[0019] FIGURE 12E is a detailed cross-sectional view of the electrode array and carrier taken in panel V in FIGURE 12C;

[0020] FIGURE 13 is an illustration of the steps of making a neural interface system of a preferred embodiment; and

[0021] FIGURE 14 is a schematic drawing of the neural interface system implanted in a patient.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The following description of preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

[0023] As shown in FIGURE 1, the neural interface system 100 of the preferred embodiments includes an electrode array 110 having a substrate 120 rolled into a three-dimensional array shape, a plurality of conductive traces 140 patterned on the substrate 120 and adapted to transmit electrical signals and a plurality of electrode sites 150 coupled to the plurality of conductive traces 140; and a carrier 170 that supports the electrode array 110. The electrode array 110 is preferably coupled to the carrier 170 such that the electrode sites 150 are arranged in a triangular lattice circumferentially around and axially along the carrier. The substrate 120 preferably includes an edge that extends axially along the carrier and is constrained between a first axial row portion of the carrier and a second axial row portion of the plurality of electrode sites adjacent to the first axial row portion. The electrode sites 150 may include recording electrode sites

[0019] FIGURE 12E is a detailed cross-sectional view of the electrode array and carrier taken in panel V in FIGURE 12C;

[0020] FIGURE 13 is an illustration of the steps of making a neural interface system of a preferred embodiment; and

[0021] FIGURE 14 is a schematic drawing of the neural interface system implanted in a patient.

SUMMARY

In accordance with a first aspect of the present disclosure, there is provided a neural interface system comprising a) a substrate that is configured to be formed into a three-dimensional shape and comprises spaced apart first and second lateral edges extending from a proximal edge to a distal edge, wherein the first and second lateral edges comprise respective first and second wavy shapes curving alternatively in opposite lateral directions as they extend axially at least part way from the proximal edge to the distal edge of the substrate; b) a plurality of conductive traces patterned on the substrate and adapted to transmit electrical signals; and c) a plurality of electrode sites supported on the substrate and individually electrically coupled to one of the plurality of conductive traces; and d) a carrier supporting the substrate in a three-dimensional shape, wherein the first wavy shape of the first lateral edge is interleaved with the second wavy shape of the second lateral edge to thereby form an interleaved boundary at the first and second lateral edges of the substrate supporting the electrical sites and the conductive traces on the carrier.

In accordance with a second aspect of the present disclosure, there is provided a method of making a neural interface system, comprising the steps of a) providing a flexible substrate comprising spaced apart first and second lateral edges extending from a proximal edge to a distal edge, wherein the first and second lateral edges comprise respective first and second wavy shapes curving alternatively in opposite lateral directions as they extend axially at least part way from the proximal edge to the distal edge of the substrate; b) depositing a first polymer layer on the substrate; c) building a plurality of conductive traces on the first polymer layer; d) depositing a second polymer layer on the substrate; e) building a plurality of electrode sites that are individually electrically coupled to one of the plurality of

conductive traces; and f) forming a carrier supporting the substrate including the electrode array into a three-dimensional electrode array such that the first wavy shape of the first lateral edge is interleaved with the second wavy shape of the second lateral edge to thereby form an interleaved boundary at the first and second lateral edges.

In accordance with a third aspect of the present disclosure, there is provided a neural interface system, which comprises a) an electrode array comprising: i) a substrate provide in a three-dimensional shape; ii) a plurality of conductive traces patterned on the substrate; and iii) a plurality of elliptically shaped electrode sites coupled to the plurality of conductive traces, wherein the electrode sites include at least one of a recording electrode site and a stimulation electrode site that is configured to electrically communicate with its surroundings; and b) a carrier that supports the electrode array; c) wherein the plurality of electrode sites are arranged in a triangular lattice circumferentially around and axially along the carrier; and d) wherein the substrate includes a longitudinal edge that extends axially along the carrier and is constrained between a first axial row portion of the plurality of electrode sites and a second axial row portion of the plurality of electrode sites adjacent to the first axial row portion; e) wherein the longitudinal edge of the substrate includes a set of undulatory extensions with a ratio of a major axis of the plurality of electrode sites to a minor axis of the plurality of the electrode sites being: i) proportional to the amplitude of the set of undulations; ii) proportional to an outer diameter of the three-dimensional shape of the substrate; and iii) inversely proportional to the edge-to-edge spacing.

