the opening second dimension. The opening first dimension can be, for example, about 0.05 mm to about 1.00 mm, less than 10.00 mm, including every 0.01 mm increment within these ranges (e.g., 0.24 mm). The opening second dimension can be, for example, about 0.04 mm to about 1.00 mm, less than 10.00 mm, including every 0.01 mm increment within these ranges (e.g., 0.08 mm).

(242) FIGS. **43**C and **43**D illustrate that wire bonds **230** can be made between the pads on the stent **101** and the pads **226** on the overlay **222**. FIG. **43**D is a magnified view of the wire bonds **230** of FIG. **43**C at section **43**D-**43**D. One or multiple wires **232** can pass through each of the windows **228**. For example, two wires **232** are shown in FIGS. **43**C and **43**D passing through two different windows **228**.

(243) FIGS. **43**E and **43**F illustrate that the wires **141** can be attached (e.g., welded) to the pads **226** on the overlay **222**. FIG. **43**F is a magnified view of the wires **141** attached to the pads **226** of FIG. **43**E at section **43**E-**43**E. An insulating material **234** (e.g., epoxy) can cover at least a portion of the wires **141**.

(244) FIGS. **44**A-**44**D illustrate a variation of an overlay **222** for wire bonding to a stent **101**. The overlay **222** can have the various dimensions shown (in inches). The overlay **222** of FIGS. **44**A-**44**D is similar to the overlay **222** of FIGS. **43**A-**43**F except the pattern of the pads and openings **226**, **228** is different, and the openings **228** are larger. FIG. **44**C is a magnified view of one of the pads **226** of FIG. **44**A at section **44**C-**44**C. FIG. **44**D is a magnified view of the opening **228** of FIG. **44**A at section **44**D-**44**D. The pads and openings **226**, **228** can have the various dimensions shown (in inches). Wire bond pads can be placed in specific locations to enable all 16 electrode tracks to fit within the 900 μm width with enough separation that unwanted electrical connection is avoided. The overlay **222** can have a similar width to enable deployment through a 1 mm internal diameter catheter.

(245) FIGS. **45**A and **45**D illustrate a variation of an overlay **222** for wire bonding to a stent **101**. FIG. **45**A illustrates a top view of the overlay **222** and FIG. **45**B illustrates that the overlay **222** can be placed over the portion of the stent **101** having pads. The pads of the stent can be electrically connected to the electrodes **131** (not shown) via the electrode tracks **236**. The pads and openings **226**, **228** can have the various dimensions shown. This design, and similar changes to the pads on the stent **101**, can advantageously allow for linear attachment of the pads **226** to the wire bonding holes **228**, which can make manufacturing the connection panel **220** easier than, for example, the connection panel associated with FIGS. **44**A-**44**D.

(246) FIGS. **43**A-**45**D illustrate that the wires **141** can be indirectly connected to the stent **101**, for example, with wire bonding. The wires **141** can be indirectly connected to pads on the stent **101** via connection to intermediate pads **226** on the overlay **222**. Such an intermediate connection method can advantageously allow for thicker/stronger wires **141** to be used to connect the lead **200** to the overlay **222**. Welds from the overlay **222** to the stent **101** can overcome limitations on the stent **101** of having a small amount of platinum to weld to. This is advantageous relative to, for example, laser welding because laser welding typically requires more material which is melted to form a pool during welding. With a small amount of material, the melted pool can cause the track material to be sucked up into the pool, causing the tracks to break during manufacture.

(247) FIGS. **46**A-**46**F illustrate variations of stents **101** having various electrode **131** configurations. Each of these stents **101** can advantageously position electrodes **131** in a manner that, regardless of the manner in which the stent **101** is delivered into a vessel, there will always be sufficient electrodes **131** pointing to an information rich area of the brain (e.g., motor cortex, sensory cortex, among others) upon expansion from a compressed configuration. For purposes of illustration, the stents **101** are shown without any connecting structure that electrically couples the electrodes **131** to leads or other such structure that allows electrical communication between the electrodes **131** and the control unit **12** as described above.

(248) As shown, the electrodes **131** can be dispersed about the body of the stents **101** at various

locations. FIGS. **46**A-**46**F illustrate that the stents **101** can have one or more cell sizes and/or shapes (e.g., diamond-shaped, V-shaped, among others). For example, the stents **101** can have cells that are longer than they are wide (L>W). This can advantageously allow for greater compression and reduce the force required to retract the stents **101** into a delivery instrument (e.g., a stylet or delivery catheter) and reduce the force required to deploy the stents **101** from within the delivery instrument. The stents **101** can have one or more cells that are wider than they are long (W>L). The stents **101** can have some cells that are longer than they are wide (L>W) and some cells that are wider than they are long (W>L). Such cell variations can advantageously accommodate various vessel physiologies.

(249) One or more of the electrodes **131** can be attached to, embedded into, and/or otherwise integrated with the stents **101** as described above. For example, the stents **101** can have one or more integrated conductive layers (also referred to as electrode tracks and electrical tracks). The electrode tracks can have a thickness from about 200 μm to about 1000 μm. Other track thicknesses, more or less, as well as other ranges, narrower or wider, are also appreciated. Electrode tracks with these thicknesses can advantageously decrease the electrical resistance of the electrode track and provide more material (at the connection end) for welding. In FIGS. **46**A-**46**F, the electrode track thickness is the dimension into the page (i.e., not width or length, which can remain constant to reduce the overall thickness of the Stentrode struts where multiple tracks are present, such as the fork **302** on the far left of the figures). The thickness of the struts **108** (i.e., the material underneath the insulation layers and electrical tracks) can be from about 50 μm to about 100 μm, for example, 50 μm, 85 μm, or 100 μm. Other strut thicknesses, more or less, as well as other ranges, narrower or wider, are also appreciated. The strut **108** thickness can increase or decrease gradually and/or in a step-wise manner along the stent **101** (e.g., gradually increase from 50 μm to 85 μm or step up from 50 μm to 85 μm). Thicker struts can have a larger radial and axial force relative to thinner struts. The thicker struts can therefore advantageously increase the apposition between the stent **101** and a vessel wall. The thicker struts can therefore increase the ability of the stent **101** to be pushed forward and deployed from within a delivery instrument (e.g., a catheter). The stents **101** can be thickest near the forks **302** on the proximal end of the stents **101** and can be thinnest at the distal end of the stents **101**. The stents **101** can become thinner from the proximal end to the distal end. The stents **101** can have any suitable thickness(es), including a constant thickness.

(250) The configurations of struts **108** and cells shown in FIGS. **46**A-**46**F can enhance the apposition between the electrodes **131** and tissue or vessel walls when the stents **108** are in their expanded configuration. The strut and electrode configurations **108**, **131** can advantageously allow the stents **101** to be compressed into a catheter. The strut and electrode configurations **108**, **131** can advantageously allow the stents **101** to be expanded after being compressed in a catheter. The cells (e.g., their size and/or shape) and the electrode **131** positions can allow the stents **101** to compress and/or expand so that the struts and electrodes **108**, **131** do not physically interfere with the compression and/or expansion of the stents **101**. For example, the relative positions of the cells and the electrodes **131** can allow the stents **101** to compress and/or expand without getting stuck in a partially compressed configuration or a partially expanded configuration. The cells and the electrode **131** positions can help prevent electrodes and struts **131**, **108** from becoming snagged with one another during compression or expansion of the stents **101**. The relative positions of the cells and electrodes **131** can facilitate expansion and/or compression of the stents **101**. The struts can be curved and/or straight. The struts that define the cells can be curved and/or straight.

(251) To reduce the number of leads/wires from the stent **101** to external equipment, a multiplexing unit (not shown) can be used. The multiplexing unit can be placed on the connection panel/paddle of the stent **101** (e.g., second panel **224**). The multiplexing unit can be placed on the stent **101**, for example, on a strut **108**. One or multiple multiplexors can be used. The multiplexing unit can be small enough so that it does not impede the radial force and flexibility of the stent **101**.

Multiplexing can reduce the number of wires required. One or more wires can be used with a multiplexor to power and switch between the electrodes **131** as required. The stent **101** can be wirelessly powered.

(252) FIGS. **46**A-**58**D illustrate various arrangements of stent cells, but any open cell configuration is appreciated. Moreover, although not shown, one or more of the stent cells can be closed such that there is not an opening in the cell. For purposes of illustration, the stents **101** shown in FIGS. **46**A-**58**D are illustrated as having various lengths and various numbers of electrodes **131**. However, other lengths, greater or smaller, as well as other numbers of electrodes, more or less, are also appreciated. The stent lengths shown in FIGS. **46**A-**58**D is not limiting. The length of the stents **101** can be increased, for example, by including more stent in the longitudinal direction. For example, the length of the stents **101** can be increased by increasing the number of cells and/or by increasing the length and/or width of the cells. Similarly, length of the stents **101** can be decreased, for example, by having less stent in the longitudinal direction. For example, the length of the stents **101** can be decreased by decreasing the number of cells and/or by decreasing the length and/or width of the cells. The open cell designs in FIGS. **46**A-**58**D are for illustrative purposes only as well. The cell arrangements shown can be repeated, changed, and/or altered to achieve the desired length of the stents **101** and/or the desired open cell design. FIGS. **46**A-**58**D illustrate various cell shapes and sizes, but any open cell configuration for the stents **101** is appreciated. For example, any of the cells in FIGS. **46**A-**58**D can be combined with one another to form a stent (e.g., stent **101**). The numbers of electrodes in FIGS. **46**A-**58**D can be increased or decreased as needed. For example, the stents **101** in FIGS. **46**A-**58**D can have between 1 and 32 or more electrodes **131** (the numbers of electrodes **131** in the figures are exemplary only). In this way, the stents **101** can advantageously accommodate various vessel physiologies and sense and/or stimulate various tissues in one or multiple locations.

(253) The stents **101** can have one or more sections of electrodes **131**. The one or more sections can be separated by one or more sections of struts **108** that do or do not have electrodes.

(254) As described above, the stents **101** disclosed and contemplated herein, for example, the stents **101** shown in FIGS. **46**A-**56**D, can stimulate and/or sense various activity of media (e.g., tissue and/or fluids). For example, the stents **101** can stimulate and/or sense activity of fluid inside a lumen of a vessel, activity of a vessel itself, and/or activity of media (e.g., tissue and/or fluids) outside of the vessel such as the motor and/or sensory cortex of the brain.

(255) FIG. **46**A illustrates that the stent **101** can have seven electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated (e.g., between 1 and 32 or more electrodes). The seven electrodes **131** can span radially across a length of the vessel with no electrode overlap. For example, the seven electrodes **131** can span radially across a length of an 8 mm vessel with no electrode overlap. The seven electrodes **131** can be at different radial positions along a length of the stent **101** such that there is no overlap of electrodes **131** when the stent **101** is expanded in a vessel. The seven electrodes **131** can be at different circumferential positions along the length of the stent **101** such that there is no overlap of electrodes **131** when the stent **101** is expanded in a vessel. As described above, this can advantageously ensure that the stent **101** has a sufficient number of electrodes **131** pointing to information rich areas of the brain (e.g., the motor cortex, the sensory cortex, among other areas) upon expansion from a compressed configuration.

(256) FIG. **46**A illustrates that the stent **101** can have large cells and small cells. The small cells can be inside the large cells. The struts **108** can define the cells. Some of the struts **108** can define at least a portion of a small cell and at least a portion of a large cell. Some of the struts **108** can define at least a portion of a small cell or at least a portion of a large cell. The electrodes **131** can be located on the small cells and/or the large cells. For example, the electrodes **131** can be integrated with the small cells. The electrodes **131** can be located anywhere on the small cells. For example, the electrodes **131** can be located at an apex of the small cells. The electrodes **131** can be located anywhere on the struts **108**. As shown, the electrodes **131** can be located at the distal longitudinal

apexes of the small cells. Although not shown, the electrodes **131** can be located on a portion of the small cells away from the distal longitudinal apexes, including for example, the transverse and proximal apexes. The electrodes **131** can be indirectly coupled to the large cells. The small cells can be inside the large cells for advantageous electrode placement and to assist with electrode-vessel wall apposition. The stent **101** can have a full set of small closed cells on top for stent overlap (e.g., the top row of small closed cells in FIG. **46**A). The small cells can have a cell length L and a cell width W. The stent **101** can have a total length TL and a total width TW. The configuration in FIG. **46**A can enhance the apposition between the electrodes **131** and the tissue of a vessel wall.

(257) FIG. **46**B illustrates that the stent **101** can have sixteen electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. The electrodes **131** can be positioned in bipolar pairs for neural recording and stimulation efficiency. The bipolar pair arrangement can advantageously enable direct stimulation or recording from one electrode to another (e.g., between any two electrodes **131**). This can elicit a response or record a signal from a focal region of the brain in a region between the electrodes **131** that form the bipolar pair (as opposed to an electrode **131** and a distant ground, with the second or return electrode placed off the stent). The electrodes **131** can be independent from one another. The electrodes **131** can be used in pairs. The electrodes **131** can be used in multiple pairs, for example, by switching among the electrodes **131**. The electrodes **131** can be used in pairs and can be independent from one another. The configuration in FIG. **46**B can enhance the apposition between the electrodes **131** and the tissue of a vessel wall.

