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(54) Three-dimensional neural probe microelectrode array

Dreidimensionale Nervensondenmikroelektrodenanordnung und Verfahren zur Herstellung

Réseau de microélectrodes de sonde neurale tridimensionnelle et procédé de fabrication

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(73) Proprietor: **NeuroNexus Technologies, Inc.**
Ann Arbor, MI 48108 (US)

(72) Inventors:
- **Vetter, Rio J.**
  Van Buren, MI 48111 (US)
- **Hetke, Jamille Farraye**
  Brooklyn, MI 49203 (US)
- **Pellinen, David S.**
  Ann Arbor, MI 48103 (US)
- **Suwarato, Bencharong**
  Ann Arbor, MI 48105 (US)
- **Kong, Kc**
  Ann Arbor, MI 48103 (US)

(74) Representative: **Schwabe - Sandmair - Marx**
Patentanwälte Rechtsanwalt
Partnerschaft mbB
Joseph-Wild-Straße 20
81829 München (DE)

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to the field of devices used for neural interventions.

2. Prior Art

[0002] The conventional method used to interface the nervous system includes a multi-contact electrode array. Electrode arrays are designed to transmit signals into the tissue ("stimulation") or extract signals from the tissue ("sense"). These electrode arrays are commonly used in neuroscience and neurophysiological research as well as in clinical therapeutic applications. Often, a precise volume of tissue in the peripheral nervous system or in the central nervous system is the target for placement of the electrode array. Additionally, it is desirable to interface with the targeted volume in three-dimensions. Commercially available electrode arrays are limited in their ability to position electrode contacts in a three-dimensional arrangement. Two examples are the planar silicon array, often referred to as the "Michigan Probe" and an alternative silicon-based technology referred to as the "Utah Array". The Michigan Probe is limited to positioning electrode contacts in a two-dimensional arrangement, all within a single plane. The Utah Array is also limited to positioning electrode contacts in a two-dimensional plane. Moreover, electrode contacts in a Utah Array are limited to placement on the tip of each electrode shank.

[0003] The document US 2005/283,203 A1 discloses devices, systems and methods for a neural access device that includes an implant which transcutaneously exits the skin of a patient and provides transport of signals between a sensor implanted in a patient and an external device. The transcutaneous implant has integrated features to provide reduced risk of injury due to mechanical forces as well as electrostatic discharge energy applied to the external portion of the device.

[0004] The present invention presents a method for creating a true three-dimensional arrangement of electrode contacts using two or more two-dimensional planar silicon microelectrode arrays. The planar electrode arrays are aligned in rows to provide a three-dimensional tissue interface. There is prior art where researchers have constructed three-dimensional microelectrode arrays using various methods, but the present invention is a novel approach using a multitude of planar neural electrode probes combined to make a customizable and scalable three-dimensional array.

SUMMARY OF THE INVENTION

[0005] The present invention is defined in claim 1 with preferred embodiments defined in the claims dependent thereon.

[0006] The present invention seeks to prevent the array from being damaged during shipping and subsequent assembly of the electronics housing to the skull mounting plate.

[0007] There is further disclosed a structure for stimulation and sensing of neurophysiological signals from an array of microelectrode contacts positioned in a three-dimensional arrangement. This provides a "richer" communication pathway to and from the neural circuit of interest.

[0008] The primary advantage is that the present invention describes a method of creating a three-dimensional electrode tissue interface using multiple neural probe electrode arrays consisting of two or more planar probes arranged in side-by-side electrically connected to flexible ribbon cables. The multiple neural probe electrode arrays are supported by a pedestal to thereby provide a plurality of neural electrode probes in an "x" and "y" configuration, for example a 4 x 4 array of neural electrode probes. Additionally, each probe has a number of stimulation or sensing electrodes along its "z" length. This effectively provides a three-dimensional stimulation or sensing

array. Any one of a number of neural electrode arrays can be designed for a desired application. In that respect, the present invention leverages a long standing history of a proven technology (i.e., planar neural electrode probes, but arranged into an x, y and z configuration) and is a method that is scalable and customizable with regards to the geometry, size and number of electrode contacts.

[0009] A three dimensional electrode array configuration is important for many reasons. One example is when considering interfacing with the cortex where neurons are structured in an inhomogeneous manner that differs anatomically and physiologically across ventral/dorsal and medial/lateral directions. Neurons in the cortex are generally oriented vertically. Being able to arrange electrode contacts across depths provides more tolerance in positioning to help ensure that a richest signal can be obtained. This also allows positioning of electrode contacts at multiple points along a single neuron, for example spanning the distance from a particular neuron's cell body to its respective dendritic tree. Neurons in the cortex are organized in columns where cells within a specific column perform similar functions and these functions may differ between columns. Therefore, a three-dimensional arrangement (x, y and z) of contacts has the ability to span multiple neuronal columns.

[0010] These and other objects will become apparent to one of ordinary skill in the art by reference to the following description and the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a perspective view of a neural probe electrode array system 10 according to the present invention.

FIG. 1A is a perspective view of the neural probe electrode array system 10 shown in FIG. 1 mounted to a skull 150 adjacent to a craniotomy opening 202.

FIG. 2 is a perspective view of a skull mounting plate 12 of the neural probe system 10.

FIG. 3 is a perspective view showing an electronics housing 14 separated from the skull mounting plate 12 of the neural probe system 10.

FIG. 4 is a perspective view of an exemplary embodiment of a neural probe electrode assembly 18 according to the present invention.

FIGs. 5 and 6 are front elevational views of exemplary neural probe electrode arrays 78A and 92, respectively.

FIG. 7 is an exploded view of a 4 x 4 neural probe electrode assembly 18 according to the present invention.

FIGs. 8 and 9 are photographs showing rivets connecting the bond pads of a neural electrode probe 100 to a ribbon cable 102.

FIG. 10 is a perspective view of a neural probe electrode assembly 18 according to the present invention.

FIG. 11 is a perspective view of neural probe electrode array system 10 shown in FIG. 1 just prior to removal of the electrode assembly 18 from its cradle 56 on the electronics housing 14.

FIG. 12 is a perspective view of the neural probe electrode array system 10 shown in FIG. 11, but with the electrode assembly 18 removed from cradle 56.

FIG. 13 is a perspective view of the neural probe electrode array system 10 shown in FIG. 12 and with the electrode assembly 18 attached to an actuatable vacuum insertion tool 128.

FIG. 14 is a perspective view of the neural probe electrode array system 10 shown in FIG. 13, as the electrode assembly 18 would be positioned in body tissue.

FIGs. 15 and 16 are perspective views of the neural probe system 10 shown in FIG. 14, but with the shipping cover 52 being removed and replaced by permanent cover 136.

FIGs. 17 to 21 illustrate of an exemplary process for manufacturing the platform 76 for the neural probe assembly 18.

FIGs. 22 to 26 illustrate an exemplary process for manufacturing a cover for the platform 76 shown in FIGs. 4, 7 and 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Turning now to the drawings, FIG. 1 is a perspective view of a neural probe electrode array system 10 according to an embodiment of the present invention.

[0013] The neural probe system 10 comprises a skull mounting plate 12 supporting an electronics housing 14. A flexible ribbon cable 16 connects from electronics (see connectors 134A to 134D in FIGs. 15 and 16) in the housing 14 to a neural probe electrode assembly 18. A neural probe electrode assembly 18 according to the present invention includes at least one, and preferably a plurality of neural probe electrode arrays as exem-plified in FIGs. 5 and 6. The housing 14 further includes wires 19 for grounding the subject. These wires not only ground the animal, but may be used as a reference when performing differential recording, or as a return path for current when stimulating.

[0014] FIG. 2 illustrates the skull mounting plate 12 comprising a curved mount body 20 supporting a plurality of extending legs 22. The curved body 20 is a dome-shaped member having a plurality of first, unthreaded openings 24 adjacent to a perimeter 26 thereof. Preferably the first openings 24 are at regularly spaced intervals. Legs 22 extend from the perimeter 26 and provide a number of second, unthreaded openings 28. While not necessary, the second openings 28 are illustrated as being spaced at regular intervals along the length of each leg 22. Seven legs 22 are shown, but that is not necessary. There can be more or less than that number of legs.

[0015] FIG. 2 further illustrates that first screws 30 are received in the first unthreaded openings 24 in the dome-shaped body 20 and second screw 32 are received in the second unthreaded openings 28 in the legs 22. Moreover, the second screws 32 can be positioned in any one of the three second openings 32 of each leg 22. Leg 22A shows screw 32A positioned in a first leg opening 28A adjacent to the mount body 20, leg 22B shows screw 32B positioned in a second opening 28B and leg 22C shows screw 32C positioned in a third, most distal opening 28C. If desired, the legs 22 can be cut to shorten their lengths and thereby eliminate some or all of the leg openings 28 as desired for a particular surgical procedure. FIG. 1 shows an exemplary embodiment where the skull mounting plate is devoid of any legs 22. The legs 22 can also be bent to match the curvature of a skull.

[0016] It is noted that the length of first screws 30 is desirably somewhat longer than that of the second screws 32. The first screws 30 are of a sufficient length to provide first threads screwed into the skull or cranium bone to accommodate for the offset distance of the mount body 20 from a skull as a result of its dome shape. That is in comparison to the legs 22, which are relatively closely spaced to the skull. In any event, screws 30, 32 have threads that are configured for threading into the skull 150 (FIG. 1A). In one embodiment according to the present invention, the first screws 30 are 2.4 mm wide x 6 mm long and the second screws 32 are 2 mm wide x 4 mm long. The screws 30, 32 are preferably titanium.

[0017] The skull mounting plate 12 has a cylindrical-shaped pedestal 34 extending upwardly from the dome-shaped mount body 20. A U-shaped yoke 36 is supported on an upper face of the pedestal 34. A threaded opening

38 is provided into the depth of each arm 36A, 36B of the yoke. There is also a threaded opening 40 extending into the depth of each arm 36A, 36B adjacent to the pedestal 34. Preferably, the threaded openings 38 and 40 do not intersect each other.

[0018] FIG. 3 illustrates the electronics housing 14 just prior to being mounted to the skull mounting plate 12. In one embodiment according to the present invention, the electronics housing 14 is a rectangular-shaped member of a biocompatible metal, such as titanium. As those of skill in the art will readily understand, the shape of electronics housing 14 illustrated in the drawings is exemplary and should not limit the scope of the present invention. Other shapes for the electronics housing 14 may be desired for a particular surgical procedure or application.

[0019] In the illustrated embodiment, the electronics housing 14 comprises right and left sidewalls 42 and 44 meeting front and back sidewall 46 and 48, all extending to a bottom wall 50 and a top wall 51 (FIGs. 15 and 16). A shipping cover plate 52 is temporarily secured to the upper edges of the right, left, front and back sidewalls using screws 54 threaded into receptacles therein.

[0020] The shipping cover plate 52 supports a cradle 56 for the neural probe assembly 18. The cradle 56 comprises spaced apart webs 58 and 60 that are aligned perpendicular to the front sidewall 46. Enlarged portions of the webs 58, 60 extending out past the front sidewall 46 support a guard bar 62 received in openings in the webs 58, 60. The guard bar 62 has an L-shaped end 62A that nests in a recess 58A of web 58 (FIG. 11). The L-shaped end 62A acts as a stop so that the guard bar 62 cannot be moved completely through the web openings.

[0021] A shaped secondary cover 64 is supported on the cradle 56 by screws 66 threaded into the shipping cover plate 52. With the secondary cover 64 mounted to the shipping cover plate 52 over cradle 56, there is a forwardly facing opening 68 underneath guard bar 62. The significance of opening 68 will be described in detail hereinafter.

[0022] FIG. 3 further illustrates the electronics housing 14 just prior to it being mounted on the cylindrical pedestal 34 of the skull mounting plate 12. The bottom wall 50 of the electronics housing 14 has an opening (not shown) configured to receive the yoke 36. With the electronics housing 14 supported on the skull mounting plate 12, screws 70 are received through oversized openings 70A (FIGs. 11 to 14) in the cover plate 52 and threaded into openings 38 in the yoke arms 36A, 36B adjacent to the cylindrical pedestal 34. That way, the cover plate 52 can be removed from the housing 14 without having to disconnect the electronics housing from the skull mounting plate 12.

[0023] Those skilled in the art will readily understand that the electronics housing 14 can be secured to the skull mounting plate 12 by means other than screws 70 threaded into the yoke 36. For example, the yoke could be replaced with a threaded post and the housing could have a matching opening in its bottom wall for threadingly connecting the housing 14 to the mounting plate 12. A ball and detent connection can also be used.

[0024] A silicone gasket 72 is disposed between the electronics housing and the skull mounting plate. That is for the purpose of providing a fluid barrier as well as cushioned connection between the housing 14 and pedestal 34. The gasket 72 also serves as a barrier when skin is cinched up against the pedestal 34, but underneath the electronics housing 14 during a surgical procedure.

[0025] FIG. 4 is an enlarged view of the ribbon cable 16 connected to a neural probe electrode assembly 18. The ribbon cable is designed to be flexible so that the neural probe electrode assembly is virtually untethered from the electronics housing. This allows the neural probe electrode assembly to "float" with the brain during brain pulsation or brain shift. The ribbon cable may be a thin-film based cable like those made from polyimde, parylene, or silicone with embedded conductors (e.g., gold, platinum, etc.).

[0026] The neural probe electrode assembly 18 comprises a probe platform 76 supporting a plurality of neural probe electrode arrays. Four neural probe electrode arrays 78A, 78B, 78C and 78D are shown with each array having four neural probes 80A, 80B, 80C and 80D.

[0027] FIG. 5 shows that the exemplary thin-film neural probe electrode array 78A comprises a proximal bond pad plate 82 (e.g., titanium/gold stack) connected to buried conductive traces that run along each shank 90A, 90B, 90C and 90D (e.g., titanium/gold/platinum stack) to connect to the electrode contacts 88 (e.g., titanium/gold/platinum stack).

[0028] The bond pad plate has an upper edge 82A spaced from a lower edge 82B, both the upper and lower edges meeting spaced apart right and left edges 82C and 82D. A step 84A resides where the right edge 82C meets the lower edge 82B. An opposed step 84B resides where the left edge 82D meets the lower edge 82B. Plate 82 supports a plurality of bond pads 86 that are electrically connected to a respective one of the plurality of electrodes 88 supported on a shank by buried conductive traces. The exemplary neural probe electrode array 78A has four equally spaced apart shanks 90A, 90B, 90C and 90D extending distally from the plate 82. The shanks are of equal lengths.

[0029] While not shown in the drawing, each thin-film neural probe electrode array according to the present invention is comprised of multiple metal traces and electrode sites. As many as 100 conductive traces and electrode sites can be realized on an array that is as narrow as 30 microns and as thin as 6 microns. In order to be strong enough to be inserted into tissue, these neural probe electrode arrays must be either integrated during fabrication on a carrier that provides strength, or attached to a strengthening carrier post-fabrication. If the strengthening carrier is stiff, the electrode array can be inserted into tissue along a desired axial direction of a guiding element. Moreover, the electrode array shanks have pointed tips, which help reduce the tissue resistance to insertion.

