



US006048692A

# United States Patent [19]

[11] Patent Number: **6,048,692**

Maracas et al.

[45] Date of Patent: **\*Apr. 11, 2000**

[54] **SENSORS FOR ELECTRICALLY SENSING BINDING EVENTS FOR SUPPORTED MOLECULAR RECEPTORS**

[75] Inventors: **George N. Maracas**, Phoenix; **Travis Johnson**, Chandler, both of Ariz.

[73] Assignee: **Motorola, Inc.**, Schaumburg, Ill.

[\*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] Appl. No.: **08/946,620**

[22] Filed: **Oct. 7, 1997**

[51] Int. Cl.<sup>7</sup> ..... **C12Q 1/68**

[52] U.S. Cl. .... **435/6; 435/91.2; 536/21.3**

[58] Field of Search ..... **435/6, 91.2; 536/21.3**

[56] **References Cited**

**U.S. PATENT DOCUMENTS**

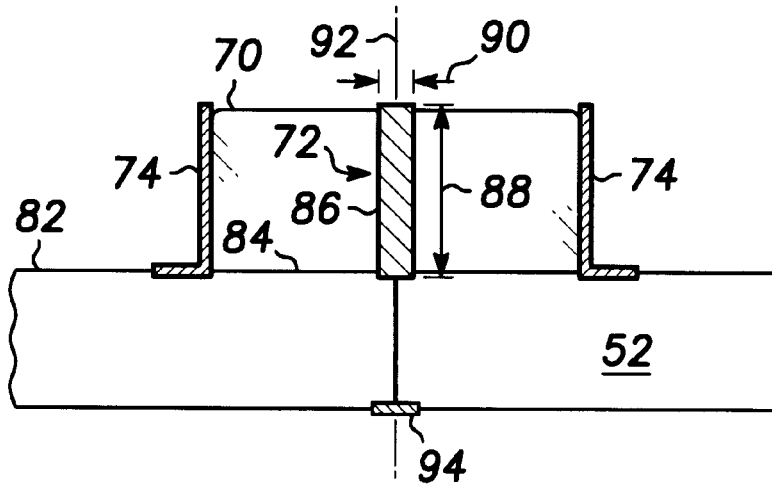
5,436,170	7/1995	Cornell et al. ....	436/527
5,527,703	6/1996	Cully et al. ....	435/252.3
5,653,939	8/1997	Hollis et al. ....	422/50

*Primary Examiner*—Scott W. Houtteman  
*Attorney, Agent, or Firm*—James E. Gauger

[57] **ABSTRACT**

A first sensor (18) for electrically sensing a molecular binding event includes a receptor-supporting element (20) into which a reagent is diffusable, at least one molecular receptor (22) supported by the receptor-supporting element (20), and a first electrode (24) embedded in the receptor-supporting element (20). A second sensor for electrically sensing a molecular binding event includes a receptor-supporting element (130), at least one molecular receptor (132) supported by the receptor-supporting element (130), an electrode (134) coupled to the receptor-supporting element (130), and a porous electrode (136) coupled to the receptor-supporting element (130).