(258) FIG. **46**C illustrates that the stent **101** can have **14** electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. The electrodes **131** can be positioned in bipolar pairs. The stent **101** of FIG. **46**C is similar to the stent **101** of FIG. **46**B, except that the bipolar electrode pairs are constructed with one electrode mounted to an open cell and another electrode mounted in an open cell style to that electrode to enhance electrode apposition while ensuring known distance between electrodes.

(259) FIG. **46**D illustrates that the stent **101** can have 16 electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. The electrodes **131** can be positioned in bipolar pairs. FIG. **46**D illustrates that the stent **101** can have a straight, single strut bipolar pair open cell design. The electrodes **131** can be mounted on the inside of open cell struts with a bipolar pair electrode **131** attached with single linear strut **108**. This can reduce the amount of material required (compared, for example, to the amount of material required for the stent **101** illustrated in FIG. **46**C). The configuration in FIG. **46**D can enhance the apposition between the electrodes **131** and the tissue of a vessel wall.

(260) FIG. **46**E illustrates that the stent **101** can have 16 electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. The electrodes **131** can be positioned in bipolar pairs. The cells of the stent **101** can have the shapes shown. The electrodes can have the locations shown, although any location on struts **108** defining the cells is appreciated. The stent **101** can be flexible and require less material that the stents **101** illustrated in FIGS. **46**A-**46**D. The configuration in FIG. **46**E can enhance the apposition between the electrodes **131** and the tissue of a vessel wall. For example, the configuration in FIG. **46**E can appose the vessel wall around vascular chordae which maintaining superelasticity, at least partly to the large open cell design.

(261) FIG. **46**F illustrates that the stent **101** can have sixteen electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. The stent **101** of FIG. **46**F is similar to the stent **101** of FIG. **46**A except that the stent **101** of FIG. **46**F can have a greater length and is illustrated with more electrodes **131**.

(262) FIGS. **47**A-**47**F illustrate variations of stents **101** having various electrode **131** configurations. The stents **101** of FIGS. **47**A-**47**F are similar to the stents **101** of FIGS. **46**A-**46**F except for the different cell configurations and electrode **131** locations. FIGS. **47**A-**47**F illustrate

that the stents **101** can have strut crosslinks **109** that are offset from one another, for example, by offset angles **304**. The offset crosslinks **109** can advantageously allow the stents **101** to be compressed without having any stent overlap. This can, in turn, advantageously allow the stents **101** to be more easily expanded by preventing or otherwise reducing the risk of cells and/or electrodes **131** from becoming entangled or snagged with one another when the stents **101** are expanded. For purposes of illustration, the stents **101** in FIGS. **47**A-**47**E have been illustrated with linearly arranged struts **108**, forming various diamond- and rectilinear-shaped cells. However, the cells of the stents **101** can be shaped as shown in the lower left insets of FIGS. **47**A-**47**F, which are similar to the small cells of FIGS. **46**A-**46**F except for the offset angles **304** described above. The offset angle can be, for example, 101 degrees (e.g., 101.3 degrees), although other offset angles, more or less, are also appreciated (e.g., 80 degrees to 120 degrees, or narrower or wider ranges).

(263) FIGS. **47**A-**47**F illustrate that the length to width ratio of the cells can be 7:5. The 7:5 ratio helps ensure that the stents **101** can compress and expand.

(264) FIGS. **47**A-**47**F illustrate that the stents **101** can have a fork angle **302**. FIG. **47**A shows that the stents **101** can have a first fork angle **302**F and a second fork angle **302**S. The first and second fork angles **302**F, **302**S can be the same or different from one another. As shown, the first and second fork angles **302**F, **302**F can be measured, for example, between a center axis and first and second struts (not separately labeled) that extend from the connection panel **224**. The first and second fork angles **302**F, **302**S can each be from about 30 degrees to about 50 degrees. For example, the first fork angle **302**F can be about 41.5 degrees and the second fork angle **302**S can be about 35.5 degrees. Other fork angles, more or less, as well as other fork angle ranges, narrower or wider, are also appreciated. The fork angle **302** can advantageously allow for easier deployment (e.g., expansion) and retraction (e.g., compression) of the stents **101**.

(265) FIG. **47**B illustrates that the stent **101** can have sixteen electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. The sixteen electrodes can be arranged in a ladder style having two or more "rungs." For example, the sixteen electrodes can be arranged in five rungs of electrodes **131** having a 2-4-4-5-1 pattern. The stent **101** can have any number of rungs and any number of electrodes **131** in each of the rungs, including four rungs having a 2-4-5-5 electrode pattern. As another example, FIG. **47**C illustrates that the stent **101** can have sixteen electrodes arranged in five ladder rungs having a 1-3-3-4-5 electrode pattern. The 1-3-3-4-5 pattern of FIG. **47**C can advantageously provide additional electrical evaluation length (e.g., stimulation and/or recording length) relative to shorter ladder configurations, for example, the 2-4-5-5 pattern of FIG. **47**B. The ladder style can advantageously assist with delivery through vascular tortuosity and enable navigation of vascular chordae whilst ensuring electrode apposition and self-expansion.

(266) FIG. **47**D illustrates that the stent **101** can have ten electrodes **131** arranged as shown. The ten electrodes **131** are shown in a 1-2-2-2-3 five rung ladder pattern, although any ladder pattern having ten electrodes is appreciated. The stent **101** can have relative cell sizes similar to the large and small cells described above with reference to FIG. **46**A.

(267) FIG. **47**E illustrates that the stent **101** can have sixteen electrodes **131** arranged as shown. FIG. **47**E illustrates that the stent **101** can have larger cells on the border (e.g., perimeter) of the stent **101** and more dense cells closer to the center (e.g., in the center) of the stent **101**. This arrangement of cells and electrodes **131** can advantageously provide an enhanced region for recording or stimulation closer to the center of the stent **101**. As shown, the electrodes **131** can be arranged in an eight rung 1-2-3-2-3-2-1-2 ladder pattern, although any ladder pattern having sixteen electrodes **131** is appreciated.

(268) FIG. **47**F illustrates that the stent **101** can have sixteen electrodes arranged in seven ladder rungs having a 2-1-4-2-2-3-2 electrode pattern. The 2-1-4-2-2-3-2 pattern of FIG. **47**F can advantageously provide additional electrical evaluation length (e.g., stimulation and/or recording length) relative to shorter ladder configurations, for example, relative to the ladder patterns of FIG.

47B-**47**D. FIG. **47**F illustrates fork angles **302**F, **302**S that assist with delivery, retraction and deployment, skewed electrode locations for improved deliverability and reducing overlap, interleaved cells for overlap and radial force, cell aspect ratio for deliverability and self-expansion.

(269) For purposes of illustration, the stents **101** in FIGS. **46**A-**47**F described above and FIGS. **48**A-**48**B, **46**B-**46**C, **51**B, **52**B, **53**B-**53**C, **54**A-**57** and **58**C described below are shown flat so that the cells, struts **108**, electrodes **131**, and/or electrode tracks **236** can be easily seen. However, the stents **101** are curved in practice (e.g., when in the compressed and/or expanded configuration). The top of the stents **101** can be directly joined to the bottom of the stents **101** (the top and bottom as shown in FIGS. **46**A-**47**F) to form cylindrical tube-like stent structures that can exert radial outward forces against a vessel wall. The top of the stents **101** can curve around to meet (with or without permanent attachment) the bottom of the stents **101**. A portion of the top and bottom of the stents **101** can overlap or there can be a gap therebetween.

(270) FIGS. **48**A-**48**D illustrate a variation of a stent **101**. FIG. **48**A illustrates that the stent **101** can have eight electrodes **131** arranged as shown. The stent **101** can have a proximal end **250** and a distal end **260**. The proximal end **250** can include a second panel **224** as described above. The second panel **224** can have stent pads **238**. FIG. **48**B illustrates the struts **108** of FIG. **48**A that have electrode tracks **236**. For purposes of illustration, the stent **101** is shown flat in FIGS. **48**A and **48**B but can be curved as described above. FIG. **48**C is a magnified view of the proximal end **250** of the stent **101** of FIG. **48**A at section **48**C-**48**C and shows the electrode tracks **236** electrically connected to the stent pads **238**. An overlay **222** can be placed over the stent pads **238**. FIG. **48**D is a magnified view of an electrode **131** of FIG. **48**A at section **48**D-**48**D.

(271) FIGS. **49**A-**49**C illustrate a variation of a stent **101** having seven electrodes **131** arranged as shown. The stent **101** of FIGS. **49**A-**49**C is similar to the stent **101** of FIG. **46**A. FIG. **49**A illustrates a perspective view of the stent **101** having a curved profile in an expanded configuration. FIG. **49**B illustrates the stent **101** in a flat configuration. FIG. **49**C illustrates the struts **108** of FIGS. **49**A and **49**B that have the electrode tracks **236**. FIGS. **49**B and **49**C illustrate that the struts **108** can get thicker from the distal end **260** to the proximal end **250**, for example, to accommodate multiple electrode tracks **236** as they merge into a common strut and/or to increase the axial and radial forces/resilience of the stent **101**. Multiple electrode tracks **236** on a common strut can be parallel to each other.

(272) FIGS. **50**A-**50**C illustrate front perspective, rear perspective and top views of a variation of a stent **101** connected to a connection panel **220**. The stent **101** can have eight electrodes **131** arranged as shown.

(273) FIGS. **51**A and **51**B illustrate a variation of a stent **101** having eight electrodes **131** arranged as shown. FIG. **51**A illustrates a perspective view of the stent **101** having a curved profile in an expanded configuration and FIG. **51**B illustrates the stent **101** in a flat configuration. The stent **101** can have a reinforced section **62**. As shown, the electrode tracks **236** from each of the electrodes **131** can merge into the reinforced section **62**. The multiple electrode tracks **236** in the reinforced section **62** can be parallel to each other. Some of the struts **108** and/or the reinforced section **62** can get thicker from the distal end **260** to the proximal end **250**. The stent pads **238** can be directly connected to the lead wires **141** of a connector **200** (not shown). The stent pads **238** can be indirectly connected to the lead wires **141** of a connector **200** (not shown).

(274) FIGS. **52**A-**52**C illustrate a variation of a stent **101** having sixteen electrodes **131** arranged as shown. The proximal end **250** can include a second panel **224** as described above. The second panel **224** can have stent pads **238**. FIG. **52**A illustrates a perspective view of the stent **101** having a curved profile in an expanded configuration and FIG. **52**B illustrates the stent **101** in a flat configuration. The stent **101** can have a reinforced section **62**. FIG. **52**B illustrates that some of the electrode tracks **236** can merge into a top, bottom, or middle strut **108**, or any other strut. The middle strut **108** can be the reinforced section **62**. Some of the struts **108** and/or the reinforced section **62** can get thicker from the distal end **260** to the proximal end **250**. FIG. **52**C is a magnified

view of the proximal end **250** of the stent **101** of FIGS. **52**A and **52**B and shows the electrode tracks **236** electrically connected to the stent pads **238**. An overlay **222** can be placed over the stent pads **238**. The stent pads **238** can be directly connected to the lead wires **141** of a connector **200** (not shown). The stent pads **238** can be indirectly connected to the lead wires **141** of a connector **200** (not shown).

(275) FIGS. **53**A-**53**D illustrate a variation of a stent **101** having sixteen electrodes **131** arranged as shown. FIG. **53**A illustrates a perspective view of the stent **101** having a curved profile in an expanded configuration. FIG. **53**B illustrates the stent **101** in a flat configuration. FIG. **53**C illustrates the struts **108** of FIGS. **53**A and **53**B that have electrode tracks **236**. FIG. **53**C illustrates that some of the electrode tracks **236** can merge into a top strut and some of the electrode tracks **236** can merge into a bottom strut. FIG. **53**D is a magnified view of the proximal end **250** of the stent **101** of FIGS. **52**A and **52**B and shows the electrode tracks **236** electrically connected to the stent pads **238**.

(276) FIGS. **54**A and **54**B illustrate a variation of a stent **101**. FIG. **54**A illustrates that the stent **101** can have eight electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated. FIG. **54**B illustrates the struts **108** of FIG. **54**A that have electrode tracks **236**. FIG. **54**B illustrates that some of the electrode tracks **236** can merge into a top strut and some of the electrode tracks **236** can merge into a bottom strut.

(277) FIGS. **55**A and **55**B illustrate a variation of a stent **101**. The stent **101** of FIGS. **55**A and **55**B is similar to the stent **101** of FIGS. **54**A and **54**B except that the cells in FIG. **55**A have a uniform size.

(278) FIGS. **56**A-**56**D illustrate various variations of stents **101** without electrode tracks. The stents **101** can have electrodes **131** arranged as shown. Other numbers of electrodes, more or less, are also appreciated.

(279) FIG. **57** illustrates a variation of a lattice structure for a stent **101**.

(280) FIGS. **58**A-**58**C illustrate a variation of a stent **101** having sixteen electrodes **131** arranged as shown. The stent **101** of FIGS. **58**A-**58**C is similar to the stent **101** of FIG. **47**F. FIGS. **58**A and **58**B illustrate perspective and side views of the stent **101** having a curved profile in an expanded configuration. The curved profile can have a gap **240**. FIG. **58**C illustrates the stent **101** in a flat configuration. The stent **101** can have the various dimensions shown (in millimeters) in FIG. **58**C.