[0030] FIG. 6 illustrates another embodiment of a neural probe electrode array 92 comprising a bond plate 94 supporting bond pads 96. Four equally spaced apart electrode shanks 98A, 98B, 98C and 98D depend from the bond plate. In this exemplary array, the shanks are of unequal lengths. Those skilled in the art will readily understand that a neural probe array according to the present invention can have more or less than four electrode shanks. If there are two or more shanks, but not one, they can be of the same or different lengths. If there are three or more electrode shanks, but not two or one, they can be equally or unequally spaced apart from each other. Moreover, any one shank can support more or less electrodes 88 than another shank.

[0031] FIG. 7 is an exploded view illustrating a 4 x 4 neural probe electrode assembly 18 (four neural probes having four electrode shanks each). The first neural probe array 100 has four electrode shanks 100A extending from bond plate 100B. Bond plate 100B supports bonds pads 100C which are physically and electrically connected to cable bond pads 102A at a distal end of a first flexible ribbon cable 102. The second neural probe array 104 has four electrode shanks 104A extending from bond plate 104B. Bond pads 104C supported on plate 104B are physically and electrically connected to cable bond pads 106A at a distal end of a second flexible ribbon cable 106. The third neural probe array 108 has four electrode shanks 108A extending from bond plate 108B. Bond pads 108C supported on plate 108B are physically and electrically connected to cable bond pads 110A at a distal end of a third flexible ribbon cable 110. Finally, the fourth neural probe array 112 has four electrode shanks 112A extending from bond plate 112B. Bond pads 112C supported on plate 112B are physically and electrically connected to cable bond pads 114A at a distal end of a fourth flexible ribbon cable 114.

[0032] Referring back to FIG. 4, the probe platform 76 of the neural probe electrode assembly 18 comprises right and left sidewalls 76A and 76B extending to distal and proximal sidewalls 76C and 76D. The sidewalls 76A, 76B, 76C and 76D extend to an upper face wall 76E and a lower face wall 76F. There are four slots 116, 118, 120 and 122 extending through the thickness of the platform from the upper face wall 76E to the lower face wall 76F thereof. The slots are aligned parallel to each other and to the distal and proximal sidewalls 76C, 76D. The four slots extend to, but do not meet the right and left sidewalls 76A, 76B. While four slots are shown, that is by way of example. Moreover, the slots need not be parallel to each other. Instead, they can be aligned at an angle other than 180° with respect to each other.

[0033] Slot 116 is exemplary of the other slots. It comprises a proximal slot portion 116A of a width extending toward the right and left sidewalls 76A, 76B that is longer than the width of a distal slot portion 116B. However the proximal slot portion 116A is of a lesser depth measured along axis A-A intersecting the distal and proximal sidewalls 76C, 76D than the depth of distal slot portion 116B.

[0034] With reference to the exemplary schematic shown in FIG. 7, FIGs. 8 and 9 are photographs showing rivets connecting the bond pads 100C on bond plate 100B of neural electrode probe array 100 to the cable bond pads 102A at the distal end of ribbon cable 102. The increased width of the distal slot portion 116B accommodates these rivet connections when the neural probe array 100 is seated into slot 116. Moreover, the distal slot portion 116 extends completely through the thickness of the platform, but the proximal slot portion 116A does not. The steps 84A, 84B of bond plate 82 (FIG. 8) register where the proximal and distal slot portions 116A, 116B meet inside the platform 76. In this position, the neural probe array 100 is aligned perpendicular to axis A-A. With the first to fourth neural probes 78A, 78B, 78C and 78D received in the respective first, second, third and fourth slots 116, 118, 120 and 122 in platform 76, the respective neural probe flexible ribbon cables 102, 106, 110 and 112 lay over the upper platform face wall 76E.

[0035] Referring to FIG. 11, locating slots (not shown) are provided in the webs 58, 60 of the cradle 56. Spaced apart locating ears 124A and 124B are supported on the left and right sidewalls 76A, 76B of the platform 76. A cover 126 is mounted on the upper cover wall 78E to protect the connection between bond plates 100B, 106B, 110B and 114B and their respective ribbon cables 102, 106, 110 and 114.

[0036] FIG. 12 illustrates the neural probe electrode array system 10 at the beginning of a surgical procedure. The flexible ribbon cable 16 has its proximal end 16A extending through the face wall 46 to physically and electrically connect to electronic circuits in the housing 14. The distal end of ribbon cable 16 physically and electrically connects to the respective neural probe electrode arrays 100, 104, 108 and 112. Prior to implanting the neural probe electrode assembly 18 into brain tissue, the electrode assembly is nested in the cradle 56 between the spaced apart webs 58, 60. The guard bar 62 blocks the neural probe electrode assembly 18 from inadvertently falling out of the cradle 56 while the secondary cover 64 prevents the array from being damaged during shipping and subsequent assembly of the electronics housing 14 to the skull mounting plate 12.

[0037] As shown in FIG. 1A, the mounting plate 12 is secured to the skull 150 adjacent to the access opening 202. That is done using screws 30 and 32 received into the unthreaded openings 24 and 28 of the respective dome-shaped mount body and legs 20, 22. The screws are then threaded into the skull 150. As previously described, the electronics housing 14 is secured to the skull mounting plate 12 with screws 70 received through oversized openings 70A in the cover plate 52 and threaded into openings 38 in the yoke arms 36A, 36B.

[0038] With the electronics housing 14 fixedly secured to the mounting plate 12, the neural probe electrode array 18 is ready for implantation into the brain. The secondary cover 64 is removed from the electronics housing 14 by unthreading screws 66 from the housing cover plate 52. The guard bar 62 is manipulated in a direction to remove the L-shaped end 62A from recess 58A in web 58 until the bar is clear of the opening 68 between the webs 58, 60. A pair of tweezers or a similar type tool is used to grab the ribbon cable 16 adjacent to the neural probe electrode assembly 18 and move the cable and electrode assembly out of the cradle 56. The neural probe electrode assembly 18 is turned upside down to access the back face of a platform 76 for the assembly.

[0039] FIG. 1A is a schematic view of the neural probe electrode array system 10 mounted to a skull 150 adjacent to a craniotomy opening 202 during a surgical procedure.

[0040] An actuatable vacuum insertion tool 128 is maneuvered to grab onto the cove 126 of the platform 76. The insertion tool 128 is a computer-controlled, microsite machine that provides for accurate and controlled insertion of the neural array 18 into the brain tissue. The motor for the insertion tool 128 is designed for fifty millimeters of movement with step depths as small as 0.5 μm. The insertion speed and acceleration are also adjustable.

[0041] FIG. 14 shows the neural probe electrode assembly 18 as it will appear once insertion into brain tissue is complete. The durotomy and craniotomy are then closed using conventional techniques. Cinching and suturing of skin are performed over the dome-shaped mount body 20 and around the pedestal 34 and underneath gasket 72. A cable guard 130 is secured to the electronic housing 14 using screws 132 extending through openings 132A in face wall 46 and threaded into openings 40 in the arms 36A, 36B of yoke 36.

[0042] FIG. 15 illustrates the electronics housing 14, but with the shipping cover plate 52 removed. That is done by unthreading screws 54 from receptacles in the upper edges of the right, left, front and back sidewalls 42, 44, 46 and 48. Four connector assemblies 134A, 134B, 134C and 134D are shown housed inside the housing 14. These connector assemblies serve as interfaces from the respective neural probe electrode assemblies 78A, 78B, 78C and 78D to any one of a number of external devices. Suitable external device include, but are not limited to, a printed circuit board with or without on-board integrated circuits and/or on-chip circuitry for signal conditioning and/or stimulus generation, an Application Specific Integrated Circuit (ASIC), a multiplexer chip, a buffer amplifier, an electronics interface, an implantable rechargeable battery, integrated electronics for either real-time signal processing of the input (recorded) or output (stimulation) signals, integrated electronics for control of a fluidic component, integrated electronics for control of a light source for delivery of light for optogenetic applications, or any other suitable electrical subsystem, or any combination thereof.

[0043] Since there is no longer a need to cradle the electrode assembly 18, the shipping cover 52 including its cradle 56 is no longer needed. FIG. 16 shows that the shipping cover 52 is replaced with a top cover 136. The top cover 136 is used throughout the surgical procedure.

[0044] Upon completion of the surgical procedure, the skull mounting plate 12 can be removed from the skull or left in place, affixed to the skull . The latter might be desirable if it is determined that a different electronics housing 14 including the flexible cable 16 connected to a different neural probe assembly 18 is desired. For example, that could be for the purpose of using a different neural stimulation protocol or a different configuration for the neural probe arrays comprising the neural probe assembly 18.

[0045] FIGs. 17 to 21 illustrate of an exemplary process for manufacturing the platform 76 for the neural probe assembly 18. The process begins with an SOI (silicon-on-insulator) wafer 200, preferably about 500 μm thick. A photo mask (not shown) having interior outlines of the shapes of the respective slots 116, 118, 120 and 122 and their relative orientation to each other is first provided on the upper and lower surfaces of the wafer 200. Wafer 200 consists of a first silicon layer 202, preferably about 100 μm thick, supported on a buried oxide layer 204. The oxide layer 304 is from about 0.5 to 1 μm thick and is sandwiched between the first layer 202 and a second silicon layer 206, which is preferably about 400 μm thick (FIG. 17).

[0046] FIG. 18 shows that the first silicon layer 202 has undergone a reactive ion etch (dry etch) to remove portions of the dielectric material, leaving the buried oxide layer 204 exposed between the spaced apart silicon portions 202A and 202B.

[0047] In FIG. 19, the patterned silicon layer 202 supported on the oxide layer 204 is turned upside down and temporarily supported on a carrier wafer 208. In FIG. 20, the second silicon layer 206 and the oxide layer 204 are subjected to a further reactive ion etch process. This serves to pattern the second silicon layer into sections 206A, 206B and the oxide layer into corresponding sections 204A, 204B. Relatively thin oxide layers 204A, 204B are supported on the first silicon layers 202A, 202B. As shown, the outer edges of the respective first silicon layer 202, oxide layer 204 and second silicon layer 206 are aligned with each other. This defines previously described the right and left sidewalls 76A, 76B for the platform. Moreover, the inner edges of the first silicon layer and the oxide layer are aligned, but spaced from the inner edge of the second silicon layer. This serves to define where the steps 84A, 84B of the bond pad plate 82 for the exemplary neural probe array 78A reside in the finished neural assembly 18.

[0048] FIG. 21 is a cross-sectional view along line 21-21 of FIG. 4 that shows the finished platform section 210 comprising the shaped first silicon layer 202, oxide layer 204 and second silicon layer 206 after having been released from the carrier 208. That is done by dissolving the carrier in a suitable solvent. The resulting open area designated 116 is the slot shown in FIG. 4. The other slots 118, 120 and 122 are manufactured at the same time from the SOI wafer 200. FIG. 21 further illustrates the exemplary thin-film neural probe electrode array 78A in phantom as it would be positioned in slot 116.

[0049] FIGs. 22 to 26 illustrate an exemplary process for manufacturing another embodiment of a cover for the platform 76 shown in FIGs. 4, 7 and 10. The process is similar to that described with respect to FIGs. 17 to 21 for manufacturing the platform 76 and begins with an SOI (silicon-on-insulator) wafer 300, preferably about 500 μm thick. The wafer 300 consists of a first silicon layer 302, preferably about 100 μm thick, supported on an oxide layer304. The oxide layer 304 is from about 0.5 to 1 μm thick. The oxide layer is sandwiched between the first layer 302 and a second silicon layer 306, preferably about 400 μm thick (FIG. 22).

[0050] FIG. 23 shows the first silicon layer 302 after having been subjected to a reactive ion etch (dry etch) to remove selected portions thereof. Oxide layer portions 304A and 304B are exposed on opposite sides of a central portion 302. The exposed oxide surfaces 304A, 304B extend to respective edges 306A and 306B of the second silicon layer 306.

[0051] FIG. 24 shows that the wafer consisting of the patterned first silicon layer 302 intermediate the oxide layer 304 after having been turned upside down and supported on a carrier wafer 308.

[0052] In FIG. 25, the second silicon layer 306 and the oxide layer 304 are subjected to a further reactive ion etch process. This defines upstanding protrusions 306A and 306B supported on oxide layers 304A and 304B. These structures serve as sidewalls for the cover. The carrier wafer 308 is released from the first silicon layer 302 to thereby provide the product cover. If desired, the upstanding protrusions 306A, 306B and their supporting oxide layers 304A, 304B can be eliminated. In that case, a cover similar to that designated as 126 in FIGs. 7 and 10 is the result.

[0053] Thus, a three-dimensional neural probe electrode array system is provided. The system consists of an electronics housing that can be detachably mounted to a skull mounting plate affixed to a skull adjacent to a craniotomy. A neural probe assembly connected to the housing consists of a platform supporting a plurality of planar neural probe arrays. When a plurality of two-dimensional neural probe arrays are supported in the platform, the result is a three-dimensional configuration of stimulation and recording electrodes that can be configured for a particular application or surgical procedure. The detachable electronics housing means that, if desired, one neural probe assembly can be changed out for another.

[0054] While this invention has been described in conjunction with preferred embodiments thereof, it is evident that the present invention is defined by the appended claims.

Claims

1. A neural probe electrode system (10), which comprises:

    a) a skull mounting plate (12), comprising:

        i) a mount body (20) configured to be supported on the skull of a subject; and
        ii) at least two first openings (24) extending through the mount body (20); and

    b) at least two first threaded screws (30) configured for registry in the at least two first openings (24) of the mount body (20) to threadingly mount the skull mounting plate (12) to a skull;
    c) a housing (14) configured to house electronics and to be detachably supported on the skull mounting plate (12) ;
    d) an electrical cable (16) extending from a proximal cable portion having a proximal cable end to a distal cable end, wherein the proximal cable end is detachably electrically connected to the electronics housed in the housing (14) with the proximal cable portion extending through an opening in the housing (14);
    e) at least one neural probe electrode assembly (18) comprising a proximal probe end spaced from a distal probe portion having a distal probe end, wherein the proximal probe end is electrically connected to the distal cable end and wherein the distal probe portion has at least one neural probe electrode array configured for electrical stimulation of body tissue or recording of biological characteristics of the body tissue; and
    f) a cradle (56) supported on the housing (14), wherein the at least one neural probe electrode array is configured to be nested in the cradle (56) prior to placement in a body tissue;
    g) wherein after the housing (14) is supported on the skull mounting plate (12) mounted to a skull by the at least two first screws (30) received in respective ones of the at least two first openings (24) and threaded into the skull, the at least one neural probe electrode array is accessible from outside the housing (14) for placement in a body tissue.

2. The neural probe system (10) of claim 1, wherein the mount body (20) has a dome shape.

3. The neural probe system (10) of claim 1, wherein the skull mounting plate (12) has at least one leg (22) extending outwardly from a perimeter of the mount body (20); preferably wherein the at least one leg (22) is bendable; and/or
wherein the at least one leg (22) has at least one second opening for receiving a second screw con-

figured for threading into a skull; more preferably wherein the at least two first openings (24) of the mount body (20) and the at least one second opening (28) of the at least one leg (22) are unthreaded; and/or
wherein the first screws (30) are longer than the second screw (32) .