**24 Claims, 4 Drawing Sheets**



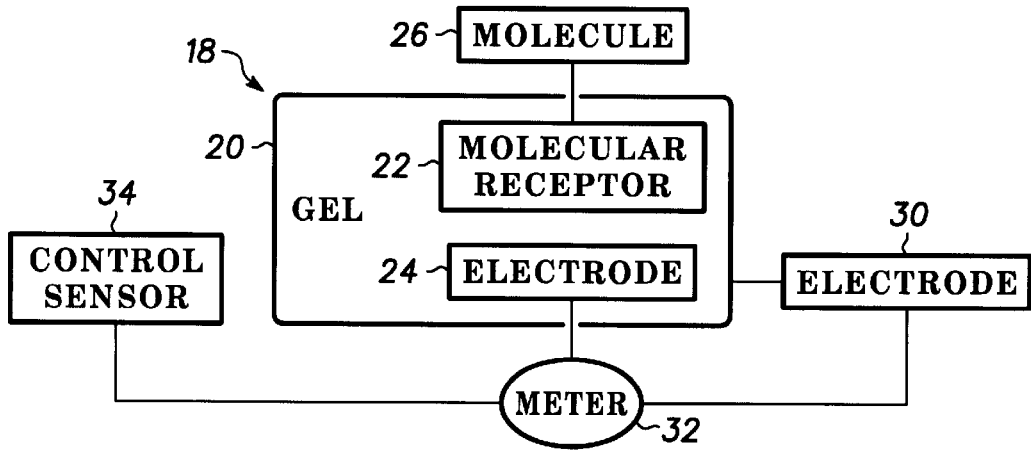


FIG. 1

FIG. 2

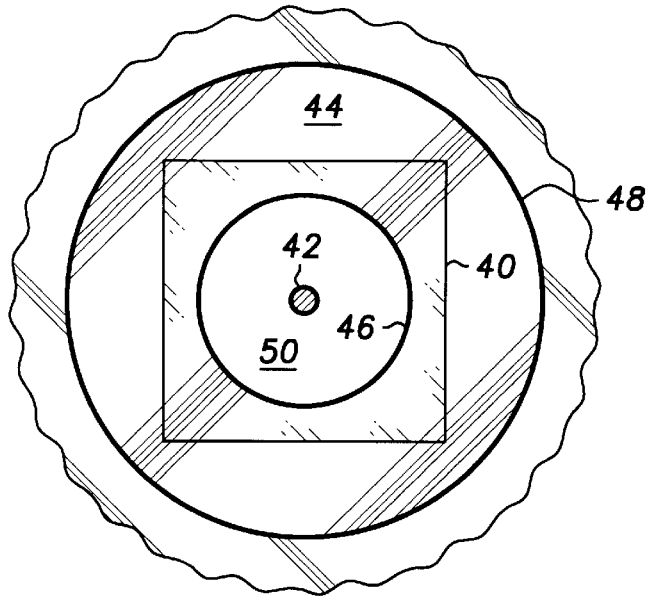
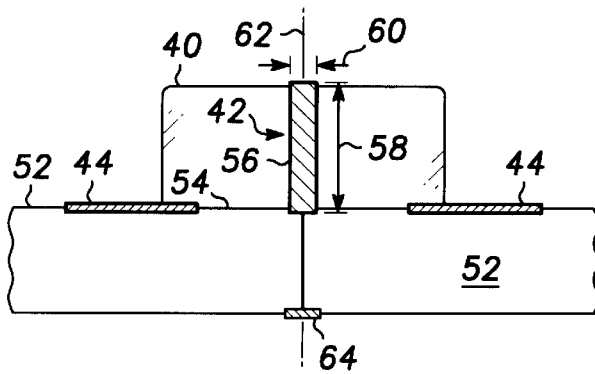
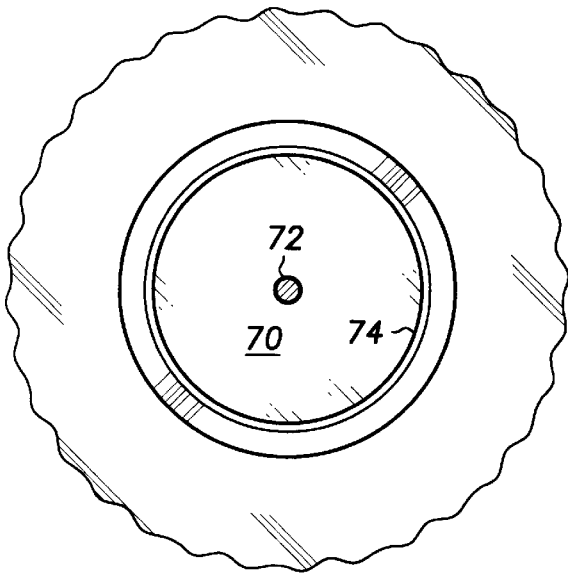
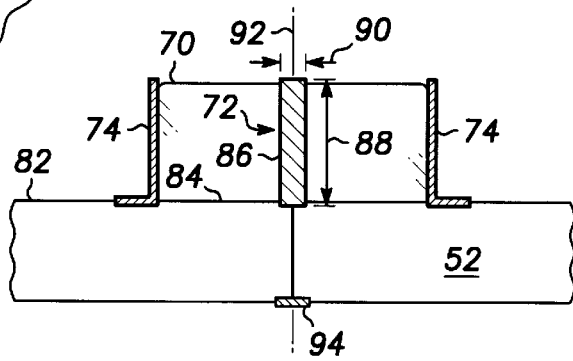