(281) Any of the stents **101** disclosed and/or contemplated herein can be wireless stents (also referred to as wireless electrode systems). The stents **101** can have one or more wireless transmitters (e.g., the wireless transmitter **1002** of FIG. **31**). The wireless transmitters can be attached to or integrated with the stents **101**. The wireless transmitters can be a separate device and/or can be an arrangement of one or more electrodes **131** of the stents **101**. For example, an arrangement of one or more electrodes **131** can form a wireless antenna that can send and/or receive information. The electrodes **131** can record or pick up neural information and relay this information to a wireless transmitter. This recorded information can be wirelessly transmitted through the skull to a wireless receiver (e.g., the wireless receiver **1004** of FIG. **31**). The wireless receiver can decode and transmit the acquired neural information to a device such as a prosthetic limb or a visual prosthesis.

(282) The wireless stents (e.g. stents **101**) can be configured for the transmission of both power and data. Power can be wirelessly transmitted to the wireless stents to operate the circuitry of the stents and data can be wireless transmitted from the wireless stents to, for example, a control unit (e.g., control unit **12**). In addition to or in lieu of the wireless power, the stents can be powered with a piezoelectric energy power generator that generates energy from blood flow and/or from vascular constriction and dilation.

(283) The wireless stent systems can be fully or partly wireless. Fully wireless means that no portion of the stent (e.g., stents **101**), including the electrodes **131** and wireless circuitry, extends beyond a vessel wall after implantation. Semi-wireless means that at least a portion of the stent

(e.g., stents **101**), electrodes **131** and/or wireless circuitry extends beyond a vessel wall after implantation. The stent **101** of FIG. **31** is an example of a fully wireless stent system. As shown in FIG. **31**, the entire device (stent and electronics) can be within the blood vessel, or otherwise become embedded within the blood vessel over time. The stent **101** of FIG. **2**A is an example of a semi-wireless system, where the wireless electronics sit outside the vessel in the pectoral region. The system of FIG. **2**A is similar to, for example, a pacemaker where the wireless system sits outside of the vessel. Semi wireless systems can have a wire that passes from within a blood vessel to outside a blood vessel.

(284) As described above, the stents **101** can be used to scaffold the electrodes **131** against the vessel wall. Wireless stent systems can have one or more stents (e.g., stents **101**), for example, between one and ten stents (e.g., 1, 2, or 3 or more stents **101**). Other numbers of stents, more or less, as well as ranges, narrower or wider, are also appreciated. If the wireless electronics cannot be mounted on or integrated with a first stent **101** having electrodes **131** (e.g., due to space or functional requirements), the wireless electronics can be mounted or integrated with a second stent **101** (e.g., which can have the same or a different number of electrodes than the first stent **101**, or no electrodes). Such multi-stent systems (e.g., dual-stent systems) can advantageously carry the circuitry away from the center of the vessel where it has a chance of causing occlusion or blockage. The first and second stents of a dual-stent system can advantageously form a dipole antenna, which can improve wireless transmission of the system. The second stent can be under the skull connected directly (but not electrically) to the first stent, or can be placed in the neck, tethered to the first stent. Other arrangements are also appreciated (e.g., the first and second stents can be electrically connected to one another). A benefit of placing the second stent in the neck includes a reduction in distance to the body surface. Placement in the neck is also expected to cause less interference to the acquisition and amplification of the neural signals.

(285) The system (e.g., system **10**) can have one or more stents **101** in wired and/or wireless communication with a telemetry unit (e.g., control unit **12**). For example, the system can be an endovascular telemetry and closed loop cortical recording and/or stimulation system for the diagnosis, prediction and treatment of epilepsy. Endovascular telemetry systems for epilepsy (also referred to as epilepsy care systems) can advantageously record brain activity 24 hours/day 7 days/week. This 24/7 monitoring offers a critical advantage to doctors and patients alike, as traditionally the ability of the treating physician to determine the number of seizures a patient is suffering depends on the patient recording a seizure diary, which can be, and are notoriously, inaccurate. Knowing how many and the nature of seizures occurring in a patient can be critical in determining the correct dosing for anti-seizure treatment by the physician, which the endovascular telemetry system provides. The epilepsy care systems can receive inputs that can modulate treatment doses of medications/drugs.

(286) For recording telemetry, a stent **101** can be implanted in cortical venous targets (including the transverse sinus) to achieve proximity to cortical regions of interest for seizure detection (including the temporal lobe). The stent **101** can be or can be part of an implantable telemetry unit (ITU). The ITU can house a data unit that can collect brain recordings 24/7. The ITU can be accessed wirelessly by the user or physician to review the neural information over a time period of interest. The ITU can be accessed wirelessly for real-time assessment of the neural information. For example, in periods of higher-risk (including when the patient is unwell, or having to make modifications to their treatment regimen) the physician is able to assess neural signal in real time. The neural data collected by the ITU can be streamed into a range of apps that allow various real time functions. For example, the neural data collected can be communicated to third party applications that apply software analysis of the neural data (including for seizure prediction). In this way, the collected data can be made available to third party users to generate information or modulation information to the patients upon use of the collected data. The epilepsy care systems can have closed loop feedback. For example, the collected data can be utilized in an input loop into

a treatment-delivery system to enable precise dosage determinations based upon data containing real-time seizure detection (including vagal nerve stimulator, drug delivery systems). The epilepsy care systems can perform neuromodulation. For example, responsive neural stimulation can be achieved by the endovascular systems described herein having stents **101**. This can advantageously enable a closed loop system by utilizing the stent system to record and deliver treatment by stimulating across the vessel wall (e.g., from one or more electrodes **131** of one or more stents **101**) to achieve seizure termination.

(287) FIGS. **59**A-**59**C illustrate a telemetry unit lead **400** having a snake and rung design connected to a telemetry device **12**. The snake and rung design can advantageously reduce the surgical manipulation required to shorten the lead **400**, for example, if the lead is too long. Typically, leads are shortened by winding the lead on itself; however, such winding can cause fatigue as the lead rubs on itself and wears away and/or can require a larger incision into muscles during surgery. The snake and rung design prevents/avoids these risks. As shown in FIGS. **59**A-**59**C, the telemetry unit lead **400** can be a set overall size (e.g., overall length) that is curled into a snake form **404** connected by one or more rungs **402**. The rungs **402** can be made of silicone or other biocompatible material that has some flex. If a longer lead is required, one or more of the rungs **402** can be detached (e.g., through surgical cutting or otherwise) so that the lead length can be increased. In this way, the length of a generic telemetry unit lead **400** can be tailored/customized to a patient and to the surgical placement of the telemetry device **12** during surgery. For example, FIGS. **59**A-**59**C illustrate that the lead length can be increased from L.sub.1 to L.sub.2 by detaching four rungs **402**, for example, during surgery. One or more rungs **402** (e.g., one, two, or three or more) can be placed centrally or on the left and/or right edges of the snaked portion **404** of lead **400**, or somewhere in between.

(288) As described above, the telemetry unit (e.g., control unit **12**) can communicate information (using wires or wirelessly) to and/or from an external apparatus **16**, which can include (but is not limited to) one or more of the following: (a) an exoskeleton; (b) wheelchair; (c) computer; and/or (d) other electrical or electro-mechanical device.

(289) For example, FIGS. **60***a*-**60***d* illustrate a variation of a system **10** having a stent **101** implanted in the vascular of a person's brain, for example, a vessel traversing the person's superior sagittal sinus. FIG. **60***a* illustrates the system **10** and FIGS. **60***b*-**60***c* illustrate three magnified views of the system **10** as shown. The stent **101** can be implanted for example, via the jugular vein, into the superior sagittal sinus (SSS) overlying the primary motor cortex to passively record brain signals and/or stimulate tissue. The stent **101** can record and interpret brain signals that are associated with intentions to move, so that people who are paralyzed due to neurological injury or disease, can communicate, improve mobility and potentially achieve independent through direct brain control of assistive technologies such as computer software and/or apparatuses **16** (e.g., robotic upper limb prostheses, motorized wheelchairs, and the like). Other applications for the stent **101** as described throughout this disclosure are also appreciated.

(290) The system **10** can have one or multiple telemetry units. The system **10** can have one or multiple internal and/or external telemetry units. FIGS. **60***a* and **60***d* illustrate that the system can have an internal telemetry unit (e.g., control unit **12**) in wired or wireless communication with an external telemetry unit **15**. For example, the external telemetry unit **15** can be wirelessly connected to the internal telemetry unit **12** across the user's skin. The internal telemetry unit **12** can be in wireless or wired communication with the stent **101**. For example, FIGS. **60***a*-**60***d* illustrate that the stent **101** can be electrically connected to the internal control unit **12** via a communication conduit **14**. The communication conduit **14** can be a stent lead. As shown in FIG. **60***c*, the stent lead can extend from the stent **101**, pass through a wall of the jugular, and tunnel under the skin to a subclavian pocket. In this way, the communication conduit **14** can facilitate communications between the stent **101** and the internal control unit **12**.

(291) As shown in FIGS. **60***a*-**60***d* (as well as FIGS. **1**-**2**B), the one or multiple telemetry units can

be located/implanted in and/or on the chest of a user. However, the telemetry unit can be located in any suitable location. For example, the telemetry unit can be located/implanted behind the ear of a user. For example, one or multiple telemetry units can be located/implanted behind the ear of the user at, or otherwise proximate to, location **19** shown in FIG. **60***a*. Relative to placement in and/or on the chest, positioning the control unit behind a user's ear can advantageously reduce artifacts and noise due to neck and muscle movement, for example, because the communication conduit **14** (e.g., stent lead) would not need to be located in the neck of a user.

(292) The internal telemetry unit **12** can be connected to one or multiple external apparatuses **16**. The internal telemetry unit **12** can be connected to one or multiple internal apparatuses (not shown), for example, visual prosthetics and other controllable devices implanted partially or completely within or on a person's body. The external telemetry unit **15** can be connected to one or multiple external apparatuses **16**. The external telemetry unit **15** can be connected to one or multiple internal apparatuses (not shown), for example, visual prosthetics and other controllable devices implanted partially or completely within or on a person's body.

(293) As described above, the system (e.g., system **10**) can have one or more stents **101**. The stents **101** can be in wired and/or wireless communication with a telemetry unit (e.g., control unit **12**). The stents **101** can record and or stimulate areas of the cortex associated with vision. For example, the system can be an endovascular visual prosthesis neural interface having one or more stents **101**. The stent **101** can be used to access deep, folded areas of cortex in the occipital lobe (e.g., the primary visual cortex) that are not reachable via open brain surgery, and which cannot be targeted by current technology (i.e., technology that is implanted directly onto the cortical surface of the occipital lobe). FIG. **34** shows a method for stimulation and the recording neural information or the stimulation of neurons from the visual cortex of a patient using the device **100**, including the steps of: (a) implanting the device in a vessel in the visual cortex of the patient; and (b) recording neural information associated with the vessel or stimulating neurons in accordance with received stimulation data. The stents **101** can be implanted in the superior sagittal sinus and/or the transverse sinus to advantageously achieve transvascular stimulation of the occipital region of interest, although any implant location is appreciated. Information from the visual world can be captured in a video capture. The information can be translated into a stimulation algorithm. The translated information can be delivered into the occipital lobe via stimulation via one or more stents **101**. The visual prosthetic system can contain a large number of electrodes embedded into the wall of the transverse and superior sagittal sinus via the one or more stents **101**.

(294) The one or more stents **101** can be used for an endovascular neural interface system for deep brain stimulation treatment. Current deep brain stimulation requires a craniotomy for implantation of the leads. Craniotomy procedures are associated with myriad complications and risks including hemorrhage. The stents **101** can eliminate the need for craniotomies. The stents **101** can access to deep structures suitable as targets for deep brain stimulation is viable through deep venous and arterial vessels in the brain. A catheter can be used to access the deep blood vessels. The stents **101** can enable stimulation of targeted brain tissue. Implantation of an endovascular lead into a deep structure can enable stimulation of the brain tissue. The stents **101** and systems disclosed herein can treat a range of conditions with deep brain stimulation, including Parkinson's disease, dystonia, obsessive compulsive disorder, depression, among others.

(295) FIG. **61**A illustrates a variation to the overall stent structure. In this variation, the stent structure **101** includes a single radius R but the stent structure is spaced or contiguous. This configuration allows the stent structure to accommodate a greater size range of vessels. FIG. **61**B illustrates a stent structure **101** having a first portion (such as a half) with a greater radius R**2** than the radius R of the other portion (or other half). This configuration allows the structure **101** to curl on itself in one direction preferentially, which is anticipated to: reduce the force to retract into catheter; reduce the likelihood of electrodes or struts catching; and/or enable a larger diameter (increased radial force) without requiring an increase in overall physical stent size or oversizing of

stent.

(296) FIGS. **62**A-**62**B illustrate an improvement to the electrodes **131** are configured with one or more filleted edges **116** that transition from the electrode to adjacent struts **108**. FIG. **62**A and **42**B illustrate respective filleted edges on a single side of the electrode and both sides of the electrode respectively. The filleted edges **116** can be configured as a gradual thickening from the strut towards the electrode, thereby removing a sharp corner and creating a slower, shallower transition between strut and electrode. Thickening of the strut transition **116** and creating that "smooth corner" reduces the prospect of wires or other items being caught in the intersection adjacent to the electrodes.

(297) In some variations of the device, the filleted edges **116** can add to the conductive surface of the electrode. However, in those applications where primary purpose of the edge **116** is to prevent the electrode catching on alternate stent struts or other structures, the filleted edge **116** can be non-conductive.