4. The neural probe system (10) of any one of the claims 1 to 3, wherein a pedestal (34) extending upwardly from the mount body (20) supports a yoke (36) configured for detachable attachment to the housing (14); preferably
wherein the yoke (36) comprises spaced apart upwardly extending arms (36A, 36B) and wherein the arms have threaded openings for receiving screws to secure the housing (14) to the skull mounting plate (12).

5. The neural probe system (10) of any one or more of claims 1 to 4, wherein a gasket (72) resides between the housing (14) mounted to the skull mounting plate (12).

6. The neural probe system (10) of any one or more of claims 1 to 5, wherein the at least one neural probe electrode array comprises at least one electrode shank (90) extending distally from a bond plate, and wherein the shank (90) supports the at least one electrode; preferably
wherein the bond plate supports at least one first bond pad electrically connected to the at least one electrode; more preferably
wherein the at least one first bond pad supported on the bond plate is physically and electrically connected to a second bond pad at a distal end of the electrical cable; even more preferably
wherein the first bond pad is physically and electrically connected to the second bond pad by a rivet.

7. The neural probe system (10) of claim 6, wherein the at least one neural probe electrode assembly (18) comprises a platform comprising a sidewall providing a thickness extending to spaced apart upper and lower face walls, wherein a slot (116) extending through the thickness of the platform receives the bond plate of the at least one neural probe electrode array with the electrode shank (90) extending distally below the lower face wall; preferably
wherein the slot (116) has a first slot portion in open communication with a second slot portion, and wherein the first slot portion has a greater width, but a lesser depth perpendicular to the width than the second slot portion; and/or
wherein there are at least two slots (116) through the thickness of the platform, each slot (116) supporting a neural probe electrode array, and wherein the two slots (116) are parallel or not parallel to each other.

8. The neural probe system (10) of claim 6, wherein the at least one neural probe has at least three electrode shanks (90) extending distally from the bond plate (94); preferably
wherein the at least three electrode shanks (90) are of similar or dissimilar lengths.

9. The neural probe system (10) of claim 6, wherein the at least one neural probe electrode array has at least four electrode shanks (90) extending distally from the bond plate (94), and wherein the shanks (90) are either evenly or unevenly spaced apart from each other.

10. The neural probe system (10) of claim 7, wherein with the neural probe electrode array received in the slot (116), a rivet connecting the first bond pad on the bond plate to the second bond pad at the distal end of the electrical cable resides in the depth of the second slot portion.

11. The neural probe system (10) of claim 1, wherein the housing (14) comprises a bottom wall supporting a sidewall extending to an upper sidewall edge.

12. The neural probe system (10) of claim 11, wherein a detachable cover (126) is supported on the upper sidewall edge for providing access to the electronics housed in the housing (14) .

13. The neural probe system (10) of claim 12, wherein the cradle (56) is supported on the cover (126).

Patentansprüche

1. Neuronales Sonden-Elektroden-System (10), welches umfasst:

(a) eine Schädel-Befestigungs-Platte (12), umfassend

(i) einen Befestigungskörper (20), der dafür konfiguriert ist, auf dem Schädel einer Person getragen zu sein; und
(ii) wenigstens zwei erste Öffnungen (24), die sich durch den Befestigungskörper (20) erstrecken; und

(b) wenigstens zwei erste Gewinde-Schrauben (30), die konfiguriert sind für einen Eintrag in die wenigstens zwei ersten Öffnungen (24) des Befestigungskörpers (20), um die Schädel-Befestigungs-Platte (12) an einem Schädel zu befestigen;
(c) ein Gehäuse (14), das dafür konfiguriert ist,

elektronische Bauteile unterzubringen und abnehmbar an der Schädel-Befestigungs-Platte (12) anzubringen;

(d) ein elektrisches Kabel (16), das sich von einem proximalen Kabel-Teil, der ein proximales Kabel-Ende aufweist, zu einem distalen Kabel-Ende erstreckt, wobei das proximale Kabel-Ende entfernbar elektrisch verbunden ist mit den elektronischen Bauteilen, die in dem Gehäuse (14) untergebracht sind, wobei sich der proximale Kabel-Teil durch eine Öffnung in dem Gehäuse (14) erstreckt;

(e) wenigstens eine neuronale Sonden-Elektroden-Anordnung (18), die ein proximales Sonden-Ende umfasst, das von einem distalen Sonden-Teil beabstandet ist, der ein distales Sonden-Ende aufweist, wobei das proximale Sonden-Ende elektrisch verbunden ist mit dem distalen Kabel-Ende und wobei der distale Sonden-Teil wenigstens eine neuronale Sonden-Elektroden-Anordnung aufweist, die konfiguriert ist für eine elektrische Stimulation von Körpergewebe oder für ein Aufzeichnen biologischer charakteristischer Eigenschaften des Körpergewebes;

(f) eine Wiege (56), die auf dem Gehäuse (14) angeordnet ist, wobei die wenigstens eine neuronale Sonden-Elektroden-Anordnung dafür konfiguriert ist, vor dem Platzieren in einem Körpergewebe in der Wiege (56) eingebettet zu sein;

(g) wobei, nachdem das Gehäuse (14) auf der Schädel-Befestigungs-Platte (12) angeordnet wurde, die an einem Schädel durch die wenigstens zwei ersten Schrauben (30) montiert wird, die in jeweils einzelne der wenigstens zwei ersten Öffnungen (24) aufgenommen werden und in den Schädel eingeschraubt werden, die wenigstens eine neuronale Sonden-Elektroden-Anordnung von außerhalb des Gehäuses (14) für ein Platzieren in einem Körpergewebe zugänglich ist.

2. Neuronales Sonden-System (10) nach Anspruch 1, wobei der Befestigungskörper (20) Kuppelform hat.

3. Neuronales Sonden-System (10) nach Anspruch 1, wobei die Schädel-Befestigungs-Platte (12) wenigstens ein Bein (22) aufweist, das sich von einem Umfang des Befestigungskörpers (20) nach außen erstreckt; vorzugsweise wobei das wenigstens eine Bein (22) biegbar ist; und/oder wobei das wenigstens eine Bein (22) wenigstens eine zweite Öffnung zum Aufnehmen einer zweiten Schraube aufweist, die konfiguriert ist zum Schrauben in einen Schädel; noch mehr bevorzugt wobei die wenigstens zwei ersten Öffnungen (24) des Befestigungskörpers (20) und die wenigstens eine zweite Öffnung (28) des wenigstens einen Beins (22) ohne Gewinde sind; und/oder wobei die ersten Schrauben (30) länger sind als die zweite Schraube (32).

4. Neuronales Sonden-System (10) nach irgendeinem der Ansprüche 1 bis 3, wobei ein Podest (34), das sich von dem Befestigungskörper (20) nach oben erstreckt, einen Bügel (36) trägt, der konfiguriert ist für ein lösbares Befestigen an dem Gehäuse (14); vorzugsweise wobei der Bügel (36) voneinander beabstandete, sich nach oben erstreckende Arme (36A, 36B) umfasst und wobei die Arme mit Gewinde versehene Öffnungen zum Aufnehmen von Schrauben zum Befestigen des Gehäuses (14) an der Schädel-Befestigungs-Platte (12) aufweisen.

5. Neuronales Sonden-System (10) nach irgendeinem der Ansprüche 1 bis 4, wobei sich eine Dichtung (72) zwischen dem Gehäuse (14) befindet, das an der Schädel-Befestigungs-Platte (12) befestigt ist.

6. Neuronales Sonden-System (10) nach irgendeinem der Ansprüche 1 bis 5, wobei die wenigstens eine neuronale Sonden-Elektroden-Anordnung wenigstens einen Elektroden-Schenkel (90) umfasst, der sich distal von einer Bindungsplatte erstreckt, und wobei der Schenkel (90) die wenigstens eine Elektrode trägt; vorzugsweise wobei die Bindungsplatte wenigstens ein erstes Bindungspolster trägt, das elektrisch mit der wenigstens einen Elektrode verbunden ist; mehr bevorzugt wobei das wenigstens eine erste Bindungspolster, das auf der Bindungsplatte getragen wird, physisch und elektrisch mit einem zweiten Bindungspolster an einem distalen Ende des elektrischen Kabels verbunden ist; noch mehr bevorzugt wobei das erste Bindungspolster physisch und elektrisch mit dem zweiten Bindungspolster über eine Niete verbunden ist.

7. Neuronales Sonden-System (10) nach Anspruch 6, wobei die wenigstens eine neuronale Sonden-Elektroden-Anordnung (18) eine Plattform umfasst, die eine Seitenwand umfasst, die eine Dicke bereitstellt, die sich zu voneinander beabstandeten oberen und unteren Frontwänden erstreckt, wobei ein Spalt (116), der sich durch die Dicke der Plattform erstreckt, die Bindungsplatte der wenigstens einen neuronalen Sonden-Elektroden-Anordnung aufnimmt, wobei sich der Elektroden-Schenkel (90) distal unterhalb der unteren Frontwand erstreckt; vorzugsweise wobei der Spalt (116) einen ersten Spalt-Teil in offener Verbindung mit einem zweiten Spalt-Teil aufweist und wobei der erste Spalt-Teil eine größere Breite, jedoch eine geringere Tiefe senkrecht zu der Breite als der zweite Spalt-Teil aufweist; und/oder wobei es wenigstens zwei Spalte (116) durch die Dicke der Plattform gibt, wobei jeder Spalt (116) eine neuronale Sonden-Elektroden-Anordnung trägt und wobei die beiden Spalte (116) parallel zueinander oder nicht parallel zueinander sind.

8. Neuronales Sonden-System (10) nach Anspruch 6, wobei die wenigstens eine neuronale Sonde wenigstens drei Elektroden-Schenkel (90) aufweist, die sich distal von der Bindungsplatte (94) erstrecken; vorzugsweise wobei die wenigstens drei Elektroden-Schenkel (90) von ähnlicher oder unähnlicher Länge sind.

9. Neuronales Sonden-System (10) nach Anspruch 6, wobei die wenigstens eine neuronale Sonden-Elektroden-Anordnung wenigstens vier Elektroden-Schenkel (90) aufweist, die sich distal von der Bindungsplatte (94) erstrecken, und wobei die Schenkel (90) entweder gleich oder ungleich voneinander beabstandet sind.

10. Neuronales Sonden-System (10) nach Anspruch 7, wobei sich dann, wenn die neuronale Sonden-Elektroden-Anordnung in dem Spalt (116) aufgenommen ist, eine Niete, die das erste Bindungspolster auf der Bindungsplatte mit dem zweiten Bindungspolster an dem distalen Ende des elektrischen Kabels verbindet, in der Tiefe des zweiten Spalt-Teils befindet.

11. Neuronales Sonden-System (10) nach Anspruch 1, wobei das Gehäuse (14) eine Bodenwand umfasst, die eine Seitenwand trägt, die sich zu einer oberen Seitenwand-Kante erstreckt.

12. Neuronales Sonden-System (10) nach Anspruch 11, wobei eine abnehmbare Abdeckung (126) auf der oberen Seitenwand-Kante abgestützt ist, um einen Zugang zu den elektronischen Bauteilen bereitzustellen, die in dem Gehäuse (14) untergebracht sind.

13. Neuronales Sonden-System (10) nach Anspruch 12, wobei die Wiege (56) auf der Abdeckung (126) angebracht ist.

Revendications

1. Système d'électrodes de sonde neuronale (10) qui comporte :

a) une plaque de montage crânien (12), comportant :

i) un corps de montage (20) configuré pour être soutenu par le crâne d'un sujet ; et
ii) au moins deux premières ouvertures (24) s'étendant à travers le corps de montage (20) ; et

b) au moins deux premières vis filetées (30) configurées pour s'inscrire dans les au moins deux premières ouvertures (24) du corps de montage (20) pour monter la plaque de montage crânien (12), par filetage, sur un crâne ;
c) un boîtier (14) configuré pour accueillir des équipements électroniques et pour être soutenu de manière détachable par la plaque de montage crânien (12) ;
d) un câble électrique (16) s'étendant depuis une partie de câble proximale ayant une extrémité de câble proximale jusqu'à une extrémité de câble distale, où l'extrémité de câble proximale est électriquement connectée, de manière détachable, à l'équipement électronique logé dans le boîtier (14), la partie de câble proximale s'étendant à travers une ouverture dans le boîtier (14) ;
e) au moins un ensemble d'électrode de sonde neuronale (18) comportant une extrémité de sonde proximale espacée d'une partie de sonde distale ayant une extrémité de sonde distale, où l'extrémité de sonde proximale est électriquement connectée à l'extrémité de câble distale et où la partie de sonde distale présente au moins un réseau d'électrodes de sonde neuronale configuré pour la stimulation électrique de tissus corporels ou l'enregistrement de caractéristiques biologiques du tissu corporel ; et
f) un berceau (56) soutenu par le boîtier (14), où l'au moins un réseau d'électrodes de sonde neuronale est configuré de manière à être emboîté dans le berceau (56) avant le placement dans un tissu corporel ;
g) où, une fois que le boîtier (14) est soutenu par la plaque de montage crânien (12) montée sur un crâne au moyen des au moins deux premières vis (30) reçues respectivement dans une des au moins deux premières ouvertures (24) et vissées dans le crâne, l'au moins un réseau d'électrodes de sonde neuronale est accessible depuis l'extérieur du boîtier (14) pour être placé dans un tissu corporel.

2. Système de sonde neuronale (10) selon la revendication 1, dans lequel le corps de montage (20) a la forme d'un dôme.

3. Système de sonde neuronale (10) selon la revendication 1, dans lequel la plaque de montage crânien (12) comporte au moins une patte (22) s'étendant vers l'extérieur depuis un périmètre du corps de montage (20) ; où l'au moins une patte (22) est de préférence flexible ; et/ou
où l'au moins une patte (22) comporte au moins une seconde ouverture destinée à recevoir une seconde vis configurée pour être vissée dans un crâne ; où, plus préférablement,
les au moins deux premières ouvertures (24) du

corps de montage (20) et l'au moins une seconde ouverture (28) de l'au moins une patte (22) ne sont pas filetées ; et/ou
où les premières vis (30) sont plus longues que les secondes vis (32).

4. Système de sonde neuronale (10) selon l'une quelconque des revendications 1 à 3, dans lequel un socle (34) s'étendant vers le haut à partir du corps de montage (20) soutient un étrier (36) configuré pour être attaché de manière détachable au boîtier (14) ;
où l'étrier (36) comporte de préférence des bras (36A, 36B) espacés s'étendant vers le haut et où les bras ont des ouvertures filetées pour recevoir des vis pour fixer le boîtier (14) à la plaque de montage crânien (12).

5. Système de sonde neuronale (10) selon l'une quelconque ou plusieurs des revendications 1 à 4, dans lequel un joint (72) se trouve entre le boîtier (14) et la plaque de montage crânien (12) sur laquelle il est monté.

6. Système de sonde neuronale (10) selon l'une quelconque ou plusieurs des revendications 1 à 5, dans lequel l'au moins un réseau d'électrodes de sonde neuronale comporte au moins une tige d'électrode (90) s'étendant distalement à partir d'une plaque de raccord, et où la tige (90) soutient l'au moins une électrode ;
où la plaque de raccord soutient de préférence au moins un premier bloc de raccord électriquement connecté à l'au moins une électrode ;
où l'au moins un premier bloc de raccord soutenu par la plaque de raccord est plus préférablement physiquement et électriquement connecté à un second bloc de raccord au niveau d'une extrémité distale du câble électrique ;
où le premier bloc de raccord est encore plus préférablement connecté physiquement et électriquement au second bloc de raccord par un rivet.