FIG. 3

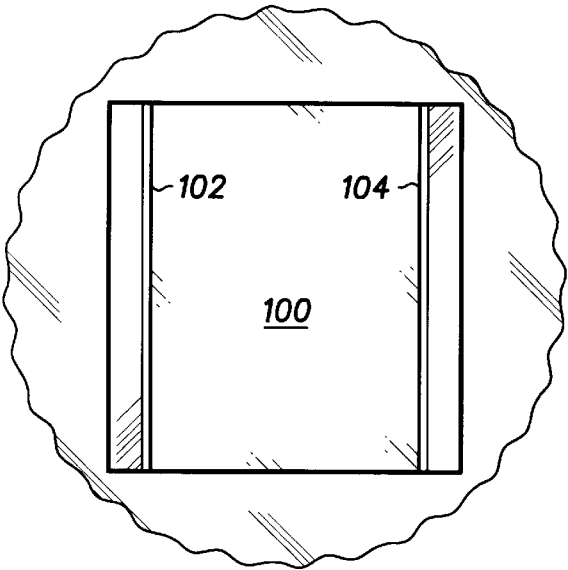




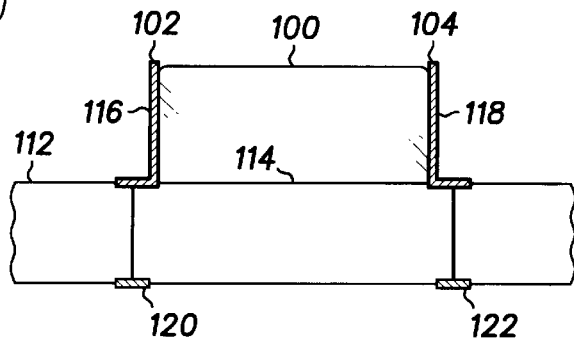
**FIG. 4**



**FIG. 5**



**FIG. 6**



**FIG. 7**

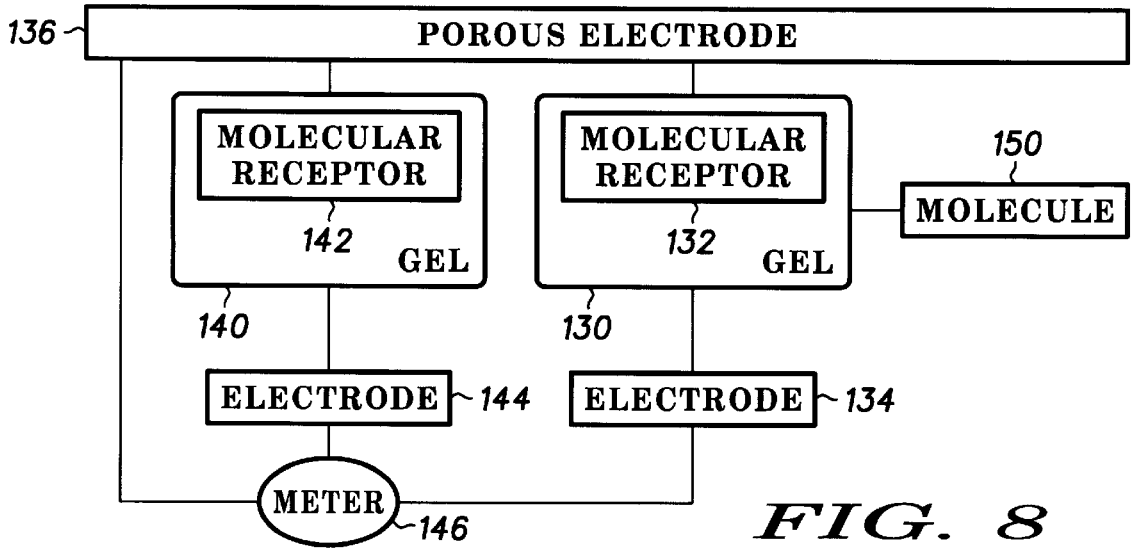


FIG. 8

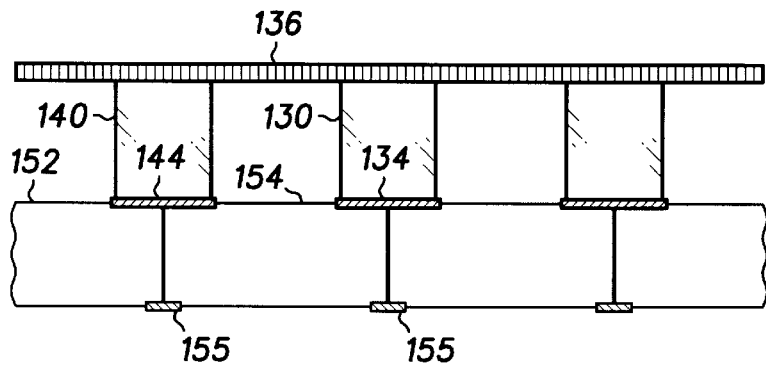


FIG. 9

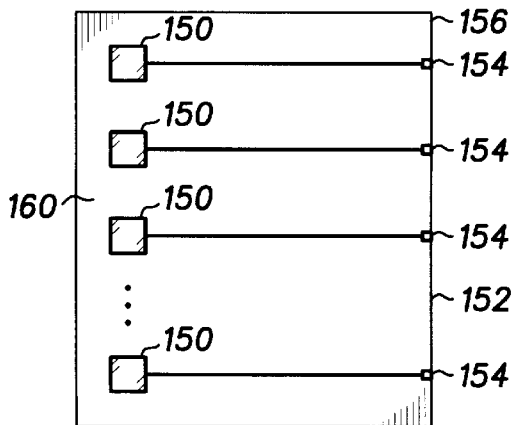
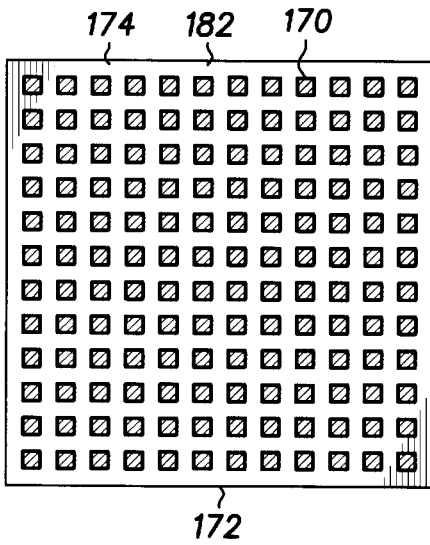
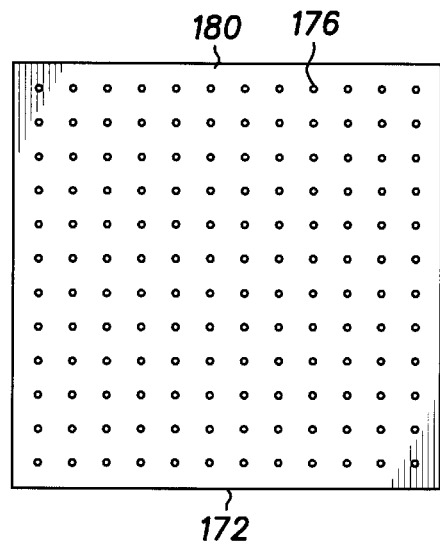