(298) FIG. **63** illustrates a variation of a stent device **100** with a stent shaft **121** that has grooves or pockets **125** (e.g., areas of the shaft **121** that are removed.) The grooves or pockets **125** allow for the epoxy/adhesive to reduce movement in multiple planes (i.e., both left/right and forward/backwards). The toothed pattern increases the grip when attached to a lead because epoxy/adhesive can be deposited between the teeth. This makes the attachment to the lead more secure and stable, while maintaining the existing geometric profile and width.

(299) FIG. **64** illustrates a planar view of a variation of a stent device **100** where the electrodes **131** are specifically designed to limit the number of tracks per strut **108**. Limiting the number of tracks per strut **108** reduces potential crosstalk and noise caused with/by parallel tracks and also reduces the width of the strut that is required to support multiple tracks. In certain variations, the tracks/struts are located/positioned in a unidirectional arrangement to: reduce thermal heating generated by high angle turns and reduce fatigue caused during flexion/extension. The track thickness can be optimized to minimise the electrical resistance/impedance (where large tracks better) as well as minimize the overall strut thickness (where small tracks are better).

(300) FIG. **65** illustrates an implantable telemetry unit **12** coupled to a connector via an extension lead **14**. In this variation, the lead **14** is arranged in a serpentine fashion, connected by a thin (possibly polymer) layer, with thicker 'bridges' **17** across each lead pass. This allows a surgeon to pull the required length of lead from the ITU body, without risking fatigue due to lead rubbing, and minimising the depth of a surgical pocket needed for implantation of the device.

(301) Other Applications

(302) The methods, device, and systems described herein are discussed in terms of controlling computers, wheelchairs, exoskeletons, robotic prosthesis, cameras, vehicles and other electrical stimulation, diagnostic and measurement hardware and software. However, specific applications of these methods, systems and devices can provide language communicators/translators, gaming and (house) device controller, enhancements to applied intelligence and memory, sleep modifications, integrated communication devices, as well as enhanced cognitive output devices.

(303) In some variations, the implants record neural activity, which transmits signals representing the neural activity to another source (whether external or internal). Next, feedback is provided to the patient/user. In one basic variation, the signals representing neural activity can be transmitted to a processing unit that includes a database of previously determined activity. Where the processing unit identifies or compares the recorded neural activity to the database of previously determined activity and generates a signal to control or trigger an external device.

(304) In the variations discussed above, the neural activity can be monitored in different areas brain areas that are being recorded from indicative of different ways that information can be acquired from the brain (i.e., signals relating to speech, movement, sight, vision, memory, emotions, touch).

(305) Transmitting the signals to the source can include delivering the information contained in the signals to a useful external source. This could be a prosthetic limb, or could be more advance (such

as a database consisting of information, or language translations etc.). In some variations, the transmission of signals could comprise the final step (as is the case with rudimentary prostheses such as a wheelchair, for speech translation or for recording memories, dreams or previous visual information).

(306) Various examples of sending feedback to the patient/user can vary based on the specific application. For example, sophisticated prostheses could provide information in the form of tactile feedback to sensory cortices within the brain. Alternatively, systems for treatment of moods, depression, or post-traumatic stress disorder provide feedback that stimulates an area of the brain that provides a feeling of happiness. Feedback could also come in the form of auditory cues (i.e., stimulation could be delivered back to the person which is interpreted as left, right, straight ahead etc.). Similarly for visual feedback, directions in the form of arrows could be presented to the visual cortex to inform which direction to take, or for other applications such as memory, could provide a complete (or near complete) scene of what you need to recall (where you live, where your car is parked, what was on the shopping list etc.). Signals generating low resolution images (e.g., around 1500 pixels), which could be used to spell words or general shapes that provide the desired feedback/Other useful cues can be delivered to justify electrical stimulation as visual feedback (i.e., flashing of numbers or symbols representing numbers). Clearly, the systems described herein can apply to medical applications as well as non-medical applications.

(307) Universal Translators

(308) The applications of one or more neural implants can assist those individuals who cannot communicate verbally by enabling direct brain control of speech or other communication. In such a case, the implants described above can function with a device that provides universal translator capabilities such as enabling people with speech difficulties to have a voice through a computer. Alternatively, or in combination, the universal translator can sense neural activity and cause stimulation of the individual's own muscles to enable communication. The implants described herein can record brain activity or signals specific to speech, relay such activity to an external device that uses signals to control a computer speech processor, a speaker, the user's own muscles, or even cause direct stimulation of a different implant in a different individual. For example, the systems can allow for signals of certain neural activity to be transmitted to another person's auditory cortex (e.g., hearing aid, cochlear implant, etc.) so that the neural activity of a first individual can be received by a second individual without traditional sounds/speech.

(309) Further, processing of this information can enable communication in any language by translating between two or more different languages. It is known that neural commands generated by the brain control the muscles used for speech (tongue, lips, mouth etc.). An implant placed in a specific cortical location, can record signals the brain sends to these muscles. Different muscles have a large, but finite, number of different combinations meaning that a finite number of commands can drive a speech or control the muscles directly.

(310) Such systems can include applications for people who are mute or have speech difficulties (stutter, lisp), suppression of unwanted speech (Tourette's), universal translator between different languages.

(311) Gaming and Device Controllers

(312) The systems, methods and devices of the present disclosure can also receive neural activity that controls muscles during high intensity gaming. Such neural activity can be processed to control an external gaming device or various house appliances and devices (e.g., light switches, appliances, locks, thermostats, security systems, garage doors, windows, shades, etc.) Again, the implants would detect brain signals specific to acts in which such devices are operated. The system can then generate signals to control one or more networked external device that to allow for neural control of the devices.

(313) Memory Assist Systems

(314) The systems described herein can also aid in memory recall of past activities. For example,

one or more electrode devices can be implanted in regions of the brain that receive information sent by the eyes to the visual cortex. Neural signals that are generated through the eyes or during sleep can be acquired within the visual cortex. The visual cortex is retinotopically mapped (i.e. fields of view in the eye have specific cortical locations). Major regions of visual cortex are inaccessible by conventional electrode arrays as it is hidden beneath a large vessel. The sensory devices described herein can access one or more regions that are otherwise inaccessible by the conventional electrode arrays. These neural signals can be relayed to a recording device. At a later time, the recorded signals can then be re-stimulated in various locations in the brain to replay the visual or other input. Such recording and replay methods can be applied to any sensory input in addition to visual. In variations where the system records multiple sensory inputs, the system can later relay a sensory recording in isolation or in combination with other sensory recordings. In addition, visual information can be delivered to a person through stimulation of the visual cortex or other accessory areas. This would enable use as a restorative visual implant for the blind or to enable people to visualise pre-developed scenes (i.e., could see and be immersed in a movie or scenery of a different location.

(315) These systems can assist in individuals where the recall of past activities is difficult, such as for people with Alzheimer's or dementia, people who experience physical or psychological trauma which causes memory loss. In addition, such a memory assist system can be used on a temporary basis where a device is implanted only for a short period of time.

(316) Intelligence Enhancement Systems

(317) Another application of the systems described in this disclosure includes establishing a connection between the brain and a database, server, and/or an internet site. The system can include using an existing networked appliance such as a cell phone and/or networked appliance that accesses information. As with the other systems described herein, an electrode device can be positioned in a region of the brain to sense neural activity and determine the intent of the neural activity (such as by comparing the neural activity to previously determined actions), which allows control of the system similar to a spoken command. The system can then stimulate the brain directly based on information provided by the database, server, and/or an internet site for applications including: augmented intelligence, non-verbal communication, etc. In this variation, there is two way communication—information or a request coming from the sensors located in the brain, sent via a computer, database or server, then information is fed back into the brain (potentially to different targets (i.e. for sight, smell, taste, memory, vision etc.). For example, an individual can ask a question to a voice activated/recognition computer interface. The computer would then provide feedback using a visual (i.e. arrows to the visual cortex) or auditory (tones or full commands for left, right, straight etc.) presentation/descriptions of a map or directions to the nearest place.

(318) The networks described herein can comprise a traditional a computer network comprising is a set of computers connected together for the purpose of sharing resources. Alternatively, or in combination, the network can comprise a directly attached equipment (i.e., a robotic limb can provide information to tell the user that they are touching something). Furthermore, there are databases that may be required to be accessed (i.e., maps, or general knowledge).

(319) Sleep Stimulation/Suppression Systems

(320) Another application of the systems described in this disclosure includes implantation of a device within a sleep center of the brain to stimulate or assist in accelerating neural reconfiguration where the stimulation and neural reconfiguration reduce the hours needed to sleep. Alternatively, the systems can be used to keep people awake where required.

(321) Integrated Communication Systems

(322) The systems described herein can also function as integrated communication systems. The disclosed and contemplated systems can augment communication for those who cannot communicate, can augment communication for those who can communicate normally, can augment

communication for those who can communicate but in a diminished capacity, or any combination thereof. For example, the device (e.g., stent **100**) can record neural activity in the motor cortex associated with making a call. The neural activity can then be relayed to circuitry either wired or wirelessly that connects to network and places the required call. Speech commands, generated through set commands (i.e., one action for hello, one action for goodbye acquired from motor cortex) or vocal activation can be acquired and sent to receiver. As with previous descriptions, the voice on the other end of the line could then relay words back to the auditory or visual cortex (via electrodes) directly.

(323) As another example, the device (e.g., stent **100**) can record neural activity in the motor cortex associated with communicating with an electronic device such as a computer, a database, a server (e.g., a web server, an internet server, a cloud server), or any combination thereof, as well as with the internet in general, including web pages, websites, search engines, or any combination thereof. The device **100** can record neural activity in the motor cortex associated with communicating with software stored on one or multiple electronic devices (e.g., on a computer, in the cloud). For example, for a subject to communicate with and/or navigate the internet, the device **100** can be in communication with an intermediary device (e.g., an electronic device) in communication with the internet. The device **100** can be in wired or wireless communication with an electronic device. The electronic device can be a remote electronic device. However, regardless of the proximity to the subject, the electronic devices can be assistive devices that the device **100** (also referred to as a brain machine interface) can communicate with and/or can be assistive technology such as assistive software that the device **100** can communicate with. A closed communication loop can be formed between the device **100** and the computers and/or assistive software that the device **100** is configured to communicate with.

(324) A subject can communicate with electronic devices and software by controlling a moveable control such as a cursor. The device **100** can record neural activity in the motor cortex associated with such control. For example, subjects who have the device **100** can communicate with electronic devices and software by willing cursor movement (e.g., by willing a mouse cursor to move) and by willing cursor selection (e.g., by willing a mouse click, including left mouse click functionality, right mouse click functionality, mouse wheel functionality, mouse wheel functionality for scrolling, click and drag functionality, or any combination thereof). In this way, the device **100** can enable a subject through the power of their thought to move a cursor on an electronic display (e.g., computer screen), to make selections on the electronic display via the cursor, or any combination thereof. Subjects can make selections with a cursor, for example, by "clicking" on a selection, by hovering over a selection for a threshold time period such as 5 seconds, by clicking and then enclosing the selection with a selection shape (e.g., a selection box), or any combination thereof. The electronic display can be a screen of a computer, for example, of a smartphone, tablet, laptop, desktop monitor, television, virtual reality system, augmented reality system, graphic display goggles, graphic display glasses, graphical user interface, or any combination thereof. The device **100** can record neural signals such that the subject can move one or multiple cursors and can make one or multiple selections (also referred to as decisions). Where the subject is controlling multiple cursors, the subject can move the multiple cursors sequentially or simultaneously relative to one another. Where the subject is making multiple decisions, the subject can make such decisions sequentially or simultaneously relative to one another.

(325) A subject's decisions associated with neural activity recorded in their motor cortex by the device **100** can include any decision people without a device **100** can make while interacting with a computer or the internet, such as, for example, selecting links, opening and closing documents, opening and closing emails, browsing websites, selecting links on websites, opening and closing software programs, using the software programs (e.g., graphical programs such as graphical word processing programs, internet browsers, email programs, video games), initiating and terminating internet connections, or any combination thereof. In this way, subjects having the device **100** can

control electronic devices, for example, to browse the internet and use software programs.

(326) An example of a software program that a subject can interact with via the device **100** is communicating software such as a speller. A subject having a device **100** can move a cursor on a display to make letter and word selections in the speller to spell and communicate with others via one or multiple electronic devices, for example, using programs having letters, words, and/or drawing features (e.g., a word processing program). The speller software can display letters on a screen and the subject can will a cursor to move on the screen to select the letters that they want.

(327) The device **100** can be unidirectional (record only or stimulate only) or can be bi-directional (record and stimulate). Once the device **100** records neural activity, the recorded neural activity can then be relayed to circuitry either wired or wirelessly that directly or indirectly connects to an electronic device or first to a processing unit that includes a database of previously determined activity. The processing unit identifies or compares the recorded neural activity to the database of previously determined activity and generates a signal to control or trigger an external device. For communication with an electronic device, feedback may (e.g., when using a bi-directional device **100**) or may not (e.g., when using a unidirectional device **100** or when using a bi-directional device **100**) be sent back to the brain. Visual feedback can be provided on the electronic display of the electronic device when the subject is communicating with the electronic device via the device **100** such that feedback to the brain is not required.

(328) Enhanced Cognitive Output

(329) Systems described herein can be used to enhance cognitive output, for improvements in such areas as: learning, memory, training, motor tasks, etc. Transcranial Direct-Current Stimulation (TDCS) and Transcranial Magnetic Stimulation (TMS) have been shown to have potential applications in improved attention, learning, and motor outputs. Implantation of an intravascular stimulation device into the appropriate area could potentially create more reliable, long term improvements to cognitive outputs using less energy due to increased access and proximity to the regions of interest.