In accordance with a fourth aspect of the present disclosure, there is provided a method of making a neural interface system, comprising the steps of a) providing a flexible substrate comprises spaced apart first and second lateral edges extending from a proximal edge to a distal edge; b) removing selected portions of the substrate to form first and second lateral edges having respective first and second wavy shapes curving alternatively in opposite lateral directions as they extend axially at least part way from the proximal edge to the distal edge of the substrate; c) depositing a first polymer layer on the substrate; d) depositing a metal layer on the first polymer layer and patterning the metal layer to form a plurality of conductive traces; e) building a plurality of electrode sites coupled to the plurality of conductive traces; f) depositing a second polymer layer on the substrate; and g) rolling the substrate to interleave the first wavy shape of the first lateral edge with the second wavy shape of the second lateral edge to thereby form an interleaved boundary at the first and

second lateral edges of the substrate supporting the electrical sites and the conductive traces on the carrier.

In accordance with a fifth aspect of the present disclosure, there is provided an electrode array, which comprises a) a substrate that is configured to be formed into a three-dimensional shape and comprises spaced apart first and second lateral edges extending from a proximal edge to a distal edge, wherein the first and second lateral edges comprise respective first and second wavy shapes curving alternatively in opposite lateral directions as they extend axially at least part way from the proximal edge to the distal edge of the substrate; b) a plurality of conductive traces patterned on the substrate; and c) a plurality of electrode sites supported on the substrate and individually electrically coupled to one of the plurality of conductive traces, d) wherein the first wavy shape of the first lateral edge is configured to interleave with the second wavy shape of the second lateral edge.

In accordance with a sixth aspect of the present disclosure, there is provided an electrode array, which comprises a) a substrate that is configured to be formed into a three-dimensional shape and comprises spaced apart first and second lateral edges extending from a proximal edge to a distal edge, wherein the first and second lateral edges comprise respective first and second patterned shapes selected from the group consisting of wavy extensions, rectangular extensions and square extensions as the lateral edges extend axially at least part way from the proximal edge to the distal edge of the substrate; b) a plurality of conductive traces patterned on the substrate and adapted to transmit electrical signals; and c) a plurality of electrode sites supported on the substrate and individually electrically coupled to one of the plurality of conductive traces, d) wherein the first lateral edge is configured to interleave with the second lateral edge to thereby form an interleaved boundary at the first and second lateral edges.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The following description of preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

[0023] As shown in FIGURE 1, the neural interface system 100 of the preferred embodiments includes an electrode array 110 having a substrate 120 rolled into a three-dimensional array shape, a plurality of conductive traces 140 patterned on the substrate 120 and adapted to transmit electrical signals and a plurality of electrode sites 150 coupled to the plurality of conductive traces 140; and a carrier 170 that supports the electrode array 110. The electrode array 110 is preferably coupled to the carrier 170 such that the electrode sites 150 are arranged in a triangular lattice circumferentially around and axially along the carrier. The substrate 120 preferably includes an edge that extends axially along the carrier and is constrained between a first axial row portion of the carrier and a second axial row portion of the plurality of electrode sites adjacent to the first axial row portion. The electrode sites 150 may include recording electrode sites

CLAIMS

1. A neural interface system, comprising:

a) a substrate that is configured to be formed into a three-dimensional shape and comprises spaced apart first and second lateral edges extending from a proximal edge to a distal edge, wherein the first and second lateral edges comprise respective first and second wavy shapes curving alternatively in opposite lateral directions as they extend axially at least part way from the proximal edge to the distal edge of the substrate;

b) a plurality of conductive traces patterned on the substrate and adapted to transmit electrical signals; and

c) a plurality of electrode sites supported on the substrate and individually electrically coupled to one of the plurality of conductive traces; and

~~e~~d) a carrier supporting the substrate in a three-dimensional shape, wherein the first wavy shape of the first lateral edge is interleaved with the second wavy shape of the second lateral edge to thereby form an interleaved boundary at the first and second lateral edges of the substrate supporting the electrical sites and the conductive traces on the carrier.

2. The neural interface system of claim 1, wherein the second lateral edge overlaps a portion of the substrate at the first lateral edge.