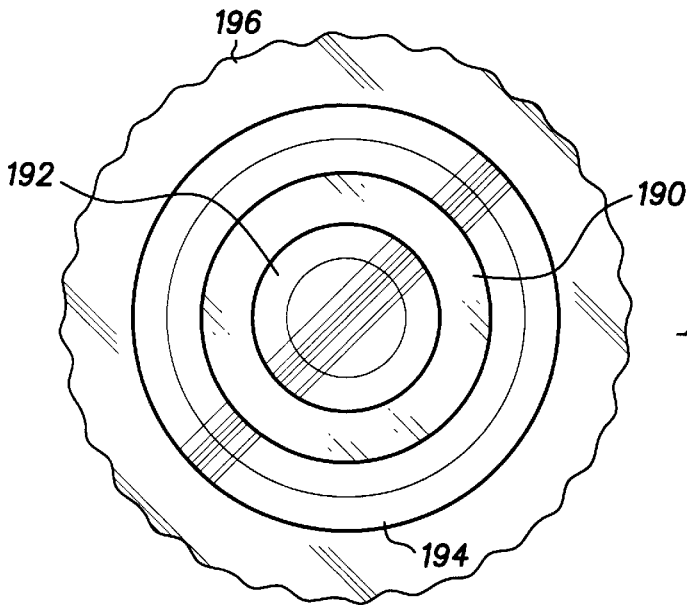
FIG. 10



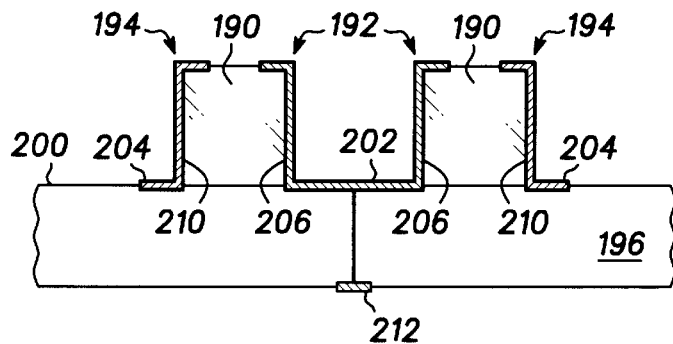
**FIG. 11**



**FIG. 12**



**FIG. 13**



**FIG. 14**

## SENSORS FOR ELECTRICALLY SENSING BINDING EVENTS FOR SUPPORTED MOLECULAR RECEPTORS

### TECHNICAL FIELD

The present invention relates to sensors for electrically sensing binding events with supported molecular receptors.

### BACKGROUND OF THE INVENTION

U.S. Pat. No. 5,552,270 to Khrapko et al. describes a device for sequencing DNA by hybridization. The device comprises an oligonucleotide array rigidly bound to a solid substrate. The oligonucleotide array consists of a multiplicity of gel portions separated from one another. Each gel portion contains one oligonucleotide of desired length.

Test DNA fragments are labeled with either a radioactive marker or a fluorescent marker. A solution including a buffer and the labeled test DNA fragments is applied to the device. The solution fully covers the gel portions containing immobilized oligonucleotides. The labeled test DNA fragments hybridize with one or more of the oligonucleotides. After performing a washing step, hybridization events are detected by detecting the radioactive marker or the fluorescent marker. A sequence associated with the test DNA fragments is reconstructed by analyzing detection data.

It is desirable to detect the hybridization events without requiring that the test DNA fragments be labeled with radioactive markers or fluorescent markers.

### BRIEF DESCRIPTION OF THE DRAWINGS

The invention is pointed out with particularity in the appended claims. However, other features of the invention will become more apparent and the invention will be best understood by referring to the following detailed description in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram of a sensor in accordance with the present invention;

FIG. 2 is a top view of a first embodiment of a sensor in accordance with the present invention;

FIG. 3 is a side sectional view of the embodiment of the sensor of FIG. 2;

FIG. 4 is a top view of a second embodiment of a sensor in accordance with the present invention;

FIG. 5 is a side sectional view of the embodiment of the sensor of FIG. 4;

FIG. 6 is a top view of a third embodiment of a sensor in accordance with the present invention;

FIG. 7 is a side sectional view of the embodiment of the sensor of FIG. 6;

FIG. 8 is a block diagram of another sensor in accordance with the present invention;

FIG. 9 is a side sectional view of an embodiment of the sensor of FIG. 8;

FIG. 10 illustrates an embodiment of a one-dimensional array of sensors;

FIGS. 11 and 12 illustrate an embodiment of a two-dimensional array of sensors;

FIG. 13 is a top view of yet another embodiment of a sensor in accordance with the present invention; and

FIG. 14 is a side sectional view of the embodiment of the sensor of FIG. 13.

### DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. 1 is a block diagram of a sensor 18 in accordance with the present invention; The sensor 18 comprises a gel 20

which supports at least one molecular receptor 22. Preferably, the gel 20 supporting the at least one molecular receptor 22 is formed in accordance with U.S. Pat. No. 5,552,270 to Khrapko et al. which is hereby incorporated by reference into the present application.

The at least one molecular receptor 22 is receptive to molecules having a predetermined and/or a preselected molecular structure. The at least one molecular receptor 22 can include either a biological molecule or a synthetic molecule having a specific affinity to its corresponding molecule. For example, each molecular receptor can include a chain of nucleotide bases to hybridize with a molecule having a complementary chain of nucleotide bases. In this case, each molecular receptor can include a DNA probe or a PNA probe for detecting a corresponding, complementary DNA base sequence, an RNA probe for detecting a corresponding, complementary RNA base sequence, or other DNA/RNA analogues.

The sensor 18 includes a first electrode 24 embedded in the gel 20. The first electrode 24 is used to electrically sense hybridization or binding of at least one molecule 26 to the at least one molecular receptor 22. For example, the at least one molecule 26 can include a molecule having a plurality of nucleotide bases such as a DNA fragment or an RNA fragment to hybridize with the at least one molecular receptor 22.

Preferably, the first electrode 24 includes an elongate portion embedded in the gel 20. More preferably, the elongate portion is linear.

Optionally, the sensor 18 further includes a second electrode 30 coupled to the gel 20. The second electrode 30 can be either directly coupled, capacitively coupled, or inductively coupled to the gel 20. The second electrode 30 assists in electrically sensing the hybridization or binding of the at least one molecule 26 to the at least one molecular receptor 22.