(330) Neural Signal Processing

(331) The systems and implants described herein can record and process neural activity to control devices that are internal and/or external to a user's body via a brain machine interface. Such processing can be done with one or more processors or microprocessors that are, for example, integrated or otherwise in communication with one or more stent devices **100** and/or with the telemetry unit **12**. The processors can be programmed with or be capable of calling a variety of control algorithms to process the neural signals received from the brain and/or from elsewhere in the body. This includes neural signals received from both the sympathetic and/or parasympathetic pathways. For example, an electrode array (e.g., the stent based electrode array **100**) can sense cortical and/or sub-cortical neural activity, and can relay such activity to a processor to control a brain machine interface. The brain machine interface can be linked to internal and/or external devices. Cortical and subcortical locations can include, for example, the primary motor cortex (M1), the supplementary motor area (SMA), the posterior parietal cortex (PPC), the primary somatosensory cortex (S1), the cerebellum, the thalamus and the brain stem. Neural activity in areas outside of the brain can also be sensed and processed, for example, from the spinal cord, muscles and organs such as the heart, lungs, stomach, kidneys and pancreas. The control algorithms can process neural activities that are sensed or recorded by the system to generate control signals. The generated control signals can allow for the neural control of one or multiple external devices, internal devices, parts of the body, or any combination thereof. For example, the algorithms can produce control signals that actuate some part of a device and/or that stimulate tissue.

(332) The algorithms can process sensed neural activity from one or more neural areas to determine, for example, whether a user intends to act, and if so how much. If the sensed neural signals correspond to intended action, the brain machine interface can generate control signals that actuate a device associated with the action intended. For example, where a user has a prosthetic

arm linked to a brain machine interface, the user can think about raising their arm and the system can detect this intent by processing the neural signals that are associated with this action. The system can transform this detected intent into a control signal to raise the prosthetic arm according to the user's intended action.

(333) Various algorithms can be used to decode or otherwise determine a user's intent as well as determine whether the sensed or decoded intent corresponds to a user's intended action. For example, the system can sense signals from multiple brain areas to rely on and detect natural synergies that exist between multiple brain areas when a user mentally forms an intent (e.g., a motor intent). Such an intent determination algorithm relies on the fact that any given intent will be replicated in multiple areas of the brain and be supplemented with additional information. For example, the system can detect and use natural cortical and/or subcortical synergies for informing the outputs of the brain machine interface when determining intent. In such a case, the system can determine a user's intent by processing neural signals from two or more neural areas and then making a determination of whether the two or more sets of neural signals are associated with one another before generating an output signal. Sensing and analysing neural synergies can reduce the risk of accidentally activating devices in communication with the brain machine interface since such a decoding process relies on multiple areas of the brain as opposed to just one, and takes advantage of the neural redundancies or lack thereof that naturally result. Utilizing such synergies can therefore enable for more accurate and reliable identification of a person's intent. This can in turn allow for the generation of more accurate and reliable control signals, as well as instil greater confidence in users for the device. The system can also determine a user's intent without relying on neural synergies, for example, by processing neural signals from a single area without associating or comparing the signals to signals from other neural areas.

(334) FIG. **66** illustrates a variation of an algorithm **350** for processing neural signals from two or more neural areas that are received, for example, from one or more stent devices **100**. The algorithm **350** can process the received neural signals to determine whether the signals correspond to a user's intended action. Upon starting at block **352**, the algorithm **350** can record brain signals **354** from multiple neural locations, decode intents **356** from the recorded signals, and perform a correlation analysis **358** on the intents decoded. For example, FIG. **66** illustrates that the algorithm **350** can record brain signals **354** from a first location **354***a* and a second location **354***b*. The neural activity in different areas can be recorded simultaneously or sequentially relative to activity recorded in one or more other areas (e.g., the signals at the second location **354***b* can be recorded at the same time as the signals at the first location **354***a* or at a later time).

(335) Recording signals from multiple neural areas **354** makes the algorithm **350** multimodal and enhances the intent determination process **356** and improves error detection **358**. The recorded signals can be measured, for example, with one or more sensors (e.g., one or more electrodes **131** of one or more stent devices **100**). For example, the brain signals in the first location **354***a* can be recorded with a first sensor and the brain signals in the second location can be recorded with the first sensor or a second sensor. The first sensor can be proximate or in the first neural area **354***a* and the second sensor can be proximate or in the second neural area **354***b*. Further, although FIG. **66** illustrates that the first and second neural areas **354***a*, **354***b* are in the brain, the neural areas **354** can be in and/or outside of the brain including, for example, the cortex, the subcortex, the cerebellum, the thalamus, the brain stem, the spinal cord, organs, muscles, or any combination thereof. The first and second neural activities **354***a*, **354***b* can be measured with the same or different implants, for example, with first and second stent devices **100**.

(336) Once the first and second signals **354***a*, **354***b* are received in step **354**, the algorithm **350** can determine the intents **356** that are associated with each of the recorded signals. For example, FIG. **66** illustrates that a first intent **356***a* can be determined from the first neural signal **354***a* and that a second intent **356***b* can be determined from the second neural signal **354***b*. The first and second intents **356***a*, **356***b* can be determined by decoding the recorded first and second neural activities

354*a*, **354***b*, respectively. Alternatively, or in combination, the intents **356** (e.g., first and second intents **356***a*, **356***b*) can be determined by referencing previously measured neural activities stored in a memory. The neural activities stored in the memory can be obtained from the user, another person, and/or from multiple people. In this way, the stored neural activities can be user specific, specific to another person, and/or be a compilation of data from multiple users. In this way, the memory can be patient-specific and/or be a global library of neural data. Where neural data from one or more other people who are different from the user is stored on and/or referenced from the memory, this data can represent a benchmark standard and/or the next neural goal for the user at any stage in their neural development and training. The memory can be configured to store new measurements, purge old measurements, organize the stored data, or any combination.

(337) Once the intents **356** are determined, the algorithm **350** can perform a correlation analysis **358** to determine whether to actuate **360** or not actuate **362** a device associated with or otherwise controllable by the algorithm **350**. The correlation analysis **358** can ascertain error between two or more of the neural areas being recorded, for example, between two or more of the measured signals **354** and/or between two or more of the determined intents **356**. FIG. **66** illustrates that if the correlation analysis **358** determines that the first intent **356***a* is the same as or substantially the same as (also referred to as associated with or substantially associated with) the second intent **356***b*, a processor can be programmed to generate one or more control signals configured to actuate **360** a device. Likewise, if the correlation analysis **358** determines that the first and second intents **356***a*, **356***b* are not associated with one another, the processor can be programmed to not actuate **362** the device. Stated differently, if the algorithm **350** confirms that two or more decoded intents **356** are associated with one another, one or more control signals can be generated and delivered to the device to actuate **360** the device, after which the algorithm **350** can return to the recording step **354** or end **364**. Likewise, if the algorithm **350** is unable to confirm that two or more decoded intents **356** are associated with one another (e.g., if an error is detected between the two or more decoded intents **356**), the algorithm **350** can proceed to the recording step **354** or end **364** without actuating **362** the device.

(338) For example, the correlation analysis **358** can calculate an error between the measured first and second activities **354***a*, **354***b* and/or between the decoded first and second intents **356***a*, **356***b*. For example, the algorithm **350** can deliver one or more control signals to the device upon determining that the calculated error between the first and second decoded intents **356***a*, **356***b* is below a pre-determined error, upon determining that the calculated error is below multiple pre-determined errors, upon determining that multiple calculated errors are below the pre-determined error, upon determining that an average of multiple calculated errors is below the pre-determined error, upon determining that an average of multiple calculated errors is below an average of multiple pre-determined errors, or any combination thereof. The predetermined error or errors can be determined, for example, using prediction class matching and/or instrumented class matching. For example, the prediction class matching can be binary (e.g., classes can be class 1−n, where each class can activate a switch). For example, if the intended class (e.g., the first decoded intent)=the predicted class (e.g., second decoded intent), then the processor can generate and deliver control signals to the device. The instrumented class matching can also be binary but the intended class can instead be provided by an external sensor (e.g., from a proximity sensor or other such device).

(339) FIG. **66** illustrates that the processor can be configured to make a "Yes" and a "No" decision. A "Yes" signal can prompt the processor to transmit one or more control signals to the device to actuate **362** the device. A "No" signal can prompt the processor to return to step **354** of the algorithm **350**. The steps **354**, **356**, **358** of the algorithm **350** can be repeated until at least one control signal is delivered to the device. The algorithm **350** can start **352** automatically when the stent devices **100** are in communication with the devices being controlled, or can be controlled by the user or another party such as a care provider. The algorithm **350** can be used to control one or

more parameters of the device, for example, a first parameter, a second parameter, a third parameter, or more parameters. The parameters can correspond to a position, velocity, or trajectory of the device (e.g., a first parameter can be a position of the device, a second parameter can another position of the device, and a third parameter can be a velocity of the device). As described above, the device can be an exoskeleton, a prosthetic limb, a speller, a wheelchair, a computer, an electrical or electro-mechanical device, or any combination thereof. Additionally, or in combination, the device can be a web browser and/or the device can be in communication with a web browser. For example, the device can be a processor in control of a web browser, the device can have a processor in control of a web browser, the device can be in wired or wireless communication with a processor in control of a web browser, or any combination thereof.

(340) Although not illustrated in FIG. **66**, the algorithm **350** can record more than two neural activities, for example, 3, 4, 5, 6, 7, 8, 9, 10, or more neural activities in 3, 4, 5, 6, 7, 8, 9, 10, or more corresponding neural locations using the first and/or second sensors and/or by using one or more other sensors (e.g., 3, 4, 5, 6, 7, 8, 9, 10, or more other sensors). The algorithm **350** can sense neural signals specific to one or more devices for one or more of the parameters being controlled.

(341) For example, the algorithm **350** can measure one or more third and fourth neural activities. In such a case, the algorithm **350** can prompt the processor to deliver one or more control signals to a device upon confirming in the correlation analysis step **358** that one or more of the fourth measured neural activities are associated with at least one first, second, and/or third intent, upon confirming that multiple fourth neural activities are associated with one or more first, second, and/or third intents, upon confirming that at least one of the one or more fourth neural activities is associated with multiple first, second, and/or third intents, upon confirming that an average of the fourth neural activities is associated with an average of the first, second, and/or third intents, or any combination thereof. The steps **354**, **356**, **358** of the algorithm **350** can be repeated for each neural area being recorded until at least one control signal is delivered to the device.

(342) FIG. **67** illustrates a variation of another algorithm **350** for processing neural signals from two or more neural areas that are received, for example, from one or more stent devices **100**. The algorithm **450** can process the received neural signals to determine whether the signals correspond to a user's intended action. Upon starting at block **452**, the algorithm **450** can record brain signals **454** from multiple neural locations, predict the neural activity **456** of at least one of the measured brain signals **454**, and perform a correlation analysis **458** between at least one of the measured activities and at least one of the predicted activities. For example, FIG. **67** illustrates that the algorithm **450** can record brain signals **454** from a first location **454***a* and a second location **454***b*. The neural activity in different areas can be recorded simultaneously or sequentially relative to activity recorded in one or more other areas (e.g., the signals at the second location **454***b* can be recorded at the same time as the signals at the first location **454***a* or at a later time). The recorded signals **454** can be measured with one or more sensors on one or multiple implants, can be measured with the same or different implants (e.g., first and second stent devices **100**), and can record signals in the brain and/or outside of the brain, for example, as described above with reference to algorithm **350**.

(343) Once the first and second signals **454***a*, **454***b* are received in step **454**, the algorithm **450** can predict **456** the neural activity of one or more of the measured brain signals **454** (e.g., the first and/or second brain signals **454***a*, **454***b*). In the prediction step **456**, activity from one of the measured neural areas can be used to predict **456** the activity in another neural area. Alternatively, or in combination, multiple measured activities of one of the neural areas can be used to predict **456** the activity in another neural area. Alternatively, or in combination, measured activities from multiple neural areas can be used to predict **456** the activity in one or multiple other neural areas. For example, FIG. **67** illustrates that the algorithm **450** can predict **456** the neural activity of the second location **456***b* using the activity measured in the first neural area **454***a*. Other information can also be used to predict neural activities, including neural data stored in the memory described

above with reference to the algorithm **350**.

(344) Once the activity of one of the neural areas is predicted **456** based at least partly on the activity measured **454** in another neural area and/or on stored neural data, the algorithm **450** can perform a correlation analysis **458** to determine whether to actuate **460** or not actuate **462** a device associated with or otherwise controllable by the algorithm **450**. The correlation analysis **458** can ascertain error between one or more of the recorded activities **454** and one or more of the predicted activities **456**. For example, the correlation analysis **458** can calculate an error between the measured first activity **454***a* and a predicted first activity **456***a* and/or between the measured second activity **454***b* and the predicted second activity **456***b*. The predicted first activity **456***a* is not shown in FIG. **67**. This activity can be predicted based on the measured second activity or on any other measured activity different from the measured first activity. Similarly, the predicted second activity can be based on the measured first activity or on any other measured activity different from the measured second activity.