7. Système de sonde neuronale (10) selon la revendication 6, dans lequel l'au moins un ensemble d'électrodes de sonde neuronale (18) comporte une plateforme comportant une paroi latérale ayant une épaisseur s'étendant jusqu'à des parois de face supérieure et inférieure espacées, où une fente (116) s'étendant à travers l'épaisseur de la plateforme reçoit la plaque de raccord de l'au moins un réseau d'électrodes de sonde neuronale avec la tige d'électrode (90) s'étendant distalement sous la paroi de face inférieure ;
où la fente (116) présente de préférence une première partie de fente en communication ouverte avec une seconde partie de fente, et où la première partie de fente présente une plus grande largeur mais une plus petite profondeur perpendiculairement à la largeur que la seconde partie de fente ; et/ou
où il existe au moins deux fentes (116) traversant l'épaisseur de la plateforme, chaque fente (116) soutenant un réseau d'électrodes de sonde neuronale, et où les deux fentes (116) sont parallèles ou ne sont pas parallèles l'une à l'autre.

8. Système de sonde neuronale (10) selon la revendication 6, dans lequel l'au moins une sonde neuronale comporte au moins trois tiges d'électrode (90) s'étendant distalement à partir de la plaque de raccord (94) ;
où les au moins trois tiges d'électrode (90) ont de préférence des longueurs similaires ou non similaires.

9. Système de sonde neuronale (10) selon la revendication 6, dans lequel l'au moins un réseau d'électrodes de sonde neuronale comporte au moins quatre tiges d'électrode (90) s'étendant distalement à partir de la plaque de raccord (94), et où les tiges (90) sont espacées l'une de l'autre de manière régulière ou irrégulière.

10. Système de sonde neuronale (10) selon la revendication 7, dans lequel, quand le réseau d'électrodes de sonde neuronale est reçu dans la fente (116), un rivet connectant le premier bloc de raccord sur la plaque de raccord au second bloc de raccord au niveau de l'extrémité distale du câble électrique se situe dans la profondeur de la seconde partie de fente.

11. Système de sonde neuronale (10) selon la revendication 1, dans lequel le boîtier (14) comporte une paroi inférieure soutenant une paroi latérale s'étendant jusqu'à un bord supérieur de paroi latérale.

12. Système de sonde neuronale (10) selon la revendication 11, dans lequel un capot détachable (126) est soutenu par le bord supérieur de paroi latérale pour donner accès à l'équipement électronique logé dans le boîtier (14).

13. Système de sonde neuronale (10) selon la revendication 12, dans lequel le berceau (56) est soutenu par le capot (126).

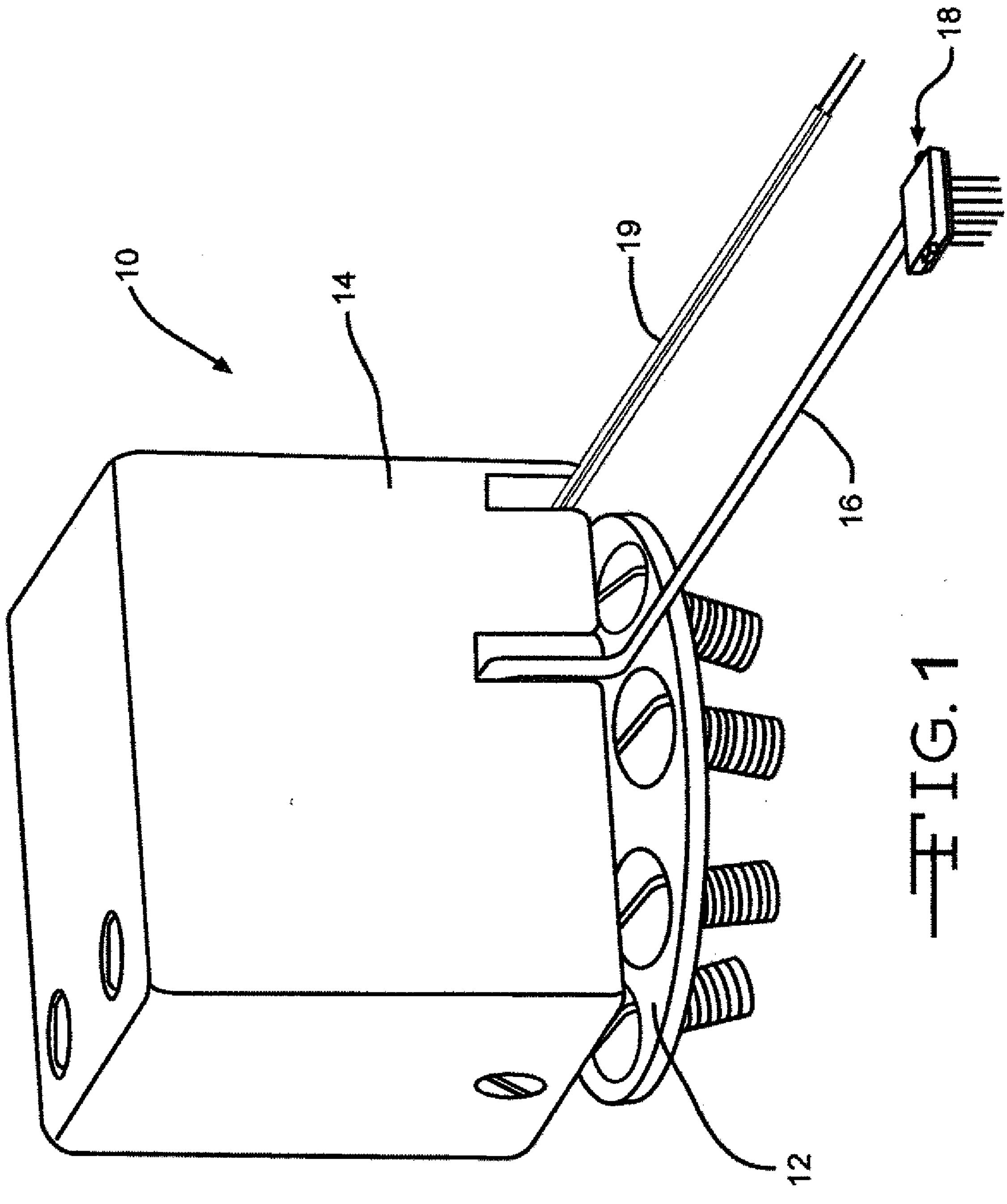


FIG. 1

FIG. 1A

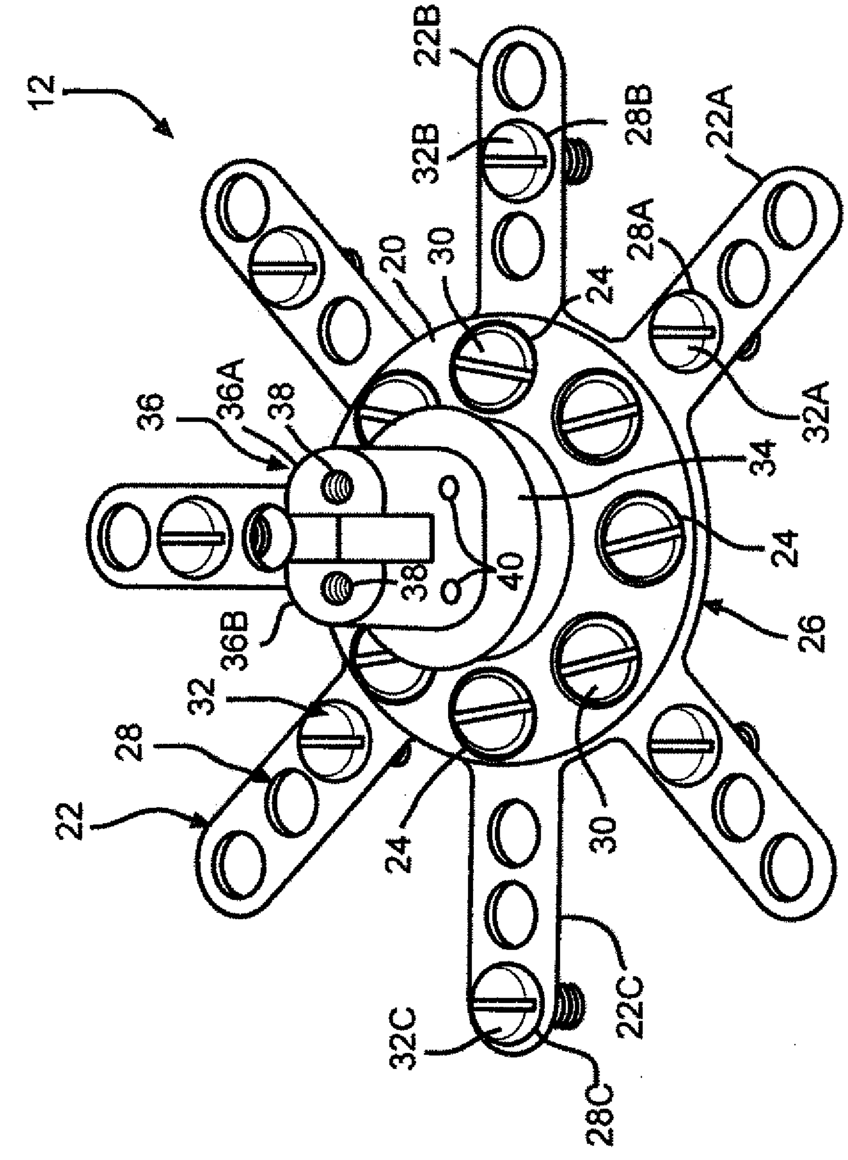
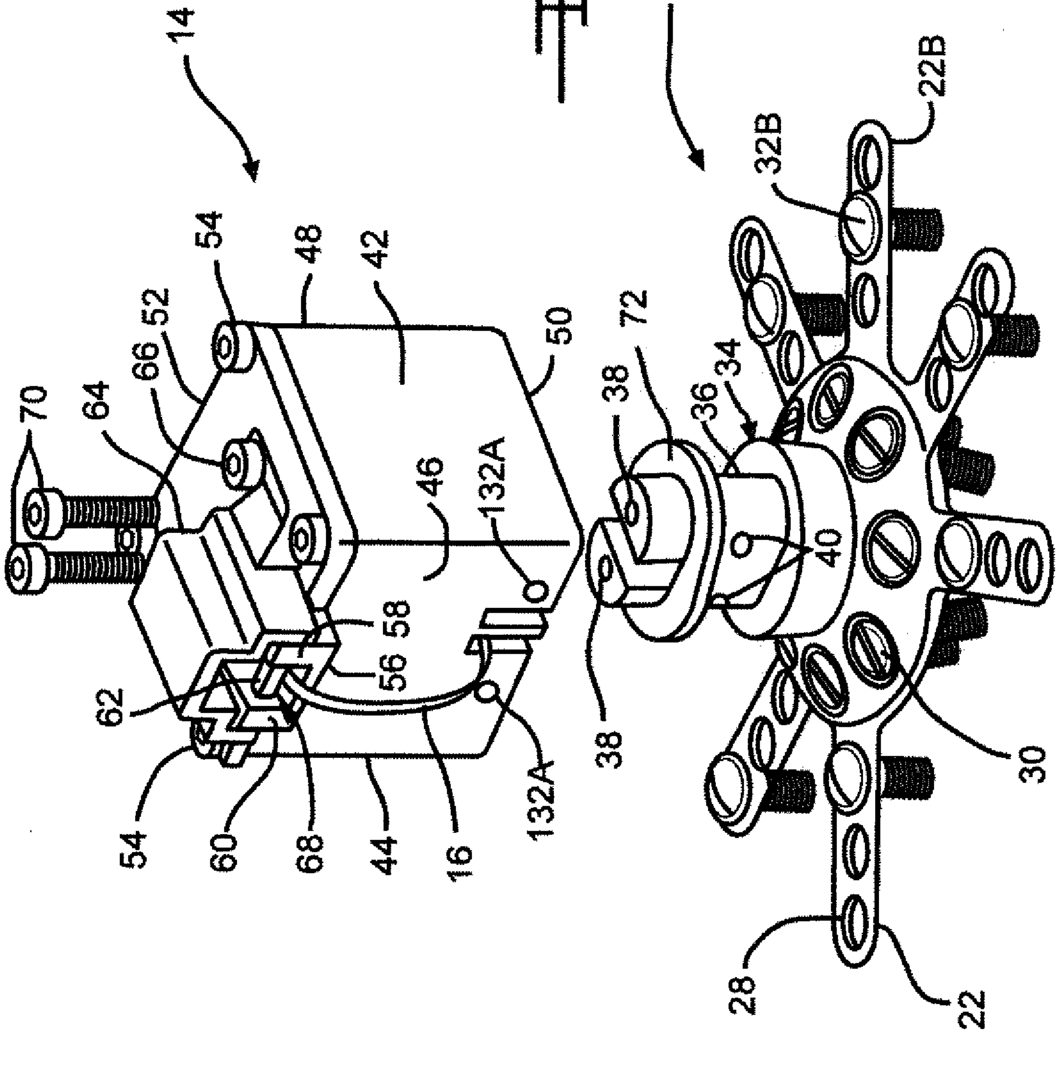
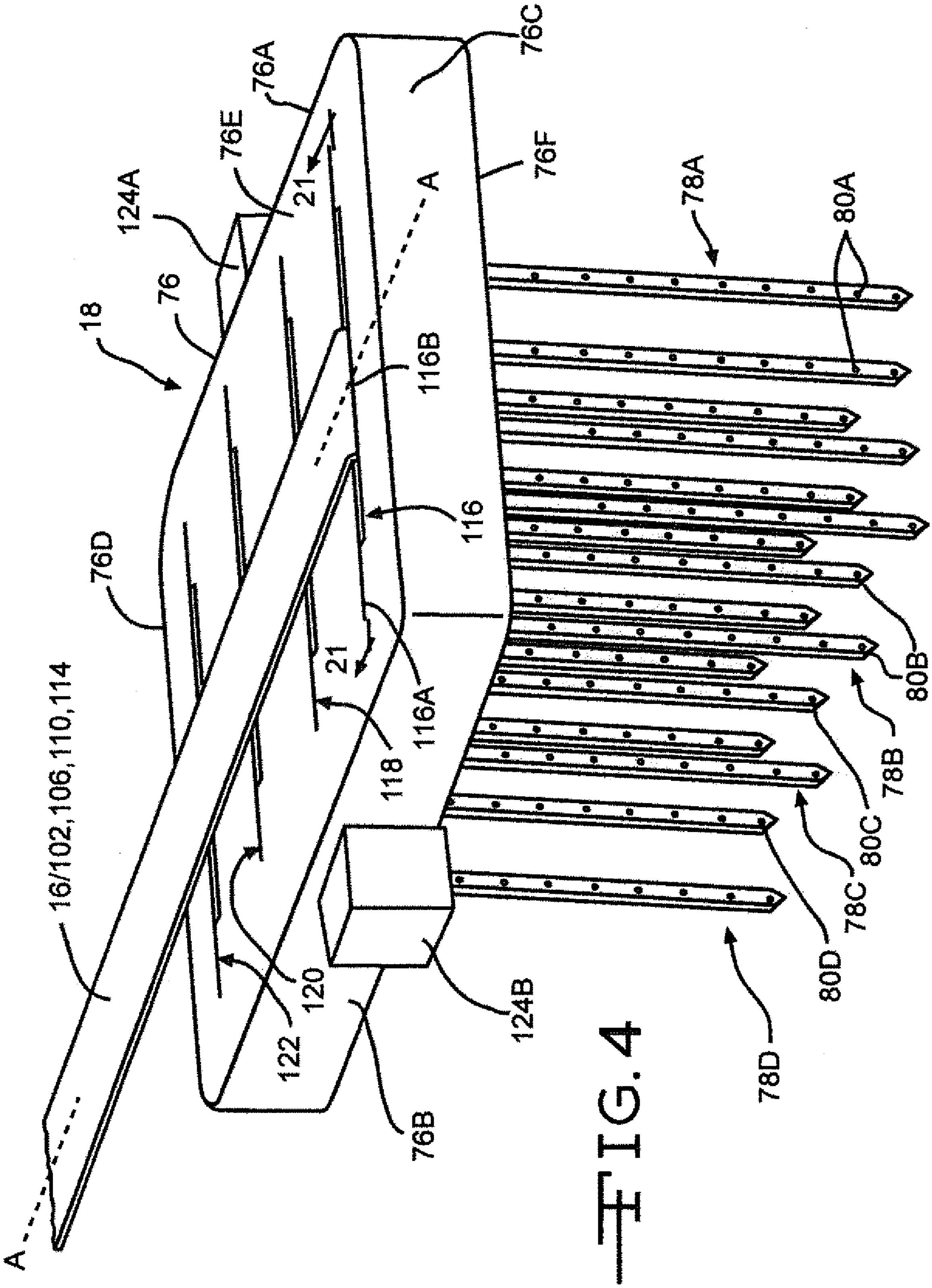