Preferably, the second electrode 30 is disposed at a side of the gel 20. Additionally, the second electrode 30 can surround at least a portion of the gel 20 and/or can surround at least a portion of the first electrode 24.

The second electrode 30 can include a cylindrical portion to surround or encircle the gel 20 and the first electrode 24. In this case, it is preferred that the first electrode 24 and the second electrode be generally coaxial. By "generally coaxial" it is meant that a first axis associated with the first electrode 24 is closer to being parallel to, rather than being perpendicular to, a second axis associated with the second electrode 30.

A meter 32 is electrically connected to the first electrode 24 and the second electrode 30. The meter 32 is used to electrically detect a binding event between the at least one molecule 26 and the at least one molecular receptor 22. Preferably, the meter 32 includes an impedance meter, such as a capacitance meter or an inductance meter, to measure and/or detect a change in impedance between the first electrode 24 and the second electrode 30 resulting from the binding event. Alternatively, the meter 32 can measure and/or detect a charge associated with the binding event, or can measure and/or detect a resonance shift resulting from the binding event.

Generally, the meter 32 can detect a change in an electrical quantity (measured between the first electrode 24 and the second electrode 30) between two instances of time (e.g. a pre-binding time and a post-binding time). Alternatively, the meter 32 can detect a change in an electrical quantity between the sensor 18 and a control sensor 34. The control

sensor **34** can include a like gel having molecular receptors, a like first electrode, and a like second electrode as the sensor **18**. The control sensor **34**, however, is not exposed to the at least one molecule **26**. The control sensor **34** is used as a calibration pixel for baseline subtraction.

FIG. 2 is a top view of a first embodiment of a sensor in accordance with the present invention. The sensor includes a gel member **40**. The gel member **40** supports a plurality of molecular receptors (not specifically illustrated) such as those described with reference to FIG. 1. Although illustrated to have a rectangular cross section, the gel member **40** can have an alternatively-shaped cross section. Examples of alternatively-shaped cross sections include, but are not limited to, a polygonal cross section, an elliptical cross section, and a circular cross section.

The sensor includes a first electrode **42** and a second electrode **44**. The first electrode **42** is embedded within the gel member **40**. The second electrode **44** is coupled to a surface of the gel member **40**.

Preferably, the first electrode **42** is directly coupled to the gel member **40**. In this case, the first electrode **42** can directly contact an inner surface of the gel member **40**. Alternatively, the first electrode **42** can be capacitively coupled to the gel member **40**. In this case, a dielectric material can be interposed between the first electrode **42** and a surface of the gel member **40**.

Similarly, it is preferred that the second electrode **44** be directly coupled to the gel member **40**. In this case, the second electrode **44** can directly contact a surface of the gel member **40**. Alternatively, the second electrode **44** can be capacitively coupled to the gel member **40**. In this case, a sheet of dielectric material can be interposed between the second electrode **44** and a surface of the gel member **40**.

The second electrode **44** defines an inner periphery **46** and an outer periphery **48**. The inner periphery **46** defines an opening **50** that is completely covered by the gel member **40**. The surface of the gel member **40** coupled to the second electrode **44** is bounded within the outer periphery **48**.

Preferably, the inner periphery **46** and the outer periphery **48** are circular-shaped so that the second electrode **44** has the shape of a circular ring. It is noted, however, that the inner periphery **46** and the outer periphery **48** can be alternatively shaped to provide an alternative annular shape for the second electrode **44**.

FIG. 3 is a side sectional view of the embodiment of the sensor of FIG. 2. As illustrated, the gel member **40**, the first electrode **42**, and the second electrode **44** are supported by a substrate **52**. The substrate **52** has a surface **54** that supports the gel member **40**. The second electrode **44** is integrated with the substrate **52** at the surface **54**.

The first electrode **42** includes an elongate portion **56** embedded in the gel member **40**. The elongate portion **56** has a length **58** greater than its width **60**. Although the elongate portion **56** can be nonlinear, it is preferred that the elongate portion **56** be linear. The elongate portion **56** is oriented along an axis **62** transverse to the surface **54** of the substrate **52** and a surface **64** of the second electrode **44**. The axis **62** extends through the opening **50** of the second electrode **44**.

It is preferred that the elongate portion **56** be generally normal to each of the aforementioned surfaces **54** and **64**. By "generally normal" it is meant that an angle between the elongate portion **56** and a surface is greater than 45°. More preferably, the angle between the elongate portion **56** and each of the surfaces **54** and **64** is greater than 85°.

Preferably, the first electrode **42** extends through an entire dimension of the gel member **40** to provide an improved

sensitivity for detecting binding events. Generally, the first electrode **42** can extend substantially through an entire dimension of the gel member **40**, i.e. through at least 50% of a dimension of the gel member **40**.

The first electrode **42** can be embedded in the gel member **40** using a variety of approaches. Using a first approach, the first electrode **42** includes a wire around which the gel member **40** is deposited. Using a second approach, the first electrode **42** includes a post fabricated by etching the substrate **52**. The post is metallized before the gel member **40** is deposited.

Using a third approach, the substrate **52** is formed of a deformable material such as an elastic polymer or a plastic. A surface of the substrate **52** is metallized. An elongate member such as a pin is applied to an opposing surface of the substrate **52**. The pin deforms the substrate **52** to form the first electrode **42**. In this case, the first electrode **42** may have a cone-like shape. The gel member **40** can be deposited either prior to or subsequent to the deformation of the substrate **52**.