(345) FIG. **67** illustrates that if the correlation analysis **458** determines that the predicted second activity **456***b* is the same as or substantially the same as (also referred to as associated with or substantially associated with) the measured second activity **454***b*, a processor can be programmed to determine the intent **459** of the first and/or second measured activities **454***a*, **454***b* to determine the executed action of the device. The algorithm **450** can then generate one or more control signals configured to actuate **460** the device, for example, in the decoding step **459** or subsequent to the decoding step **459**. Likewise, if the correlation analysis **358** determines that the measured and predicted second activities **454***b*, **456***b* are not associated with one another, the processor can be programmed to not actuate **462** the device. Stated differently, if the algorithm **450** confirms that the measured and predicted second activities **454***b*, **456***b* are associated with one another, one or more control signals can be generated and delivered to the device to actuate **460** the device, after which the algorithm **450** can return to the recording step **454** or end **464**. Likewise, if the algorithm **450** is unable to confirm that the measured and predicted second activities are associated with one another (e.g., if an error is detected between them), the algorithm **450** can proceed to the recording step **454** or end **464** without actuating **462** the device.

(346) For example, the algorithm **450** can determine the intent **459** of the measured activities **454** and/or deliver the one or more control signals to the device upon determining that the calculated error is below a pre-determined error, upon determining that the calculated error is below multiple pre-determined errors, upon determining that multiple calculated errors are below the pre-determined error, upon determining that an average of multiple calculated errors is below the pre-determined error, upon determining that an average of multiple calculated errors is below an average of multiple pre-determined errors, or any combination thereof. The predetermined error or errors can be determined, for example, using prediction class matching and/or instrumented class matching as described above. Here, if the intended class (e.g., the first measured neural activity)=the predicted class (e.g., the predicted neural activity), then the processor can decode one or more of the associated intents in step **459** as described above.

(347) FIG. **67** illustrates that the processor can be configured to make a "Yes" and a "No" decision. A "Yes" signal can prompt the processor to decode **459** the measured first and/or second activities **454***a*, **454***b* and then transmit one or more control signals to the device to actuate **462** the device. A "No" signal can prompt the processor to return to step **454** of the algorithm **450**. The steps **454**, **456**, **458** of the algorithm **450** can be repeated until at least one control signal is delivered to the device. The algorithm **450** can start **452** automatically when the stent devices **100** are in communication with the devices being controlled, or can be controlled by the user or another party such as a care provider. The algorithm **450** can be used to control one or more parameters of the device as described above with reference to algorithm **350**. The device can be an exoskeleton, a prosthetic limb, a speller, a wheelchair, a computer, an electrical or electro-mechanical device, or any combination thereof.

(348) Although not illustrated in FIG. **67**, the algorithm **450** can record more than two neural activities, for example, 3, 4, 5, 6, 7, 8, 9, 10, or more neural activities in 3, 4, 5, 6, 7, 8, 9, 10, or more corresponding neural locations using the first and/or second sensors and/or by using one or more other sensors (e.g., 3, 4, 5, 6, 7, 8, 9, 10, or more other sensors). The algorithm **450** can sense neural signals specific to one or more devices and one or more of the parameters being controlled. For example, the algorithm **350** can measure one or more third and fourth neural activities, and determine one or more intents to control the device. The steps **454**, **456**, **458** of the algorithm **450** can be repeated for each neural area being recorded until at least one control signal is delivered to the device.

(349) FIG. **68** illustrates a variation of an adaptive control algorithm **500** that allows for dual control of a device via both the user and the device itself. The algorithm **500** can enable both machine learning and human learning to occur as opposed to just one or the other. The algorithm **500** can be used alone without another algorithm or with another algorithm, for example, with algorithm **350**, with algorithm **450**, or any combination thereof. For example, the algorithm **500** can be a subroutine of the algorithms **350**, **450**.

(350) As shown in FIG. **68**, the algorithm **500** can start at block **502** and then establish **504** a computer control percentage and a user control percentage that can be subsequently increased and/or decreased, for example, based on a determination of a user's competence or proficiency with the device. When the algorithm **500** is initially started **502**, the computer control percentage can be about 75% to about 100% (e.g., about 95%) and the user control percentage can be about 0% to about 25% (e.g., about 5%). The total percentage of both control percentages added together can be about 100%. Where multiple devices are used or otherwise in neural communication with a user, a separate computer control percentage can be established **504** for each device. Additionally, or in combination, a single computer control percentage can be split among multiple devices and/or among multiple control sources associated with a single device.

(351) The algorithm **500** can be used to adjust the user's and computer's control of one or more parameters of a device. For example, the control of one or more kinematic parameters can be monitored and adjusted by the algorithm **500**, including the control of trajectory, speed, velocity, position, or changes thereof. After the control percentages are set at block **504**, a neural signal associated with a parameter can be recorded **506** and an estimate of the parameter can be obtained **510**. The estimate **510** can be obtained from the device that the user is controlling or trying to control, or can be obtained from another separate device. The neural activity recorded **506** and the machine estimate **510** can be used to decode a user's intent **508**.

(352) Once the user's intent **508** is decoded, a filter (e.g., a Kalman filter) can be trained by executing the parameter **514** (e.g., movement) associated with the decoded neural activity **508**. The filter can be used to calculate an error **516**, for example, an error estimate, by comparing the executed parameter **514** with the decoded intent **508** (also referred to as the decoded parameter **508** or the intended parameter **508**). The calculated error/error estimate **516** can be based at least partly on the decoded and estimated parameters **508**, **510**. The calculated error can correspond to a calculated control correlation (also referred to as a calculated control proficiency) between the measured neural activity **506** and the desired intended parameter **510**. The algorithm **500** can perform the error calculation **516** to determine whether to adjust the user and computer control percentages.

(353) FIG. **68** illustrates that if the error analysis **516** determines that the intended parameter **508** is the same as or substantially the same as the executed parameter **514**, a processor can decrease the computer control percentage **518** and correspondingly increase the user control percentage. Likewise, if the error analysis **516** determines that the intended and executed parameters **508**, **510** are not the same, the processor can be programmed to obtain new neural signals to retrain the user at block **520** and/or increase the computer control percentage and correspondingly decrease the user control percentage. The algorithm **500** can adjust a user control percentage and a computer

control percentage upon determining that the calculated control correlation is below or above a pre-determined error. For example, a processor can increase the user control percentage and decrease the computer control percentage upon determining the calculated control correlation is below the pre-determined. decrease the user control percentage and increase the computer control percentage upon determining that the calculated control correlation is above the pre-determined error or another pre-determined error, vice versa, or any combination thereof. Alternatively, or in combination, the processor can be programmed to provide no adjustment to the user and computer control percentages upon determining the control correlation is above the pre-determined error, above another pre-determined error, below the pre-determined error below another pre-determined error, or any combination thereof. The predetermined error or errors can be determined, for example, using prediction class matching and/or instrumented class matching as described above.

(354) The adaptive training paradigm **500** can gradually and/or rapidly adjust the control percentages by training both the user and the computer. For example, the user and computer control percentages can be adjusted by a processor in percentage increments of about 1% to about 25%, for example, 1% increments, 2% increments, 10% increments, 25% or more increments, or any combination thereof. The algorithm **500** can incrementally increase the user control percentage from an initial percentage of about 0% to about 25% to a final percentage of about 75% to about 100%, with the computer control percentage being correspondingly decreased from an initial percentage of about 75% to about 100% to a final percentage of about 0% to about 25%. For example, the algorithm can start with about a 90% computer control percentage and about a 10% user control percentage, and then can gradually and/or rapidly increase the user's control leading to about 90% or more user control, for example, 100% user control. The algorithm **500** can be iterated from 1 time to 10,000 or more times for the adaptive training to transition from the initial control percentages to the final control percentages. At every change in the user control percentage, the algorithm **500** can be programmed to correspondingly change its error/error estimate calculations. The training can be tailored to each individual whereby the time between algorithm adaptation and user adaptation can be altered.

(355) For example, the time interval between user adaptation and algorithm can be varied based on individual subjects performance. As another example, the signals used for adaptation can be varied. For example the ratio of incorrect predictions to accurate prediction by the algorithm can be varied to optimize accuracy of a subject's or user's control of the external device, or any device or platform linked to the one or multiple implanted stentrodes.

(356) The algorithms **350**, **450**, **500** in FIGS. **66**-**68** can each provide discrete and/or continuous control of the device. The adaptive algorithm **500** in FIG. **68** can enhance user and machine learning and plasticity using one or more stent devices **100** as discussed above. Neural activities can be recorded and the associated intents decoded in algorithms **350**, **450**, **500**, for example, as follows: (1) record the neural signal, filter at about 2 Hz to about 200 Hz, and remove artifacts, (2) obtain features of interest, e.g., power in frequency bands 4 Hz to 12 Hz, 13 Hz to 28 Hz, 29 Hz to 45 Hz, 55 Hz to 80 Hz, 81 Hz to 120 Hz, 121 Hz to 180 Hz, (3) apply a linear regression model to the results, for example, $y(t)=X(t)\times A+E(t)$, where A represents the linear parameters, E(t) is the error term, X(t) is the feature vectors and y(t) is the desired output.

(357) Dual Phased Multipolar Neural Stimulation

(358) The methods, devices, and systems described herein can be capable of providing dual multipolar stimulation to neural tissue. In such variations, the two multipolar signals can be phased with one another to achieve dual phased multipolar stimulation. Dual phased multipolar stimulation can be provided in addition to traditional monopolar, traditional bipolar, and traditional multipolar stimulation. The use of dual phased multipolar stimulation can allow neural tissue to be more accurately targeted, for example, by allowing the stimulation to be focused on one or more regions of neural tissue (e.g., one or more regions in the brain) without affecting other adjacent regions. The location, direction and depth of stimulation can be controlled with dual multipolar stimulation

by focusing one or more currents on a target area, summing one or more of the currents in the target area, and/or adjusting the amplitude of one or more currents. Traditional stimulation techniques that do not allow for current summation. Dual multipolar stimulation can also reduce the stimulation current required to achieve the desired stimulation level by utilizing multiple current sources instead of, for example, just one current source. The total current delivered can be divided among the multiple current sources such that the desired stimulation current is only achieved or is otherwise most focused in the target area. For example, instead of a single current source at full strength, two current sources can be used in a dual phased polar stimulation arrangement where each of the two current sources has half the current strength (50% and 50%) as compared to the current strength of the single current source. However, any percentage current distribution among the two sources is appreciated, for example, 10% and 90%, 20% and 80%, 30% and 70%, 40% and 60%. When the system has multiple current sources (e.g., 2 to 50 or more current sources), one or more of the current sources can have a current strength that is less than the current strength of variations where current summation is not utilized. The current can be distributed among multiple current sources evenly or unevenly such that all the current sources deliver current having the same current strength, or such that at least two current sources deliver current having current strengths different from one another. The multiple current sources can be independent from one another and/or one or more of the current sources can be dependent on one or more other current sources. Dual phased multipolar current delivery can function similar to dual phased multipolar ultrasound delivery.

(359) To stimulate neural tissue, one or more stent devices **100** can be configured to deliver one or more currents to a target area by passing current from one or more current sources to one or more current sinks. Each current source can be distributed among one or more electrodes **131** of a stent device **100**. The current from one or more of the one or more current sources can be steered to or otherwise focused on one or more of the one or more current sinks such that the delivered currents pass through one or multiple target areas. With dual phased multipolar stimulation, the currents in the target areas can sum to achieve the desire stimulation level. For example, FIGS. **69**A-**69**D illustrate a schematic variation of electrodes **131** of a stent device **100** delivering traditional monopolar stimulation **600**_a_ in FIG. **69**A, delivering traditional bipolar stimulation **600**_b_ in FIG. **69**B, delivering traditional multipolar stimulation **600**_c_ in FIG. **69**C, and delivering dual multipolar stimulation **600**_d_ in FIG. **69**D. FIG. **69**E illustrates a schematic variation of electrodes **131**_a_ of a first stent device **100**_a_ and electrodes **131**_b_ of a second stent device **100**_b_ delivering dual multipolar stimulation **600**_e_. The patterns and polarity of the stimulations **600**_a_, **600**_b_, **600**_c_, **600**_d_, **600**_e_ shown in FIGS. **69**A-**69**E are exemplary and illustrate the area of neural activation (also referred to as the current spread). The patterns and polarities of a stimulation can be static or dynamic such that the stimulation being delivered can be held constant or adjusted in real-time, for example, based on a user's responsiveness to the stimulation and/or based on criteria unrelated to a user's responsiveness (e.g., predetermined stimulation times, pre-determined stimulation sequences, pre-determined stimulation strengths). Additionally, or in combination, the patterns and polarities can be pulsed or have another delivery protocol that is variable in nature.

(360) One or more currents can pass through one or multiple target areas and be summed with one or more other currents in each target area that can likewise pass through one or multiple target areas. For example, a first current and a second current can pass through and sum in a target area to a stimulation current. As another example, a first current can pass through a first target area and a second target area, a second current can sum with the first current in the first target area but not in the second target area, and a third current can sum with the first current in the second target area but not in the first target area. The first and second currents can sum to a first stimulation current and the first and third currents can sum to a second stimulation current equal to or different from the first stimulation current.

(361) As described above, the current from one or more of the one or more current sources can be

steered to one or more of the one or more current sinks. Steering can include pulling the current from one or more of the one or more current sources with one or more of the one or more current sinks, where each current sink can be configured to pull current from one or more designated current sources. A designated current source is a current source that is configured to deliver current to one or more specific current sinks. Steering can include pushing the current from one or more of the one or more current sources to one or more of the one or more current sinks, where each current source can be configured to push current to one or more designated current sinks. A designated current sink is a current sink that is configured to receive current from one or more specific current sources. For example, a first current can be delivered to the target area by steering the first current from a first current source to a first current sink or multiple first current sinks.