12
22B
32B
28B
22A
28A
20
30
24
32A
36
36A
38
34
40
38
24
36B
26
32
28
22
30
24
22C
32C
28C

FIG. 2

FIG. 3


14
12
70
64
66
52
54
48
42
50
46
132A
58
56
62
54
60
68
44
16
132A
38
72
38
36
34
40
38
30
32B
22B
28
22



18
76
76A
76B
76C
76D
76E
76F
21
21
A
A
16/102,106,110,114
116
116A
116B
118
120
122
124A
124B
78A
78B
78C
78D
80A
80B
80C
80D

FIG. 4

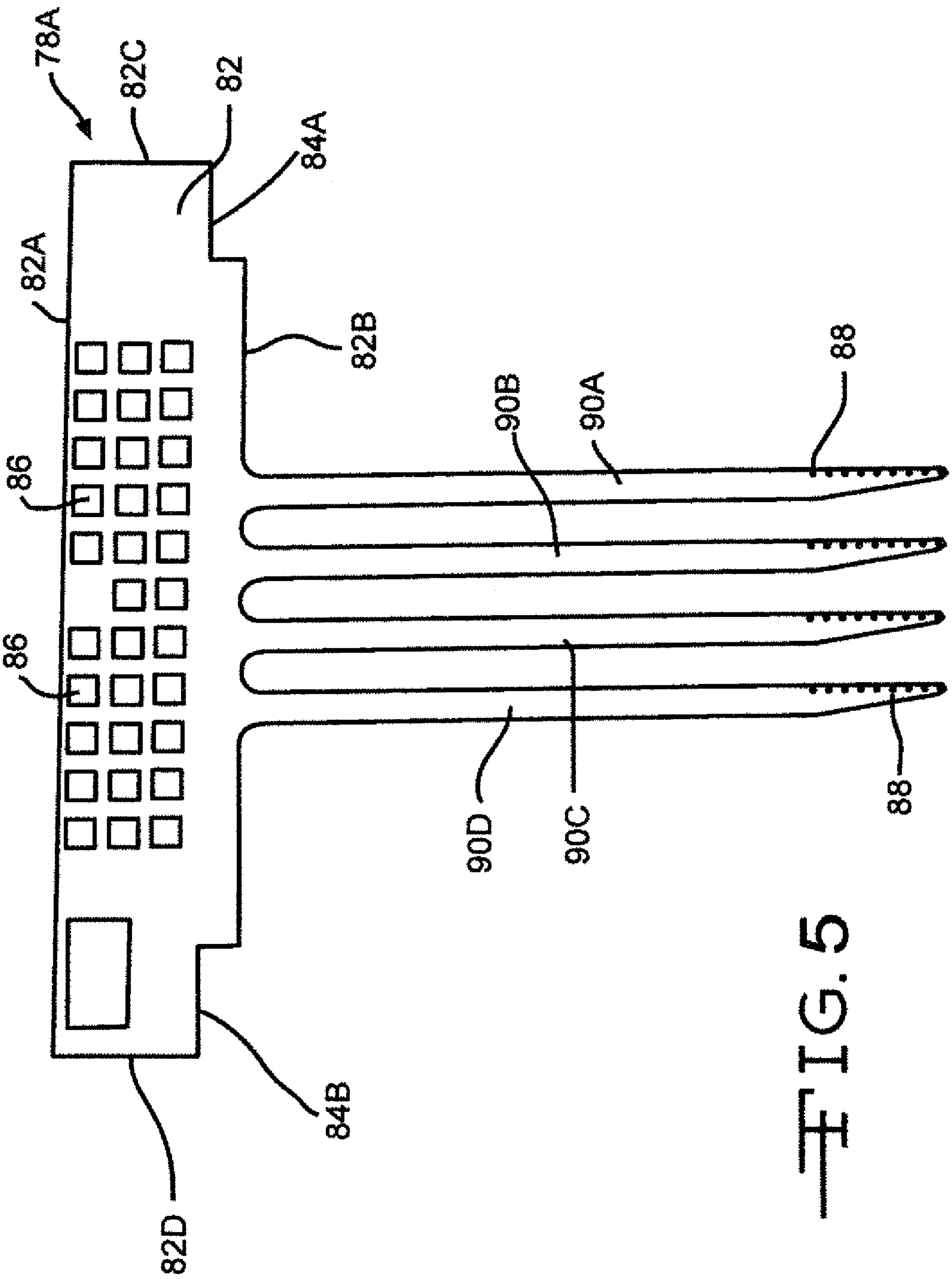


FIG. 5

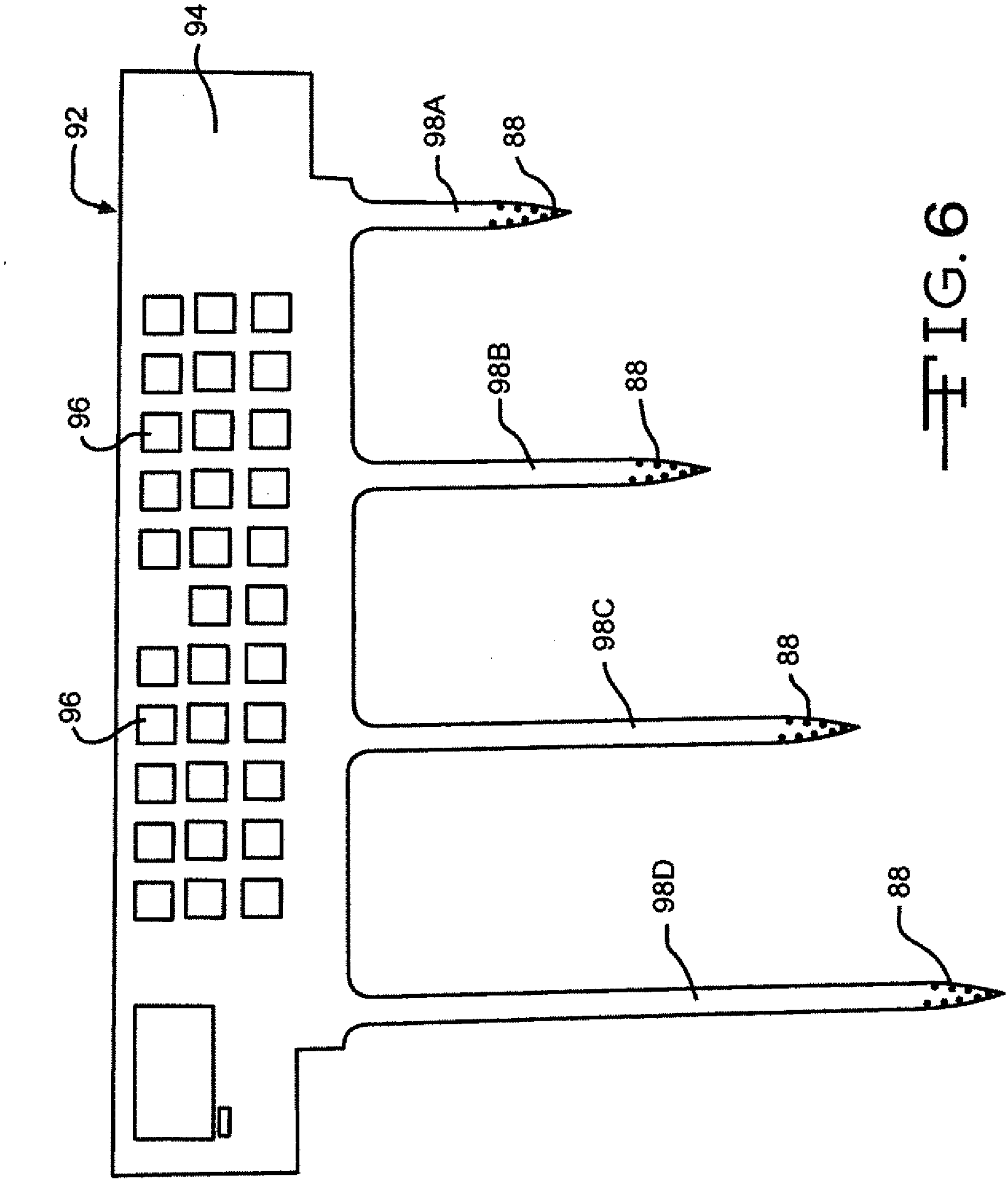


FIG. 6

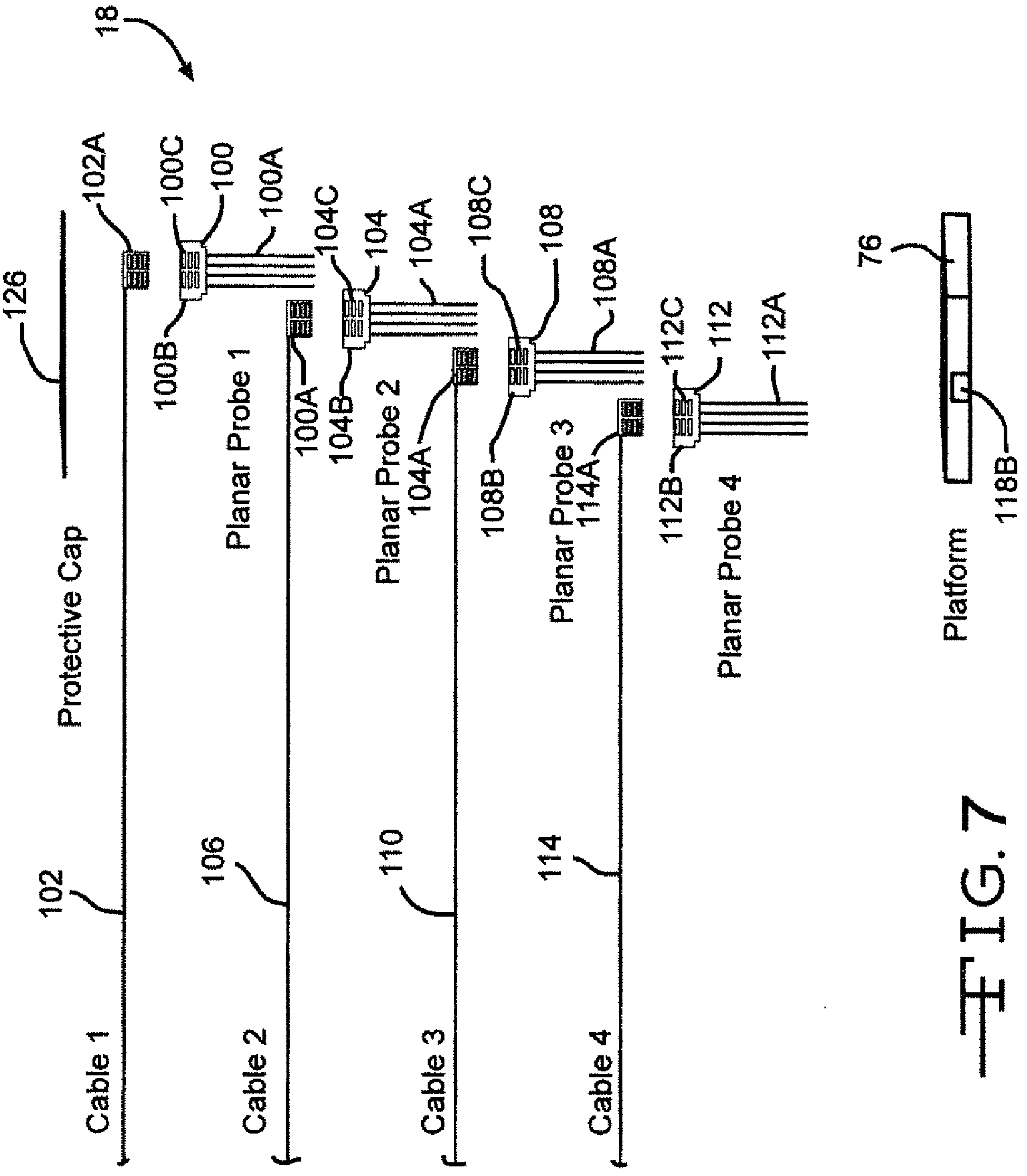

18
126
Protective Cap
102A
100C
100
100A
100B
Planar Probe 1
104C
104
104A
100A
104B
Planar Probe 2
108C
108
108A
104A
108B
Planar Probe 3
112C
112
112A
114A
112B
Planar Probe 4
76
118B
Platform
102
106
110
114
Cable 1
Cable 2
Cable 3
Cable 4