3. The neural interface system of claim 1, wherein the plurality of conductive traces are arranged in circumferential rings around the carrier.

4. The neural interface system of claim 3, wherein the plurality of conductive traces includes a first conductive trace having a first distal end and a second conductive trace having a second distal end, wherein the second conductive trace is longer than the first conductive trace and the second distal end has a wider cross-section perpendicular to an axial extent of the second conductive trace than the first distal end.

5. The neural interface system of claim 1, wherein the plurality of conductive traces extend axially along the carrier.

6. The neural interface system of claim 5, wherein the plurality of conductive traces are parallel to at least one of the first and second lateral edges of the substrate.

7. The neural interface system of claim 5, wherein the plurality of conductive traces includes a first conductive trace having a first distal end and a second conductive trace having a second distal

end, wherein the second conductive trace is longer than the first conductive trace and the second distal end has a wider cross-section perpendicular to an axial extent of the second conductive trace than the first distal end.

8. The neural interface system of claim 1, wherein at least one of the plurality of electrode sites is eccentric and has a minor axis and a major axis that is longer than the minor axis.

9. The neural interface system of claim 8, wherein the minor axis is aligned axially along the carrier.

10. The neural interface system of claim 1 wherein the carrier has a substantially circular cross-section perpendicular to a longitudinal axis of the carrier.

11. The neural interface system of claim 10 wherein the plurality of electrode sites are arranged in a triangular lattice circumferentially around and axially along the carrier.

12. The neural interface system of claim 11, wherein the triangular lattice is an equilateral triangular lattice.

13. The neural interface system of claim 11, wherein the plurality of electrode sites are distributed in the triangular lattice with equal edge-to-edge spacing.

14. The neural interface system of claim 13, wherein a ratio of the major axis to the minor axis of the plurality of the electrode sites is:

a) proportional to an amplitude of the first and second wavy shapes comprising the respective first and second lateral edges;

b) proportional to an outer diameter of at least one of the electrode sites; and

c) inversely proportional to the edge-to-edge spacing.

15. The neural interface system of claim 1 wherein the interleaved boundary extends axially along the carrier between a right axial row portion of the plurality of electrode sites adjacent to the first lateral edge and a left axial row portion of the plurality of electrode sites adjacent to the second lateral edge of the substrate.

16. The neural interface system ~~electrode array~~ of claim 1 wherein the plurality of electrode sites includes at least one of a recording electrode site and a stimulation electrode site.

17. The neural interface system ~~electrode array~~ of claim 1 wherein the plurality of electrode sites are arranged in a triangular lattice circumferentially around and axially along the carrier.

18. The neural interface system ~~electrode array~~ of claim 1 wherein the electrode sites have either a circular or elliptical shape with an eccentricity ranging from 0 to 1.

19. A method of making a neural interface system, comprising the steps of:

a) providing a flexible substrate comprising spaced apart first and second lateral edges extending from a proximal edge to a distal edge, wherein the first and second lateral edges comprise respective first and second wavy shapes curving alternatively in opposite lateral directions as they extend axially at least part way from the proximal edge to the distal edge of the substrate;

b) depositing a first polymer layer on the substrate;

c) building a plurality of conductive traces on the first polymer layer;

d) depositing a second polymer layer on the substrate;

e) building a plurality of electrode sites that are individually electrically coupled to one of the plurality of conductive traces; and

f) forming a carrier supporting the substrate including the electrode array into a three-dimensional electrode array such that the first wavy shape of the first lateral edge is interleaved with the second wavy shape of the second lateral edge to thereby form an interleaved boundary at the first and second lateral edges.

20. The method of claim 19, including removing selected portions of the substrate to form the first and second lateral edges comprising the respective first and second wavy shapes.

21. The method of claim 19, wherein the step of building a plurality of conductive traces includes depositing a metal layer on the first polymer layer and patterning the metal layer to form the plurality of conductive traces.

22. The method of claim 21, wherein the step of patterning the metal layer to form the plurality of conductive traces includes forming a plurality of lateral conductive traces arranged in a lateral direction generally orthogonal to at least one of the first and second lateral edges.

23. The method of claim 21, wherein the step of patterning the metal layer to form the plurality of conductive traces includes forming a plurality of longitudinal conductive traces arranged in an axial direction generally parallel to at least one of the first and second lateral edges.