The first electrode **42** can be electrically connected through the substrate **52** to a first contact **64**. Optionally, the second electrode **44** can be electrically connected through the substrate **52** to a second contact.

FIG. 4 is a top view of a second embodiment of a sensor in accordance with the present invention. The sensor includes a gel member **70**. The gel member **70** supports a plurality of molecular receptors (not specifically illustrated) such as those described with reference to FIG. 1. Although illustrated to have a circular cross section, the gel member **70** can have an alternatively-shaped cross section. Examples of alternatively-shaped cross sections include, but are not limited to, a polygonal cross section such as a rectangular cross section, and an elliptical cross section.

The sensor includes a first electrode **72** and a second electrode **74**. The first electrode **72** is embedded within the gel member **70**. The second electrode **74** is coupled to a surface of the gel member **70**.

Preferably, the first electrode **72** is directly coupled to the gel member **70**. In this case, the first electrode **72** can directly contact an inner surface of the gel member **70**. Alternatively, the first electrode **72** can be capacitively coupled to the gel member **70**. In this case, a dielectric material can be interposed between the first electrode **72** and a surface of the gel member **70**.

Similarly, it is preferred that the second electrode **74** be directly coupled to the gel member **70**. In this case, the second electrode **74** can directly contact a side surface of the gel member **70**. Alternatively, the second electrode **74** can be capacitively coupled to the gel member **70**. In this case, a sheet of dielectric material can be interposed between the second electrode **74** and the side surface of the gel member **70**.

The second electrode **74** is cylindrically shaped to surround the gel member **70** and the first electrode **72**. Further, the second electrode **74** is coaxial with the first electrode **72**.

FIG. 5 is a side sectional view of the embodiment of the sensor of FIG. 4. As illustrated, the gel member **70**, the first electrode **72**, and the second electrode **74** are supported by a substrate **82**. The substrate **82** has a surface **34** that supports the gel member **70**.

The first electrode **72** includes an elongate portion **86** embedded in the gel member **70**. The elongate portion **86** has a length **88** greater than its width **90**. Although the elongate portion **86** can be nonlinear, it is preferred that the elongate

portion **86** be linear. The elongate portion **86** is oriented along an axis **92** transverse to the surface **84** of the substrate **82**. The axis **92** also serves as an axis along which the second electrode **74** is oriented.

It is preferred that the elongate portion **86** be generally normal to the surface **84**. By “generally normal” it is meant that an angle between the elongate portion **86** and the surface **84** is greater than 45°. More preferably, the angle between the elongate portion **86** and the surface **84** is greater than 85°.

Preferably, the first electrode **72** and the second electrode **74** extend through an entire dimension of the gel member **70** to provide an improved sensitivity for detecting binding events. Generally, the first electrode **72** and the second electrode **74** can extend substantially through an entire dimension of the gel member **70**, i.e. through at least 50% of a dimension of the gel member **70**.

It is noted that the first electrode **72** can be formed and embedded in the gel member **70** using the approaches described with reference to FIG. 3.

The first electrode **72** can be electrically connected through the substrate **82** to a first contact **94**. Optionally, the second electrode **74** can be electrically connected through the substrate **82** to a second contact.

FIG. 6 is a top view of a third embodiment of a sensor in accordance with the present invention. The sensor includes a gel member **100**. The gel member **100** supports a plurality of molecular receptors (not specifically illustrated) such as those described with reference to FIG. 1. Although illustrated to have a rectangular cross section, the gel member **100** can have an alternatively-shaped cross section. Examples of alternatively-shaped cross sections include, but are not limited to, a polygonal cross section, an elliptical cross section, and a circular cross section.

The sensor includes a first electrode **102** and a second electrode **104**. The first electrode **102** is coupled to a first surface of the gel member **100**. The second electrode **104** is coupled to a second surface of the gel member **100**. Preferably, the first surface and the second surface are opposing surfaces of the gel member **100**.

Preferably, the first electrode **102** and the second electrode **104** are directly coupled to the gel member **100**. In this case, the first electrode **102** can directly contact the first surface and the second electrode **104** can contact the second surface. Alternatively, the first electrode **102** and the second electrode can be capacitively coupled to the gel member **100**. In this case, a sheet of dielectric material can be interposed between the first electrode **102** and the first surface, and between the second electrode **104** and the second surface.

FIG. 7 is a side sectional view of the embodiment of the sensor of FIG. 6. As illustrated, the gel member **100**, the first electrode **102**, and the second electrode **104** are supported by a substrate **112**. The substrate **112** has a surface **114** that supports the gel member **100**.

The first electrode **102** includes a planar portion **116** that is generally normal to the surface **114**. By “generally normal” it is meant that an angle between the planar portion **116** and the surface **114** is greater than 45°. More preferably, the angle between the planar portion **116** and the surface **114** is greater than 85°. Similarly, the second electrode **104** includes a planar portion **118** that is generally normal to the surface **114**. Preferably, the planar portion **116** is generally parallel to the planar portion **118**.

It is preferred that the first electrode **112** and the second electrode **114** extend along an entire side of the gel member

**110** to provide an improved sensitivity for detecting binding events. Generally, the first electrode **112** and the second electrode **114** can extend substantially along an entire side of the gel member **100**, i.e. along at least 50% of the side of the gel member **100**.

The first electrode **102** can be electrically connected through the substrate **112** to a first contact **120**. The second electrode **104** can be electrically connected through the substrate **112** to a second contact **122**.