FIG. 7

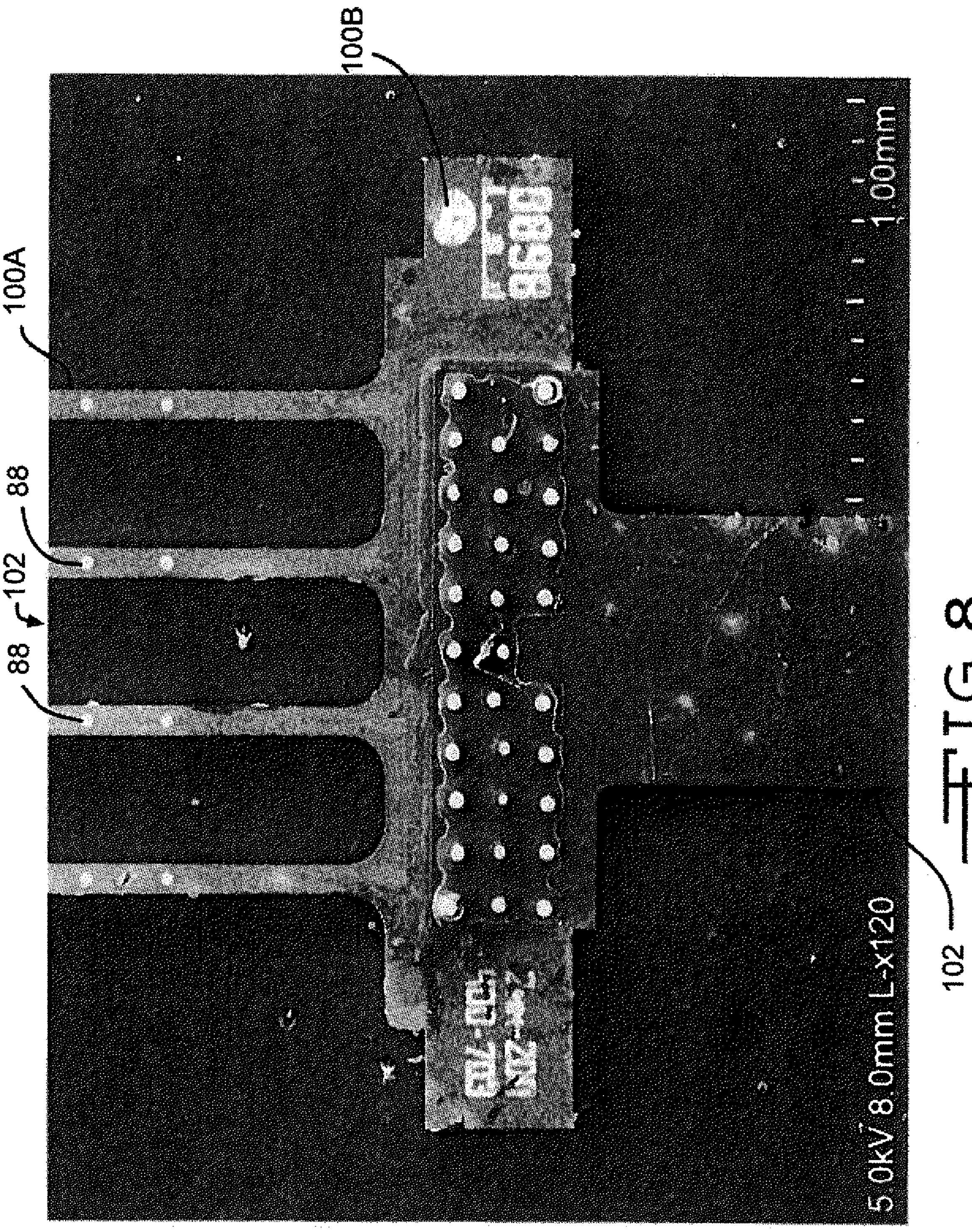


FIG. 8

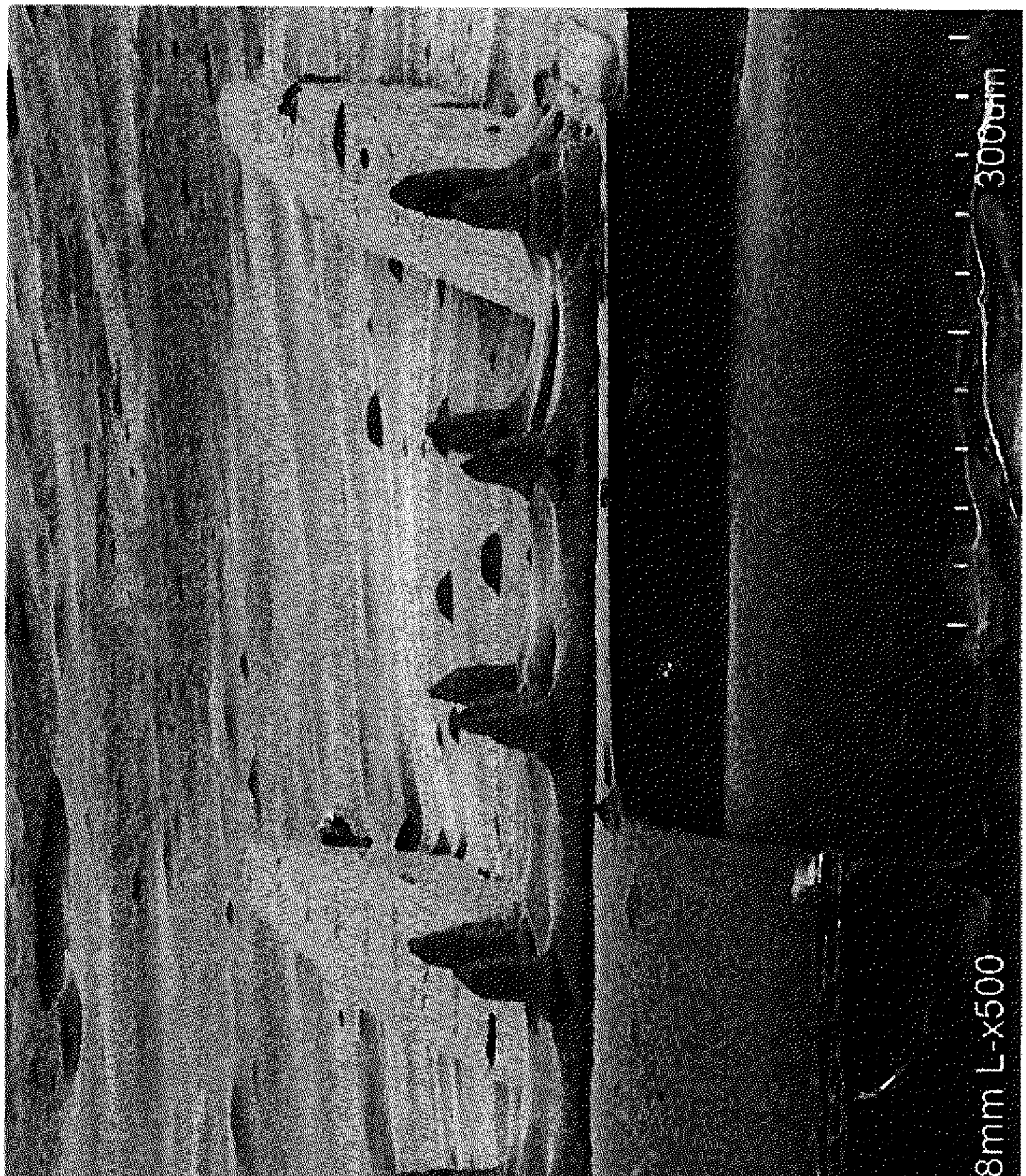


FIG. 9

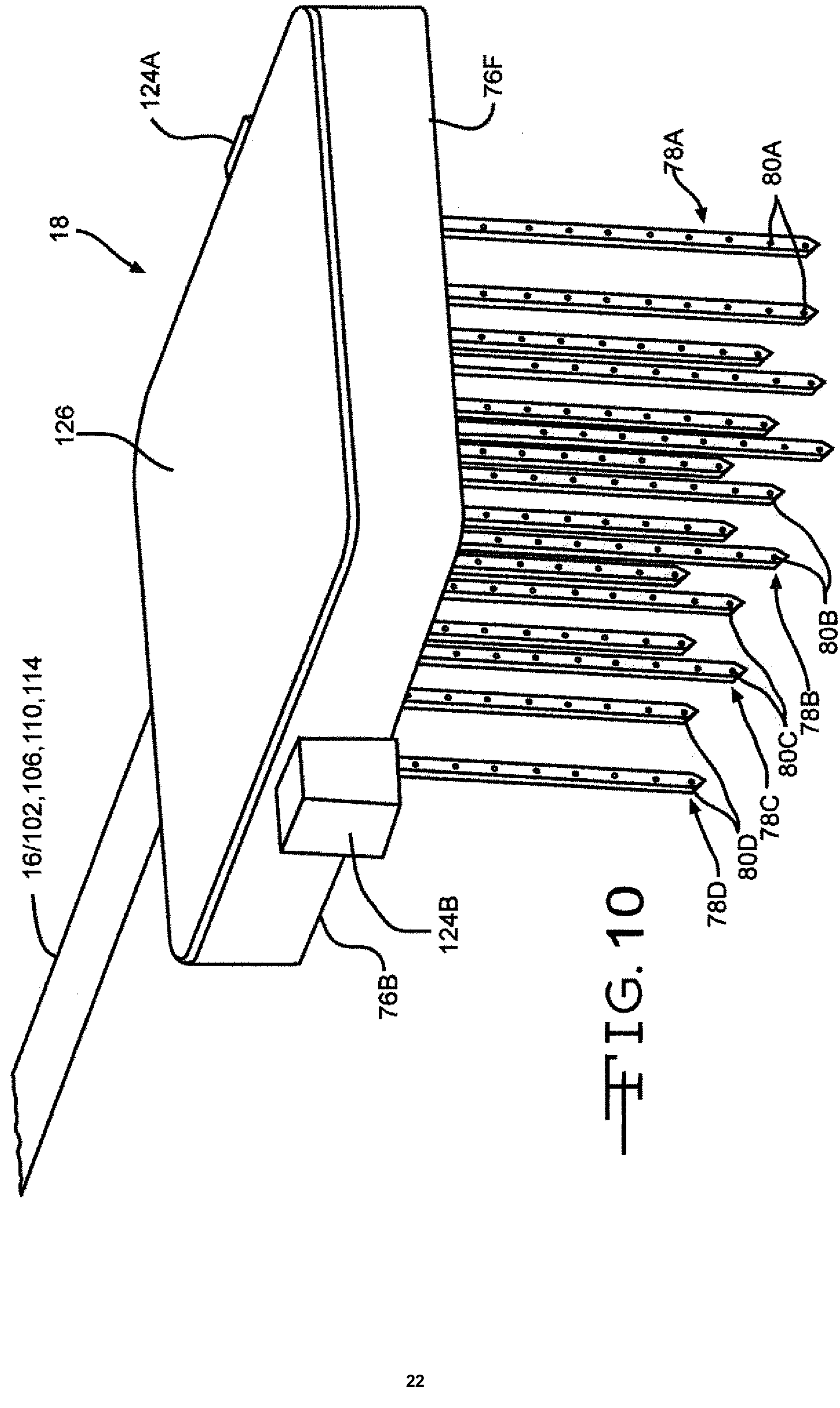
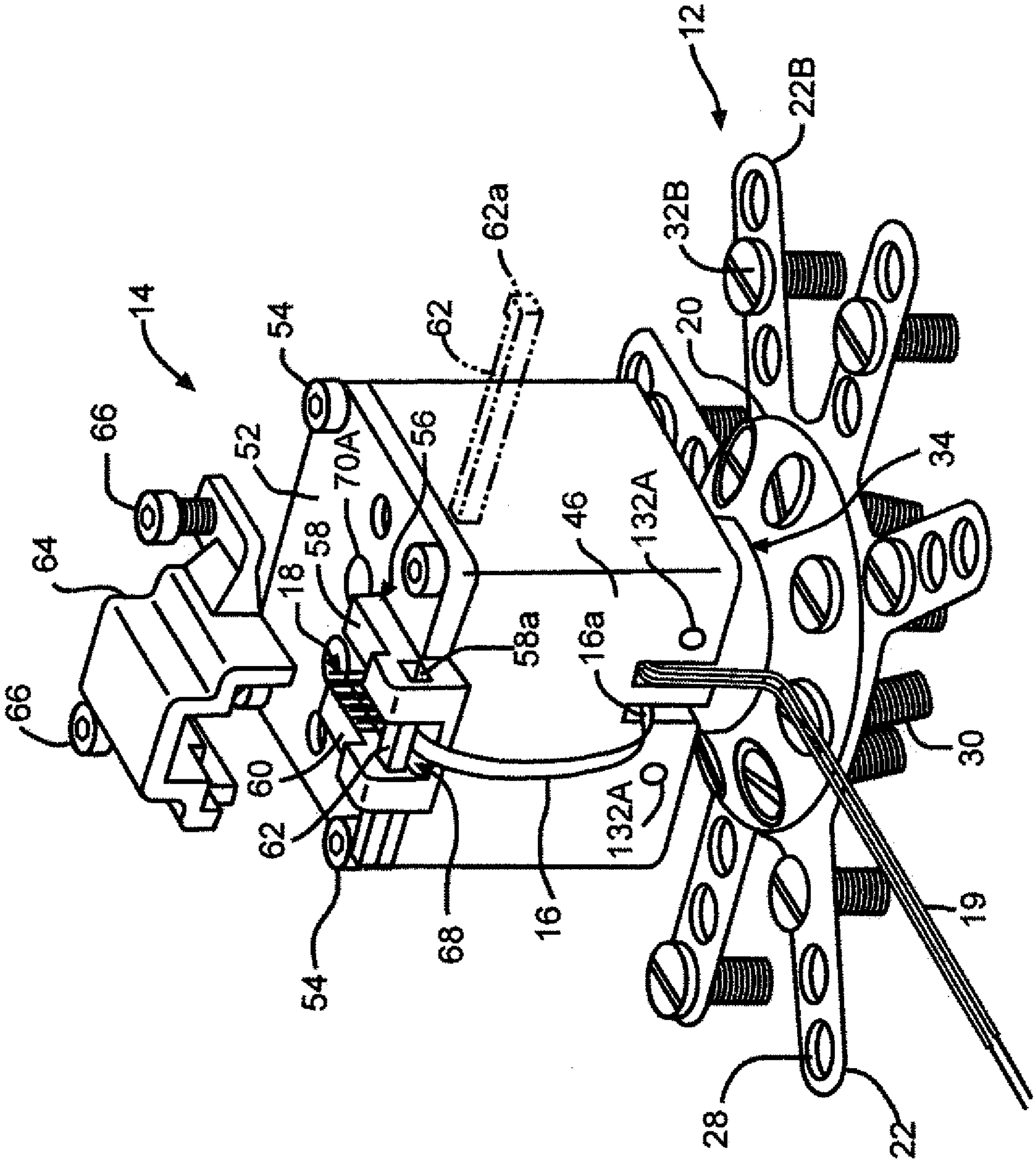