(362) At least two currents can be simultaneously delivered to a target area via pulling or pushing. For example, two or more of the at least two currents can be steered to the target area such that at least two currents sum in the target area to a stimulation current having an energy sufficient to stimulate neural tissue in the target area. As another example, a first current can be delivered to a target area by steering the first current from a first current source to a first current sink and simultaneously delivering a second current to the target area by steering the second current from a second current source to a second current sink.

(363) The one or more current sources can be independent from one another and the one or more current sinks can be independent from one another.

(364) The devices described herein can have any arrangement of current sources, current sinks, and electrodes. For example, one or more implants (e.g., stent devices **100**) can have one or more current sources and current sinks such that the current sources and current sinks are all on the same implant. In such variations, each implant can have multiple electrodes (e.g., electrodes **131**) where each current source can be one or multiple current source electrodes and each current sink can be one or multiple current sink electrodes. As another example, a first implant (e.g., first stent device **100***a*) can have the one or more current sources and a second implant (e.g., second stent device **100***b*) can have one or more current sinks such that the one or more current sources are on a different implant than the one or more current sinks. In such variations, the first implant can have one or multiple electrodes and each current source can be one or multiple current source electrodes. The second implant can likewise have one or multiple electrodes and each current sink can be one or multiple current sink electrodes. As yet another example, a first implant (e.g., first stent device **100***a*) can have at least one current source and at least one current sink and a second implant (e.g., second stent device **100***b*) can have at least one current source and at least one current sink such that each of the first and second implants have one or more current sources and one or more current sinks. In such variations, the first and second implants can each have electrodes where each current source can be one or multiple current source electrodes and where each current sink can be one or multiple current sink electrodes.

(365) The devices described herein can selectively target, simultaneously or sequentially, one or more target areas by selectively activating one or more of the one or more current sources and/or by selectively activating one or more of the one or more current sinks. For example, the devices described herein can selectively target, simultaneously or sequentially, one or more target areas by selectively activating one or more of the one or more current source electrodes and/or by selectively activating one or more of the one or more current sink electrodes.

(366) When delivering dual phased multipolar stimulation, for example, a first current source can be in a first location and a first current sink can be in a second location. The first location can correspond to a vessel first location and the second location can correspond to a vessel second location. The vessel first location can be in a first vessel and the vessel second location can be in a second vessel different from the first vessel. The vessel first and second locations can be on opposite sides of a plane that passes through the target area.

(367) As another example, a first current source can be in a first location, a second current source

can be in a second location and a first current sink can be in a third location. The first location can correspond to a vessel first location, the second location can correspond to a vessel second location and the third location can correspond to a vessel third location. The vessel first, second and/or third locations can be in the same or different vessels from one another. The vessel first and/or second locations and the vessel third location can be on opposite sides of a plane that passes through the target area.

(368) As yet another example, a first current source can be in a first location, a second current source can be in a second location, a first current sink can be in a third location and a second current sink can be in a fourth location. The first location can correspond to a vessel first location, the second location can correspond to a vessel second location, the third location can correspond to a vessel third location, and the fourth location can correspond to a vessel fourth location. The vessel first, second, third and/or fourth locations can be in the same or different vessels from one another. The vessel first and/or second locations and the vessel third and/or fourth locations can be on opposite sides of a plane that passes through the target area. The vessel first and third locations can be on opposite sides of a first plane that passes through the target area and the vessel second and fourth locations can be on opposite sides of a second plane that passes through the target area.

(369) The devices described herein can be configured to limit a first current to limit a stimulation depth of a first implant and to limit a second current to limit a stimulation depth of a second implant.

(370) As described above, the devices described herein can adjust a strength of at least one of the one or more current sources to adjust a stimulation strength and/or a stimulation depth. Such adjustments can be accomplished by increasing and/or decreasing the amperage of at least one of the one or more current sources and/or by increasing and/or decreasing the number of currents that sum in the target area.

(371) Similarly described above, one or more currents can be sequentially and/or simultaneously delivered to one or multiple target areas by passing current from one or multiple current sources to one or multiple current sinks.

(372) Dual phase multipolar stimulation can be used to target neural tissue anywhere in the body, for example, in and/or outside of the brain including, for example, the cortex, the subcortex, the cerebellum, the thalamus, the brain stem, the spinal cord, organs (e.g., heart, lungs, stomach, kidneys and pancreas), muscles, or any combination thereof. The cortical and subcortical locations can include, for example, the primary motor cortex (M1), the supplementary motor area (SMA), the posterior parietal cortex (PPC), the primary somatosensory cortex (S1), the cerebellum, the thalamus and the brain stem.

(373) Although the foregoing description refers to dual phased multipolar stimulation throughout, any single stent and/or multi-stent n-phased multipolar stimulation can be provided, for example, with one or multiple implants. In addition to dual phase multipolar stimulation, 3-phase, 4-phase, 5-phase, 6-phase, or n+1 phase multipolar stimulation can be delivered to one or more neural target areas. Alternatively, or in combination, the devices described herein can be configured to deliver two or more dual phased multipolar stimulations to one or multiple target areas. For example, FIGS. **70**A-**70**H illustrate schematic variations of stent devices **100** implanted in the brain in various locations delivering various types of stimulation. FIGS. **70**A-**70**H illustrate various MRI images with stent devices **100** delivering neural stimulation.

(374) FIG. **70**A illustrates a stent device **100** located in the superior sagittal sinus delivering monopolar stimulation **700***a*. External return stimulation is also shown.

(375) FIG. **70**B illustrates a stent device **100** located in the superior sagittal sinus delivering bipolar stimulation **700***b*.

(376) FIG. **70**C illustrates a dual stent implementation delivering multipolar stimulation **700***c*. A first stent device (e.g., a first stent **100***a*) is shown located in the superior sagittal sinus and a second stent device (e.g., a second stent **100***b*) is shown located in the inferior sagittal sinus.

(377) FIG. **70**D illustrates a dual stent implementation delivering dual multipolar stimulation **700***d*. A first stent device (e.g., a first stent **100***a*) is shown located in the transverse sinus delivering stimulation **700***d*-**1** and a second stent device (e.g., a second stent **100***b*) is shown located in the pericallosal artery delivering stimulation **700***d*-**2**. The first and second stimulations **700***d*-**1**, **700***d*-**2** can sum where the two stimulations overlap in region **700***d*-**3**. Neural tissue can be stimulated in region **700***d*-**1**, region **700***d*-**2**, and/or region **700***d*-**3**. For example, neural tissue can be stimulated in region **700***d*-**1** but not in the portion of regions **700***d*-**1** and **700***d*-**2** that do not overlap with each other in region **700***d*-**3**. As another example, neural tissue can be stimulated in region **700***d*-**1** at a first stimulation magnitude, in region **700***d*-**2** at a second stimulation magnitude, and in region **700***d*-**3** at a third stimulation magnitude. The first and second stimulation magnitudes can be the same or different from one another. The third stimulation magnitude can be the sum of the first and second stimulation magnitudes that are in the overlap region **700***d*-**3**. The strength of the stimulation delivered by the first and second stents (e.g., **100***a*, **100***b*) can decay as the distance from each respective stent increases, for example, as a result of energy being absorbed by tissue. The stimulation delivered can therefore naturally vary within each stimulation region **700***d*-**1**, **700***d*-**2**, **700***d*-**3**. The stimulation in region **700***d*-**3** can be held substantially constant or can be varied.

(378) FIG. **70**E illustrates a dual stent implementation delivering monopolar stimulation **700***e*. A first stent device (e.g., a first stent **100***a*) is shown located in the superior sagittal sinus and a second stent device (e.g., a second stent **100***b*) is shown located in the inferior sagittal sinus.

(379) FIG. **70**F illustrates a dual stent implementation delivering mono multipolar stimulation **700***f*. A first stent device (e.g., a first stent **100***a*) is shown located in the superior sagittal sinus and a second stent device (e.g., a second stent **100***b*) is shown located in the inferior sagittal sinus.

(380) FIG. **70**G illustrates a dual stent implementation delivering dual multipolar stimulation **700***g*. A first stent device (e.g., a first stent **100***a*) is shown located in the superior sagittal sinus delivering stimulation **700***g*-**1** and a second stent device (e.g., a second stent **100***b*) is shown located in the inferior sagittal sinus delivering stimulation **700***g*-**2**.

(381) FIG. **70**H illustrates a dual stent implementation delivering dual multipolar stimulation **700***h*. A first stent device (e.g., a first stent **100***a*) is shown located in the inferior sagittal sinus delivering stimulation **700***h*-**1** and a second stent device (e.g., a second stent **100***b*) is shown located in the internal carotid artery delivering stimulation **700***h*-**2**.

(382) FIG. **70**I(*a*) illustrates a first stent device **100***a* in a first vessel **800***a* having a first vessel wall **800***aw* and a second stent device **100***b* in a second vessel **800***b* having a second vessel wall **800***bw*, where the first and second stents **100***a*, **100***b* are configured to deliver signals (e.g., stimulation signals) to a target location **802**. For example, the first stent **100***a* can deliver a first stent signal **700***i*-**1** and the second stent **100***b* can deliver a second stent signal **700***i*-**2** to the target location **802**. The signals can be, for example, electrical impulses, ultrasound signals, or both, including any other type of tissue stimulating signals. The signals **700***i*-**1** and **700***i*-**2** can sum in a signal region **804**. The summed signals in the signal region **804** can stimulate tissue. The signal region **804** can be a tissue activation area. The signal region **804** can be a tissue activatable area. Tissue in the activatable area **804** can be activated, for example, when the devices (e.g., **100***a*, **100***b*) deliver or emit a signal or signals toward the target area **802**. When the two signals (e.g., **700***i*-**1**, **700***i*-**2**) add together tissue can be activated, for example, in the signal region **804**. The summed signal in the signal region **804** can be equal to or greater than a neural tissue activation threshold required to activate neurons and/or neuron bundles in the target area **802**. The signal region **804** can be in, can overlap with, or can coincide with some or all of the tissue in the desired target area **802**. As another example, the signal region **804** can be in, can overlap with, or can coincide with some or all of the tissue in an undesired or suboptimal target area **802**, for example, where anatomical constraints, medical conditions (e.g., aneurysms), surgical complications, or other mitigating factors can result in placement of the stent or stents (e.g., devices **100***a*, **100***b*) in the vessel or

vessels in secondary, tertiary or unplanned locations.

(383) Neural tissue inside and/or outside the signal region **804** can be stimulated by the first stent first signal **700***i***-1**, by the second stent signal **700***i***-2**, by the combination of the first and second signals **700***i***-1** and **700***i***-2**, or by any combination thereof. For example, FIG. **70**I(*a*) illustrates that the first and second signals can sum in the signal region **804** to stimulate neural tissue in the target area **802** but that neural tissue outside of region **804** may (e.g., in a device and/or system first variation, for example, the variation shown in FIG. **70**I(*a*)) or may not (e.g., in the device and/or system first variation and/or in a device and/or system second variation) be stimulated by the first and second stents **100***a*, **100***b* outside the signal region **804**. As a first example, FIG. **70**I(*a*) illustrates that the first and second signals can sum in the signal region **804** to stimulate neural tissue in the target area **802** but that neural tissue outside of the signal region **804** is not stimulated by the first and second stents **100***a*, **100***b*. As a second example, FIG. **70**I illustrates that neural tissue in and outside the signal region **804** can be stimulated by the first and second stents **100***a*, **100***b*, whereby the neural tissue outside of the signal summation region **804** can be, for example, stimulated to a lesser extent than the tissue inside the signal region **804**. As a third example, multiple bell-shaped signals or signal spikes (e.g., signals **700***i***-1** and **700***i***-2**) can be delivered from the stents (e.g., **100***a*, **100***b*) to control the shape of the signal summation region **804**, to create multiple signal summation regions **804** (e.g., 2 to 50, 2 to 100, 2 to 1000, including every 1 region increment within these ranges), or both, to achieve the desired shape and/or number of stimulation regions **804**.

(384) The first and second devices **100***a*, **100***b* can have any of the features disclosed, contemplated and/or illustrated herein. The first and second vessels **800***a*, **800***b* can be the same or a different vessel and can be any blood vessel in the body. The target location **802** can be any tissue location disclosed, contemplated and/or illustrated herein. The devices **100***a* and **100***b* can emit signals away from the devices **100***a* and **100***b*, respectively, for example, to stimulate tissue (e.g., tissue in the target area **802**), the devices **100***a* and **100***b* can record signals received from the tissue (e.g., tissue in the target area **802**), or both (e.g., the devices **100***a* and/or **100***b* can stimulate tissue and/or can record signals from tissue).