FIG. 8 is a block diagram of another sensor in accordance with the present invention. The sensor comprises a first gel **130** which supports a first at least one molecular receptor **132**. The sensor further comprises a first electrode **134** and a porous electrode **136** coupled to the first gel **130**. The first electrode **134** and the porous electrode **136** can be either directly coupled, capacitively coupled, or inductively coupled to the first gel **130**.

The sensor can further comprise a second gel **140** which supports a second at least one molecular receptor **142**. In this case, the second gel **140** has a second electrode **144** and the porous electrode **136** coupled thereto. The second electrode **144** and the porous electrode **136** can be either directly coupled, capacitively coupled, or inductively coupled to the second gel **140**.

Molecules to be detected by the sensor migrate through the porous electrode **136** to at least one of the first gel **130** and the second gel **140**. Examples of the porous electrode **136** include, but are not limited to, a wire mesh through which molecules can migrate, an electrode having a porosity which allows molecules to migrate there through, and a perforated electrode having one or more holes which allows molecules to migrate there through.

A meter **146**, such as the meter **32**, is electrically connected to the first electrode **134** and the porous electrode **136**. The meter **146** is used to electrically detect a binding event between at least one molecule **150** and the first at least one molecular receptor **132**. The at least one molecule **150** migrates through the porous electrode **136** to the first at least one molecular receptor **132**. Similarly, the meter **146** can be electrically connected to the second electrode **144** to electrically detect a binding event for the second at least one molecular receptor **142**.

FIG. 9 is a side sectional view of an embodiment of the sensor of FIG. 8. The first electrode **134** and the second electrode **144** are supported by a substrate **152**. The substrate **152** includes a surface **154** with which the first electrode **134** and the second electrode **144** are integrated. The first electrode **134** and the second electrode **144** are generally planar.

The first gel **130** is supported by the first electrode **134**. Preferably, the first electrode **134** is directly coupled to the first gel **130**. In this case, the first electrode **134** can directly contact a surface of the first gel **130**. Alternatively, the first electrode **134** can be capacitively coupled to the first gel **130**. In this case, a dielectric material can be interposed between the first electrode **134** and a surface of the first gel **130**.

The second gel **140** is supported by the second electrode **144**. Preferably, the second electrode **144** is directly coupled to the second gel **140**. In this case, the second electrode **144** can directly contact a surface of the second gel **140**. Alternatively, the second electrode **144** can be capacitively coupled to the second gel **140**. In this case, a dielectric material can be interposed between the second electrode **144** and a surface of the second gel **140**.

The porous electrode **136** is supported by the first gel **130** and the second gel **140**. As a result, the first gel **130** is

interposed between the porous electrode **136** and the first electrode **134**, and the second gel **140** is interposed between the porous electrode **136** and the second electrode **144**.

Preferably, the porous electrode **136** is directly coupled to the first gel **130** and the second gel **140**. In this case, the porous electrode **136** can directly contact a surface of the first gel **130** and a surface of the second gel **140**. Alternatively, the porous electrode **136** can be capacitively coupled to the first gel **130** and the second gel **140**. In this case, a dielectric material can be interposed between the porous electrode **136** and each of the first gel **130** and the second gel **140**.

The first electrode **134** and the second electrode **144** are electrically connected to contacts **155** through the substrate **152**.

Each of the herein-described sensors can be included in an array of sensors. The array can include a one-dimensional array of sensors, a two-dimensional array of sensors, or a three-dimensional array of sensors. External contacts for interfacing the sensors to the meters **32** and **146** can be located at one or more edges of the array. Alternatively, the external contacts can be located at a surface opposite to a surface supporting the sensors and the gels.

A plurality of sensors described with reference to FIGS. **1** to **5**, **13**, and **14** can have their second electrodes interconnected to form a single ground electrode. Each sensor in the array is addressed by the single ground electrode and an external contact associated with its first electrode.

FIG. **10** illustrates an embodiment of a one-dimensional array of sensors. A plurality of sensors **150** are integrated with a substrate **152**. The sensors **150** are arranged as a linear array. A plurality of electrical contacts **154** are integrated with the substrate **152** near an edge **156**. Each of the electrical contacts **154** is electrically connected to the first electrode of a respective one of the sensors **150**.

A ground plane **160** can electrically interconnect the second electrodes of the sensors **150** for sensors described with reference to FIGS. **1** to **5**. Alternatively, the ground plane **160** can comprise the porous electrode **136** described with reference to FIGS. **8** and **9**.

FIGS. **11** and **12** illustrate an embodiment of a two-dimensional array of sensors. A plurality of sensors **170** are integrated with a substrate **172** at a first surface **174**. The sensors **170** are arranged as a two-dimensional array. A plurality of electrical contacts **176** are located at an opposite surface **180** of the substrate **172**. Each of the electrical contacts **176** is electrically connected to the first electrode of a respective one of the sensors **170**. Preferably, each of the electrical contacts **176** includes a pin oriented generally normal to the opposite surface **180** of the substrate **172**.

A ground plane **182** can electrically interconnect the second electrodes of the sensors **170** for sensors described with reference to FIGS. **1** to **5**. Alternatively, the ground plane **182** can comprise the porous electrode **136** described with reference to FIGS. **8** and **9**.

FIG. **13** is a top view of yet another embodiment of a sensor in accordance with the present invention. The sensor includes a gel member **190**. The gel member **190** supports a plurality of molecular receptors (not specifically illustrated) such as those described with reference to FIG. **1**. The gel member **190** is annular shaped. The gel member **190** can have a circular, annular shape as illustrated, or can have an alternative annular shape.