18
124A
76F
126
78A
80A
80B
78B
80C
78C
80D
78D
16/102,106,110,114
124B
76B

FIG. 10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66
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64
52
54
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70A
56
58
18
58a
60
62
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62a
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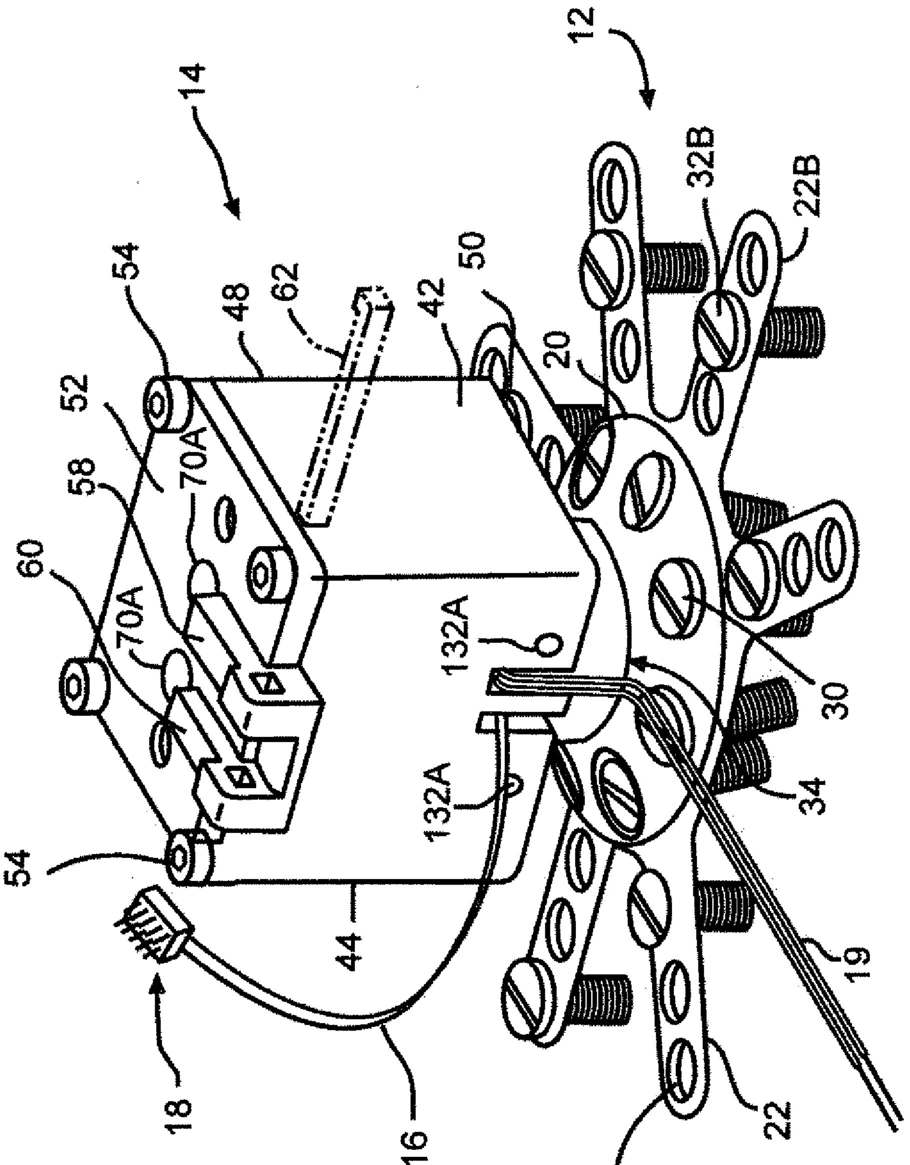
132A
132A
12
22B
32B
20
34
30
19
28
22

FIG. 11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50
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132A
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32B
22B
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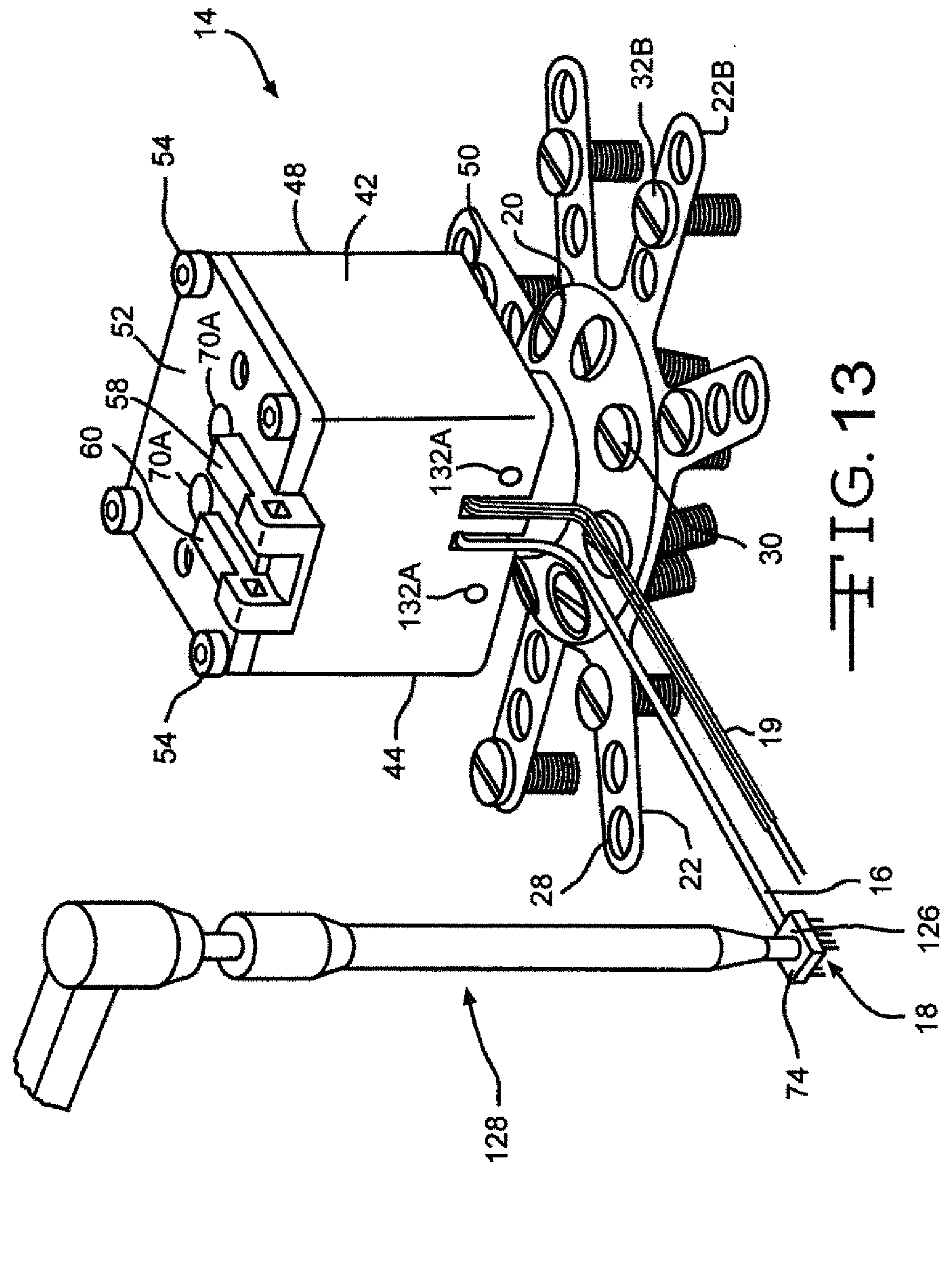
34
19
22
28
16
18
44
54

FIG. 12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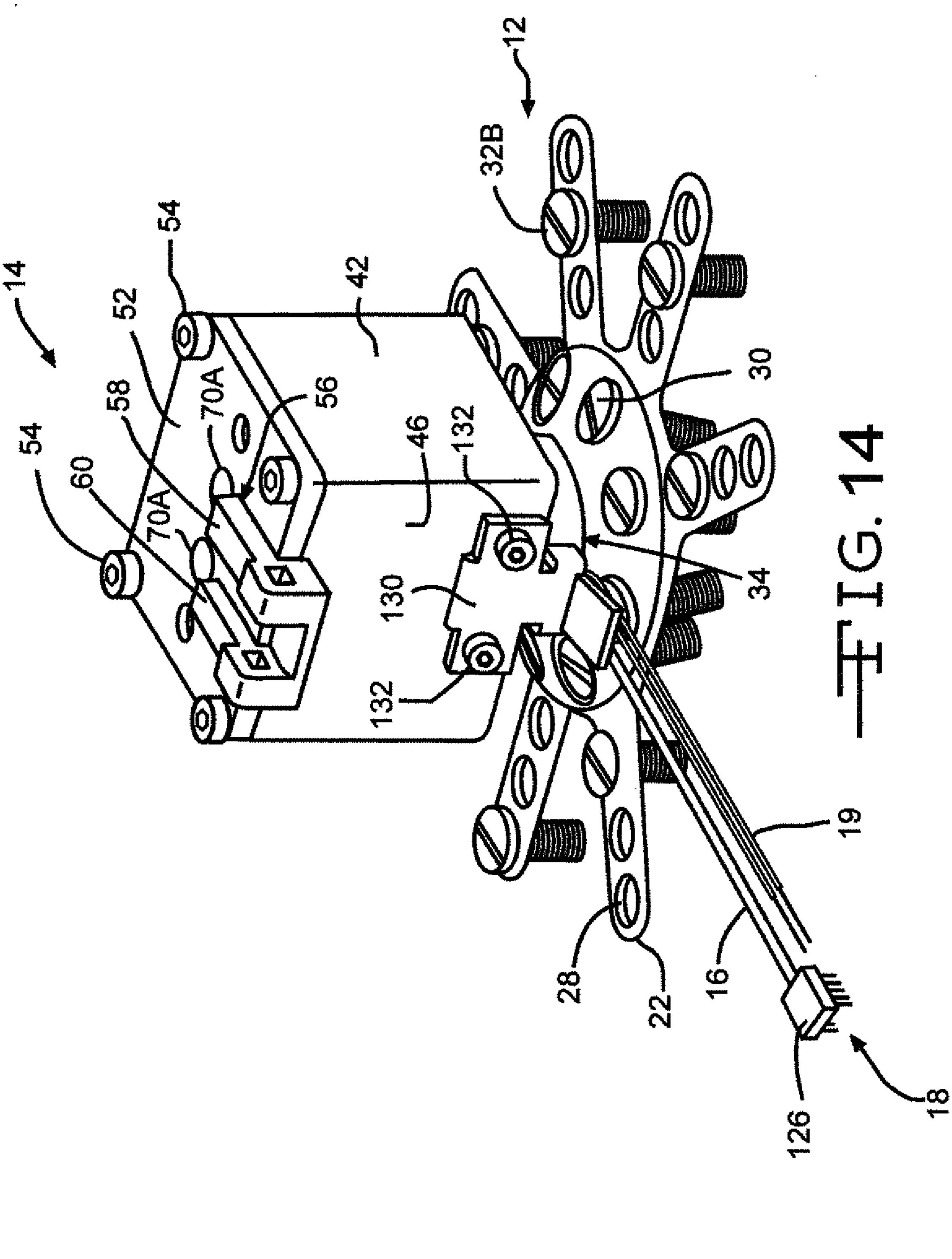
70A
58
60
70A
132A
132A
20
32B
22B
30
54
44
19
22
28
16
126
18
74
128

FIG. 13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54
52
42
58
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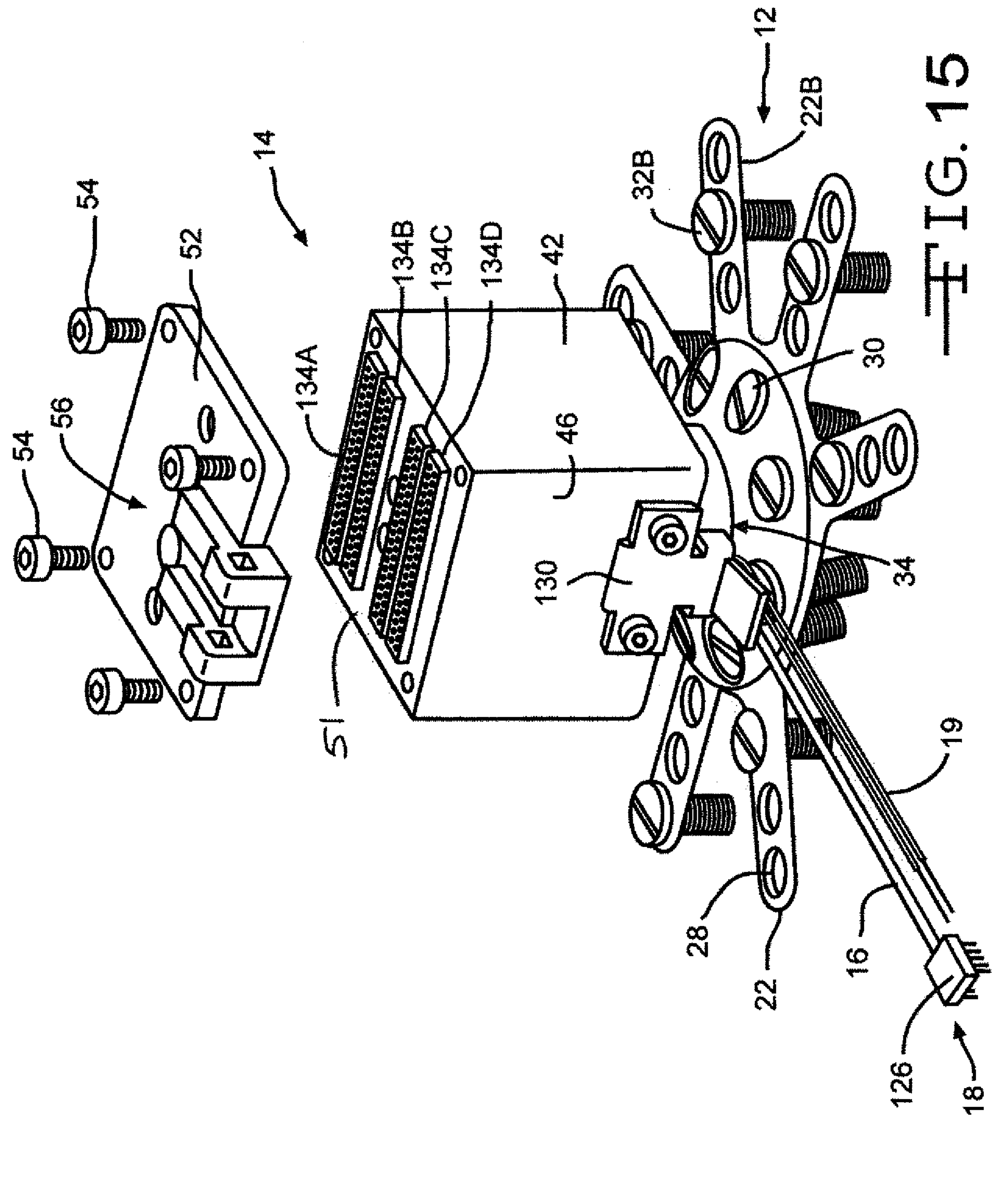
70A
70A
56
46
132
132
130
30
32B
34
19
28
22
16
126
18