(385) The devices **100** (e.g., devices **100***a*, **100***b*) can emit signals away from itself, toward itself, or both. The device **100***a* can emit signals toward itself, for example, where the devices (e.g., **100***a*, **100***b*) have a longitudinal curvature such that one or more portions of the device **100** can be oriented or directed to face back onto itself. A longitudinal axis of the device **100***a* can be straight, curved, or both. The device **100***a* can emit signals toward itself, for example, where the device **100***a* has a longitudinal curvature such that one or more first portions of the device **100** (e.g., struts, electrodes) are oriented or directed to face back onto one or more second portions of the device **100** (e.g., struts, electrodes). The energy emitters of the device **100** (e.g., the electrodes of the device **100**) can emit energy at any angle away from the device longitudinal axis, where the device longitudinal axis can be, for example, a center axis through the blood flow channel defined by the device, or as another example, a center axis through one or more of the struts. The energy emitters (e.g., electrodes) can emit energy along an emission axis that extends away from or toward the device longitudinal axis at an emission angle of, for example, about 1 degree to about 360 degrees, including every 1 degree increment within this range (e.g., 15 degrees, 45 degrees, 60 degrees, 75 degrees, 90 degrees, 105 degrees, 120 degrees, 135 degrees, 150 degrees, 165 degrees). The emission axis can intersect with or not intersect with the device longitudinal axis. Although two devices **100***a* and **100***b* and two vessels **800***a* and **800***b* are shown in FIG. **70**I(*a*), the device **100***b* can be a second portion of the device **100***a* in the vessel **800***a* such that the device **100***b* in FIG. **70**I(*a*) is another part of the device **100***a* and such that the blood vessel **800***b* is another portion of the blood vessel **800***a*, for example, where device **100***a* is curved in the vessel **800***a*. In such cases, the device first portion **100***a* can be a first longitudinal end of the device or any segment of the device **100***a* between the first longitudinal terminal end of the device and the second longitudinal

terminal end of the device. The device second portion (illustrated as **100**b in this portion of the detailed description) can be a second longitudinal end of the device or any segment of the device **100**a between the first longitudinal terminal end of the device and the second longitudinal terminal end of the device.

(386) FIG. **70**I(a) further illustrates that some or all of the signal summation region **804** can overlap with the target area **802**. For example, FIG. **70**I(a) illustrates that the signal region **804** can have a signal region first region **804**a, a signal region second region **804**b and a signal region third region **804**c, where the region **804**a is inside the target area **802** and the regions **804**b and **804**c are outside of the target area **802**.

(387) FIG. **70**I(b) illustrates that all of the target area **802** can be within the signal summation region **804**.

(388) FIG. **70**I(c) illustrates that the target area **802** can have the same exact shape and size as the signal summation region **804**. The stent or stents (e.g., **100**a and **100**b) can be controlled to emit signals which sum to approximate the desired shape, size, and number of target areas **802**.

(389) FIG. **70**I(d) illustrates that the one or multiple devices (e.g., stentrodes **100**a, **100**b) can emit multiple bell-shaped signals, signal spikes, signals, or any combination thereof (e.g., signals **700**i-1 and **700**i-2) having different strengths. Multiple signals can be delivered from the stents (e.g., **100**a, **100**b), for example, to control the size and/or shape of the signal summation region **804**, to create multiple signal summation regions **804** (e.g., 2 to 50, 2 to 100, 2 to 1000, including every 1 region increment within these ranges), or both, to advantageously achieve the desired size, shape, and/or number of stimulation regions **804**. For example, FIG. **70**I(d) illustrates that the first stent **100**a can deliver a first stent first signal **700**i-1a and a first stent second signal **700**i-1b to the target location **802** and that the second stent **100**b can deliver a second stent first signal **700**i-2a and a second stent second signal **700**i-2b to the target location **802**. The signals **700**i-1a and **700**i-2a can sum in a first signal region **804**-1. The signals **700**i-1b and **700**i-2b can sum in a second signal region **804**-2. The first signal region **804**-1 can be the same or different size and shape than the second signal region **804**-2. The first and second signal regions **804**-1, **804**-2 can stimulate the same tissue or different tissues (e.g., the same brain regions or different brain regions). The summed signals in the signal regions **804**-1 and **804**-2 can stimulate tissue in these respective regions.

(390) FIG. **70**I(e) illustrates that the signal first and second regions **804**-1, **804**-2 can be different sizes. For example, the second signal region **804**-2 is shown larger than the first signal region **804**-1.

(391) FIG. **70**I(f) illustrates that the one or multiple devices (e.g., stentrodes **100**a, **100**b) can stimulate multiple target areas **802** (e.g., 2 to 10 target areas, 2 to 100 target areas, 2 to 1000 target areas, including every 1 target area increment within these ranges, for example, a first target). For example, the first and second devices **100**a, **100**b can stimulate a first target area **802**-1 and the first and second devices **100**a, **100**b can stimulate a second target area **802**-2. For example, the first and second devices **100**a, **100**b can sum in a first activation region **804**-1 and in a second activation region **804**-2.

(392) FIG. **70**(g) illustrates that the stimulation system can include three or more stentrode devices, for example, stent **100**a, **100**b and **100**c, where a signal from the first stent **100**a can sum with the signals from the second stent **100**b and/or from the third stent **100**c, where a signal from the second stent **100**b can sum with the signals from the first stent **100**a and/or from the third stent **100**c, and where a signal from the third stent **100**c can sum with the signals from the first stent **100**a and/or from the second stent **100**b. For example, FIG. **70**I(g) illustrates that the first stent first signal **700**i-1a can sum with the second stent signal **700**i-2 and that the first stent second signal **700**i-1b can sum with a third stent signal **700**i-3.

(393) Although two devices **100**a and **100**b and two vessels **800**a and **800**b are shown in FIGS. **70**I(a)-**70**(g), the device **100**b can be a second portion of the device **100**a in the vessel **800**a such that the device **100**b in these figures is another part of the device **100**a and such that the blood

vessel **800***b* is another portion of the blood vessel **800***a*, for example, where device **100***a* is curved in the vessel **800***a*. In such cases, the device first portion **100***a* can be a first longitudinal end of the device or any segment of the device **100***a* between the first longitudinal terminal end of the device and the second longitudinal terminal end of the device. The device second portion (illustrated as **100***b* in this portion of the detailed description) can be a second longitudinal end of the device or any segment of the device **100***a* between the first longitudinal terminal end of the device and the second longitudinal terminal end of the device.

(394) Each stent device in FIGS. **70**A-**70**H is shown schematically as four dots, with the exception of FIG. **70**D in which the illustrated stent devices are each shown schematically as three dots. The various stimulation patterns **700***a*-**700***h* shown in FIGS. **70**A-**70**I(*g*) are exemplary and illustrate the area of neural activation (also referred to as the current spread). The stimulation patterns **700***a*-**700***h* illustrated by the shaded regions in FIGS. **70**A-**70**H are exemplary cross-sectional schematic variations of a portion of the three-dimensional current spread being delivered by the illustrated stent devices **100**. The stimulation patterns in FIGS. **70**I(*a*)-(*g*) are likewise exemplary. FIGS. **70**A-**70**H illustrate that one or multiple neural areas can be targeted simultaneously. As described above, the patterns and polarities of a stimulation can be static or dynamic such that the stimulation being delivered can be held constant or adjusted in real-time, for example, based on a user's responsiveness to the stimulation and/or based on criteria unrelated to a user's responsiveness (e.g., predetermined stimulation times, pre-determined stimulation sequences, pre-determined stimulation strengths). Additionally, or in combination, the patterns and polarities can be pulsed or have another delivery protocol that is variable in nature. The energy emitted from a first device in these figures can sum with energy emitted from a second device to activate tissue (e.g., in any of the configurations shown in FIGS. **70**A-**70**H). As another example, the energy emitted from the devices shown in FIGS. **70**A-**70**H can activate tissue with or without the emitted energy from the different energy sources (e.g., devices **100**) summing together, for example, from multiple devices **100** (e.g., a first device, a second device, a third device, or more devices, or any combination thereof). For example, where there are multiple summation regions **804**, these multiple regions can be stimulated independently from one another, sequentially, simultaneously, or any combination thereof, for example, over an energy delivery period.

(395) FIG. **71**A illustrates an exemplary heat map **805***a* when the device or devices (e.g., **100***a*, **100***b*) stimulate tissue with monopolar stimulation, where the heat map **805***a* shows large current spreads (e.g., the darker areas).

(396) FIG. **71**B illustrates an exemplary heat map **805***b* when the device or devices (e.g., **100***a*, **100***b*) stimulate tissue with dual multipolar stimulation, where the heat map **805***b* shows focal current distributions, for example, showing a focused current distribution **806**. Focused current distributions can advantageously allow more focused treatment of subjects and give more granularity to subjects in regards to control and accuracy, for example, when compared to the monopolar stimulation heat map **805***a* of FIG. **71**A. The focused current distributions that the device or devices (e.g., **100***a*, **100***b*) can provide can advantageously give subjects more control and/or more accurate control of the external devices or systems linked to their one or more stentrodes (e.g., **100***a*, **100***b*).

(397) The heat maps **805***a* and **805***b* can be the heat maps in the target area **802**. The heat maps **805***a* and **805***b* can be the heat maps in the signal summation regions **804**. The heat maps **805***a* and **805***b* can be the heat maps that span the target area **802** inside and outside of the signal summation regions **804**.

(398) Power Generation

(399) The devices described herein (e.g., the stent devices **100**) can be powered with blood flow, thermoelectricity, electromagnetism, piezoelectricity, or any combination thereof.

(400) Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention.

(401) The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form of suggestion that the prior art forms part of the common general knowledge in Australia

(402) In this specification and the claims that follow, unless stated otherwise, the word "comprise" and its variations, such as "comprises" and "comprising", imply the inclusion of a stated integer, step, or group of integers or steps, but not the exclusion of any other integer or step or group of integers or steps.

(403) References in this specification to any prior publication, information derived from any said prior publication, or any known matter are not and should not be taken as an acknowledgement, admission or suggestion that said prior publication, or any information derived from this prior publication or known matter forms part of the common general knowledge in the field of endeavor to which the specification relates.

(404) Any elements described herein as singular can be pluralized (i.e., anything described as "one" can be more than one). Like reference numerals in the drawings indicate identical or functionally similar features/elements. Any species element of a genus element can have the characteristics or elements of any other species element of that genus. Some elements may be absent from individual figures for reasons of illustrative clarity. The above-described configurations, elements or complete assemblies and methods and their elements for carrying out the disclosure, and variations of aspects of the disclosure can be combined and modified with each other in any combination. All dimensions shown in the drawings are exemplary.

Claims

1. A method of controlling an apparatus in communication with a brain machine interface, the method comprising: measuring a first neural activity in a first neural area associated with a first intent to control the apparatus, where measuring the first neural activity comprises using a first sensor; measuring a second neural activity in a second neural area using a second sensor; and delivering, via a processor, one or more control signals to the apparatus upon confirming that the second neural activity is associated with the first intent, where the first neural area is different than the second neural area.

2. The method of claim 1, further comprising: decoding, via the processor, the first intent from the measured first neural activity; and decoding, via the processor, a second intent from the measured second neural activity, where the delivering comprises delivering the one or more control signals to the apparatus upon confirming that the second is associated with the first intent.

3. The method of claim 2, where decoding the first and second intents comprises referencing previously measured neural activities stored in a memory.

4. The method of claim 1, further comprising repeating the measuring until at least one of the one or more control signals is delivered to the apparatus.

5. The method of claim 1, where the delivering comprises delivering the one or more control signals to the apparatus to control a first parameter and/or a second parameter of the apparatus.

6. The method of claim 1, where the first sensor is proximate or in a first neural area and where the second sensor is proximate or in a second neural area.

7. The method of claim 6, where the first and second neural areas are in a brain.

8. The method of claim 1, further comprising: determining a desired parameter of the apparatus; calculating a control correlation between the measured first neural activity and the desired parameter; and adjusting a user control percentage and a computer control percentage of the apparatus.

9. The method of claim 8, where the adjusting comprises increasing the user control percentage and decreasing the computer control percentage and/or where the adjusting comprises decreasing the user control percentage and increasing the computer control percentage.

10. A method of positioning an electrode array device for detecting, measuring, recording, stimulating, decoding, and/or modulating brain activity of a brain, the method comprising: providing a scaffold comprising one or more substrate members, the one or more substrate members embedded with conductive materials configured to be in electrical communication with an external device, the scaffold attached to a communication conduit that facilitates communication between conductive materials and a control unit; and delivering a flexible hollow delivery instrument through a vessel, the flexible hollow delivery instrument configured to translate the scaffold and its one or more substrate members from the vessel to a target location within a deposition point of the brain; wherein the scaffold the one or more substrate members are configured to be confined to a small volume for containment in the flexible hollow delivery instrument during translation to the deposition point; deploying the one or more substrate members to the deposition point such that the one or more substrate members are further configured to expand over a selected area such that the conductive materials electrically couple with a neural tissue at the deposition point while the communication conduit remains within the vessel; and where the external device and the conductive materials are configured for the transfer of electrical signals between the deposition point of the brain and the external device.

11. The method of claim 10, the conductive materials are further configured to enable sensing and relaying of cortical activity neural activity.

12. The method of claim 10, wherein the external device is a brain-computer interface.

13. The method of claim 10, further comprising an implantable wireless receiver configured to enable wireless communication with the external device.

14. The method of claim 10, wherein the flexible hollow delivery instrument comprises a catheter system.

15. The method of claim 14, wherein the scaffold is configured to be compressed into the catheter system and can be expanded after deployment from the catheter system.

16. The method of claim 10, wherein the deposition point is a motor cortex.

17. The method of claim 10, wherein the deposition point is a sensory cortex.

18. The method of claim 10, wherein the deposition point is a brain structure.

19. The method of claim 10, wherein the vessel comprises a jugular vein.

20. The method of claim 10, wherein the scaffold comprises a supporting substrate comprising a super-elastic material.