The sensor includes a first electrode **192** and a second electrode **194**. From the top view, the first electrode **192** is

substantially surrounded by the gel member **190**, and the second electrode **194** substantially surrounds the gel member **190**.

FIG. **14** is a side sectional view of the embodiment of the sensor of FIG. **13**. As illustrated, the gel member **190**, the first electrode **192**, and the second electrode **194** are supported by a substrate **196**. The substrate **196** has a surface **200** that supports the gel member **190**, a portion **202** of the first electrode **192**, and a portion **204** of the second electrode **194**.

The first electrode **192** is coupled to an inner periphery **206** of the gel member **190**. The second electrode **194** is coupled to an outer periphery **210** of the gel member **190**. The first electrode **192** and the second electrode **194** can be either directly coupled or indirectly coupled to the gel member **190** as described earlier.

As illustrated, the sensor can include a bottom contact **212** electrically coupled to the first electrode **192**. Alternatively, the sensor can include a top contact to the first electrode **192**. Similarly, the second electrode **194** can have an external contact accessible at either the top, the bottom, or sides of the substrate **196**.

For each of the herein-described embodiments of sensors for electrically sensing molecular binding events, it is preferred that the electrodes be formed of metal. In general, however, the electrodes can be formed of a conductive material or a semiconductive material. It is preferred that the herein-described substrates be formed of an elastic polymer or a plastic. In general, however, the substrates can be formed of a semiconductive material such as silicon or a dielectric material such as glass.

It is also noted that the gel members in each of the herein-described embodiments can be replaced by other receptor-supporting elements into which a reagent can diffuse. Examples of alternative elements include but are not limited to acrylamides, polypyrroles, polysaccharides, and other polymers.

Further, it is noted that embodiments of the present invention are applicable for biomolecular recognition in general. For example, the sensor can generally include ligand receptors for sensing hybridization, ligation, and analytes in solution.

Thus, there has been described herein several embodiments including preferred embodiments of sensors for electrically sensing molecular binding events for supported molecular receptors.

Because the various embodiments of the present invention electrically sense molecular binding events, they provide a significant improvement in that the use of radioactive markers and fluorescent markers is not required.

Additionally, various embodiments of the present invention as herein-described have an electrode embedded in each gel portion to provide better proximity to the molecular binding events.

Further, various embodiments of the present invention have a porous electrode coupled to each gel portion. The porous electrode is used to sense molecular binding events while allowing sample molecules to migrate there through.

It will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than the preferred form specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of the invention.

What is claimed is:

1. A sensor comprising:
  - a receptor-supporting element into which a reagent is diffusable;
  - at least one molecular receptor supported within the receptor-supporting element; and
  - a first electrode embedded in the receptor-supporting element.
2. The sensor of claim 1 wherein the at least one molecular receptor is receptive to a sequence of a plurality of nucleotide bases.
3. The sensor of claim 1 wherein the first electrode includes an elongate portion embedded in the receptor-supporting element.
4. The sensor of claim 3 further comprising a substrate having a surface to support the receptor-supporting element, wherein the first electrode is generally normal to the surface of the substrate.
5. The sensor of claim 3 wherein the elongate portion is linear.
6. The sensor of claim 1 further comprising a second electrode coupled to the receptor-supporting element.
7. The sensor of claim 6 wherein the first electrode and the second electrode are generally coaxial.
8. The sensor of claim 6 wherein the second electrode surrounds at least a portion of the first electrode.
9. The sensor of claim 6 wherein the second electrode is cylindrical.
10. The sensor of claim 6 wherein the second electrode is disposed at a side of the receptor-supporting element.
11. The sensor of claim 6 wherein the second electrode is annular-shaped.
12. The sensor of claim 6 wherein the second electrode contacts the receptor-supporting element.
13. The sensor of claim 6 wherein the second electrode surrounds a portion of the receptor-supporting element.
14. The sensor of claim 1 wherein the receptor-supporting element includes a gel.
15. A sensor comprising:
  - a first receptor-supporting element;
  - a first at least one molecular receptor supported within the first receptor-supporting element;
  - a first electrode coupled to the first receptor-supporting element; and

- a porous electrode coupled to the first receptor-supporting element.
16. The sensor of claim 15 further comprising:
  - a second receptor-supporting element;
  - a second at least one molecular receptor supported within the second receptor-supporting element; and
  - a second electrode coupled to the second receptor-supporting element;
 wherein the porous electrode is coupled to the second receptor-supporting element.
17. The sensor of claim 15 wherein the porous electrode comprises a porous mesh.
18. The sensor of claim 15 wherein the first receptor-supporting element is disposed between the first electrode and the porous electrode.
19. The sensor of claim 15 wherein the first electrode and the porous electrode contact the first receptor-supporting element.
20. The sensor of claim 15 wherein the first receptor-supporting element comprises a material selected from the group consisting of a gel, an acrylamide, a polypyrrole, and a polysaccharide.
21. A sensor comprising:
  - a receptor-supporting element into which a reagent is diffusable;
  - an annular-shaped electrode coupled to the receptor-supporting element; and
  - an elongate electrode embedded in the receptor-supporting element.
22. A sensor comprising:
  - an annular-shaped, receptor-supporting element into which a reagent is diffusable;
  - at least one molecular receptor supported within the annular-shaped, receptor-supporting element; and
  - a first electrode and a second electrode coupled to the annular-shaped, receptor-supporting element.
23. The sensor of claim 22 wherein the first electrode is coupled to an inner periphery of the annular-shaped, receptor-supporting element.
24. The sensor of claim 22 wherein the second electrode is coupled to an outer periphery of the annular-shaped, receptor-supporting element.

\* \* \* \* \*