FIG. 14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56
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134B
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46
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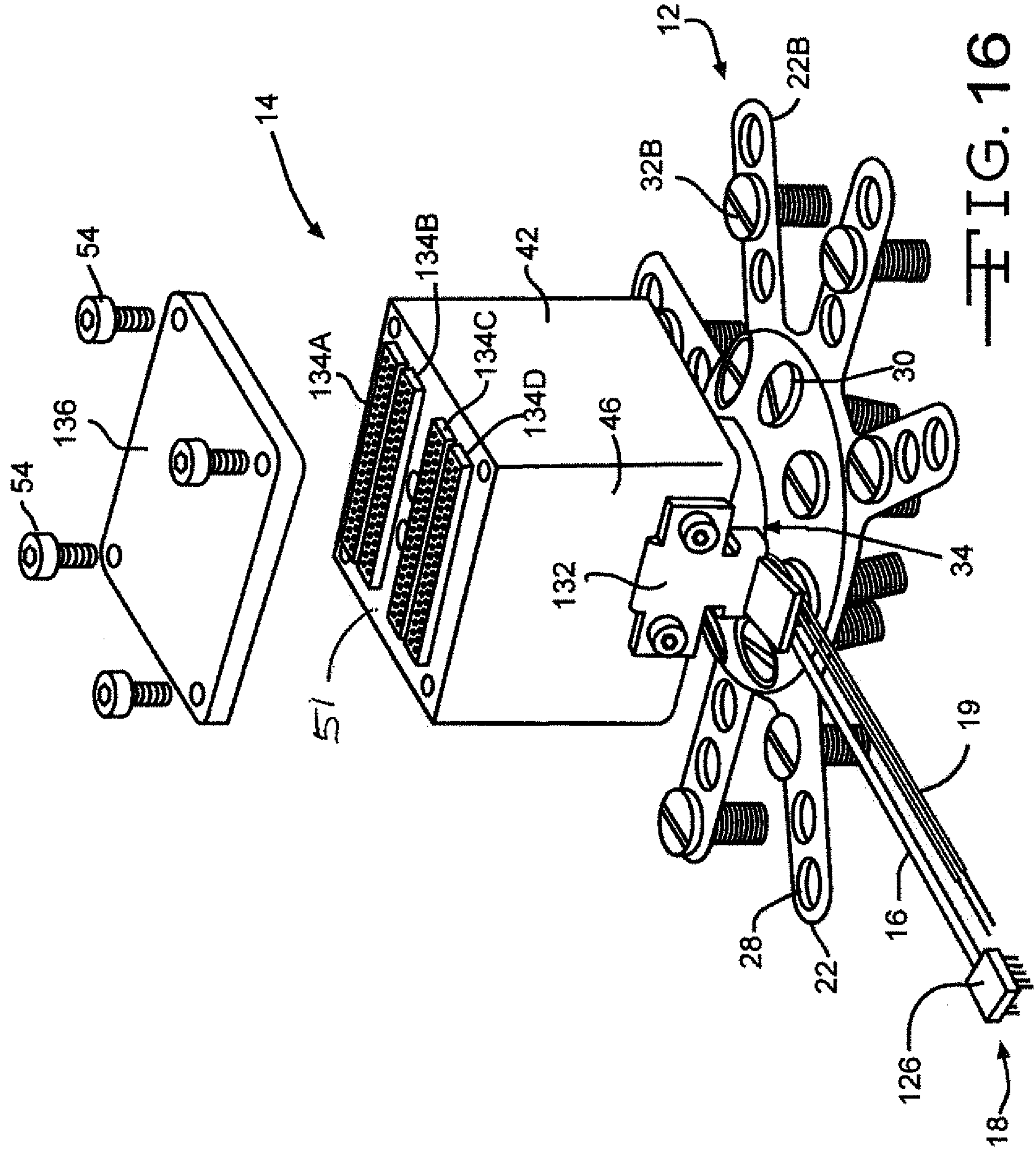
32B
22B
12
19
28
22
16
126
18

FIG. 15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54
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134C
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126
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FIG. 16

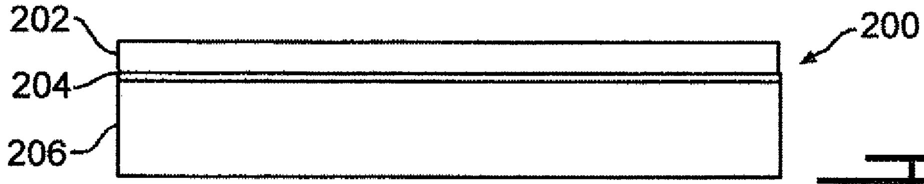

FIG. 17

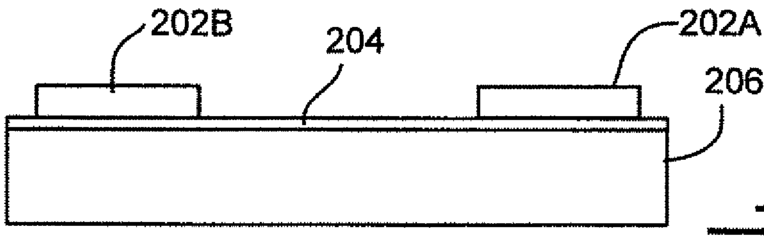

FIG. 18

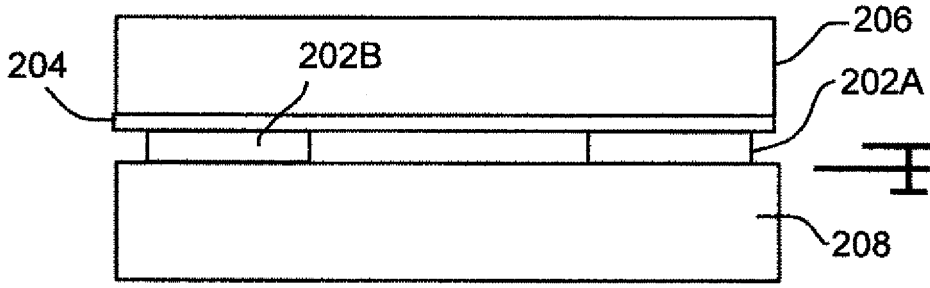

FIG. 19

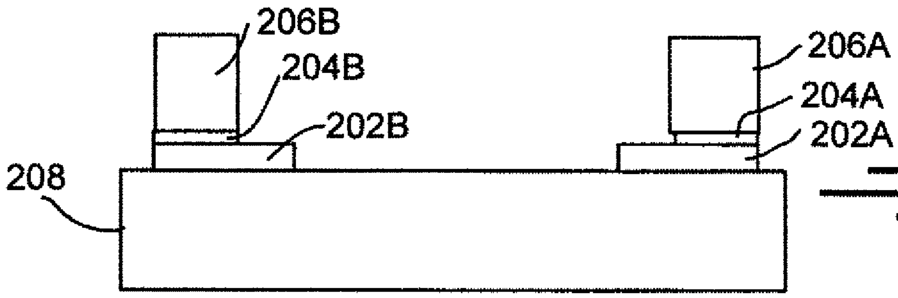

FIG. 20

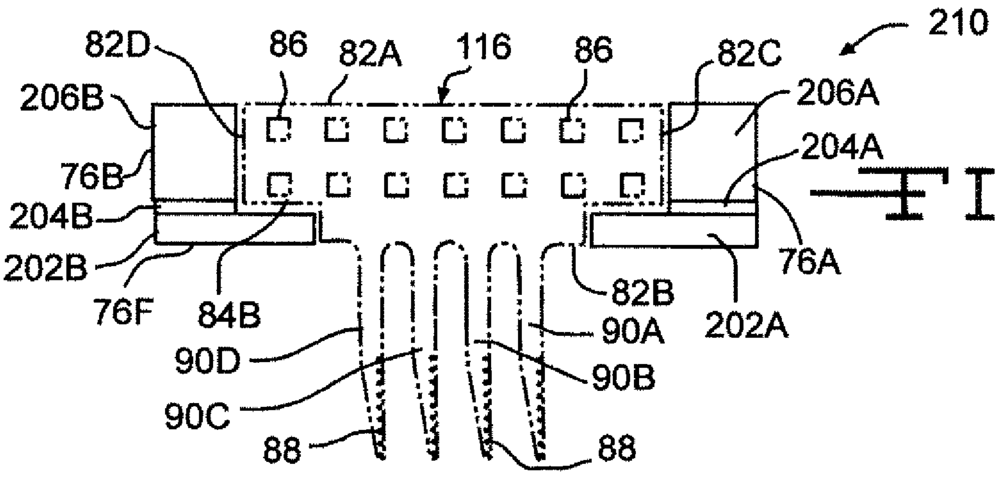

FIG. 21

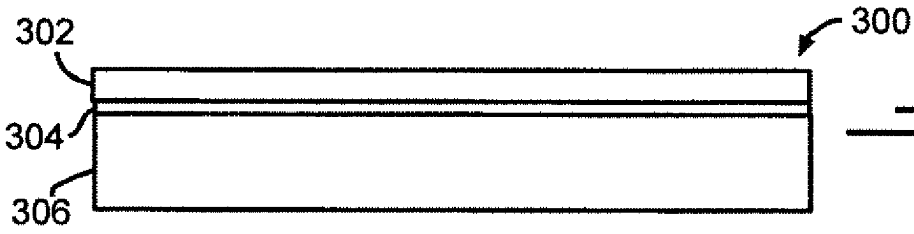

FIG. 22

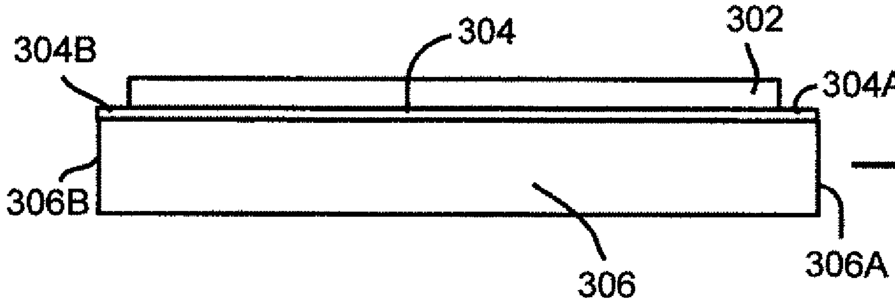

FIG. 23

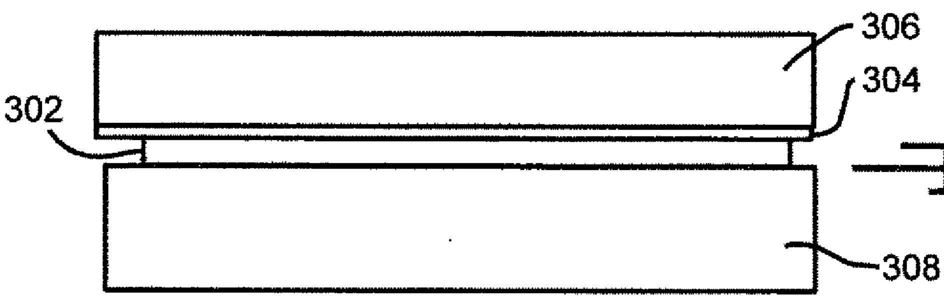

FIG. 24

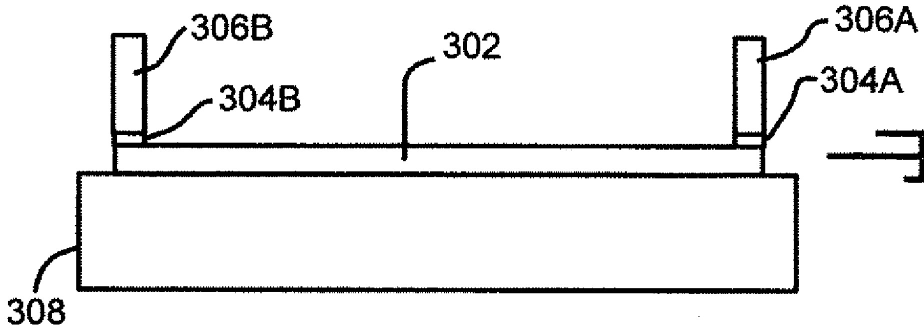

FIG. 25

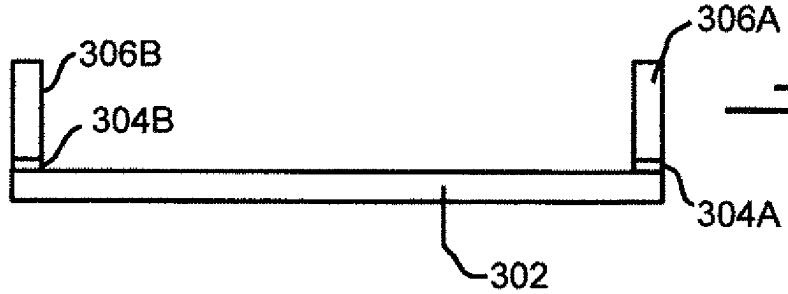

FIG. 26

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2005283203 A1 **[0003]**

专利名称(译)	三维神经探针微电极阵列		
公开(公告)号	EP2870980B1	公开(公告)日	2018-08-08
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[标]申请(专利权)人(译)	神经连结科技公司		
申请(专利权)人(译)	NEURONEXUS TECHNOLOGIES , INC.		
当前申请(专利权)人(译)	NEURONEXUS TECHNOLOGIES , INC.		
[标]发明人	VETTER RIO J HETKE JAMILLE FARRAYE PELLINEN DAVID S SUWARATO BENCHARONG KONG KC		
发明人	VETTER, RIO J. HETKE, JAMILLE FARRAYE PELLINEN, DAVID S. SUWARATO, BENCHARONG KONG, KC		
IPC分类号	A61N1/05 A61B5/04 A61B5/00 A61B5/0478 A61N1/04 H01R43/26		
CPC分类号	A61N1/0529 A61B5/04001 A61B5/0478 A61B5/6868 A61B5/6882 A61N1/0456 A61N1/0472 A61N1/0539 H01R43/26 Y10T29/49169		
优先权	61/901783 2013-11-08 US		
其他公开文献	EP2870980A3 EP2870980A2		
外部链接	Espacenet		

摘要(译)

描述了一种三维神经探针电极阵列系统。平面探针是微制造的，并使用铆钉粘合技术电连接到柔性微加工带状电缆。每根电缆的远端连接到探针，电缆的近端被定制以连接到印刷电路板。最终装配包括将多个这样的装配组合成单个结构。每个二维神经探针阵列定位在微机械平台中，为每个阵列提供机械支撑和对准。最后，将微机械盖放置在每个神经电极探针和电缆组件的顶部，以保护它们在运输和随后使用期间免受损坏。盖子提供了相对平坦的表面，用于连接计算机控制的插入器，以便精确地插入组织中。

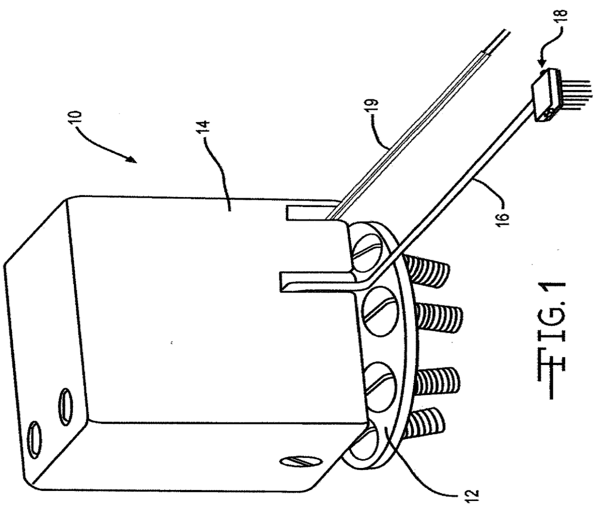

FIG. 1