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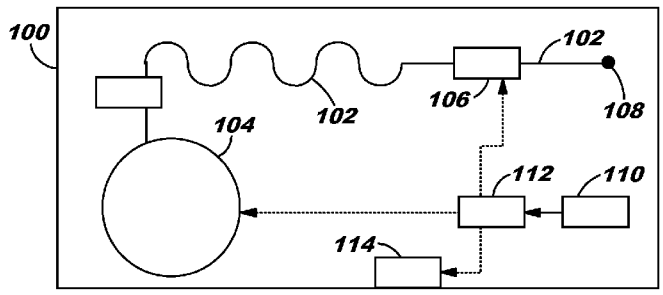
(54) **Title**: APPARATUS AND METHOD FOR MEASURING BIOCHEMICAL PARAMETERS

FIG. 1



(57) **Abstract**: In a first embodiment, electrodes are coupled to a surface at first, second, and third locations, the first location being further from the third location than from the second location. Impedance is measured at distinct frequencies between pairs of the electrodes. As a result, impedance is measured at differing regions below the surface, one region being deeper below the surface than the other region. In a second embodiment, a microfluidic device carries out an analysis. The analysis may be within a flexible patch adhered to a surface, or may be in a solid device implanted in a body of liquid surrounded by tissue. The analysis may involve pumping a fluid or may involve drawing an analyte electrophoretically through a microfluidic channel.

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Apparatus and method for measuring biochemical parameters

Cross-reference to related applications

This application claims the benefit of US application number 61/235,979 filed August 21, 2009, which application is incorporated herein by reference for all purposes.

Background

Microfluidic technology and other techniques may be employed to measure various types of physiologic parameters that might be important to diagnose or manage a disease.

Generally, the term "microfluidics" refers to the art making very small channels using microlithographic and microfabrication techniques. For example, a substrate such as glass with polymers may be used to make channels. Other substances used in formulating substrates include, for example, silicon and aluminum. Various other types of substrates are possible. The channels may be fabricated using various techniques, e.g., by etching silicon using a deep reactive ion etch with a mask that provides precise control of geometry. Various patterns may be employed, e.g., curved lines, straight lines, etc.

Microfluidics may be used, inter alia, to perform a function such as ion chromatography or liquid chromatography to look for and measure an ion or molecule. A typical application in an ion chromatograph is introduction of a small sample liquid in a column of fluid that is otherwise neutral. Introduction, for example, may be achieved via various fluid introduction components, e.g., a pump, a microsuction component, etc.

The sample moves through the column. In some examples, a field, e.g., an electric field, is applied across the column which affects the diffusion times of the ions of the sample as the ions move through the column. The ions are detected, e.g., at the end of the column. A time of injection of the ions of the sample can be calculated based on detection, diffusion rates, and the dimensions of the column.

Information may be obtained in various ways, e.g., based on measuring electroconnectivity. In various aspects, channels are filled with different materials that modify the motion rates of different

ions.

Such diagnosis or disease management by means of a microfluidic approach would be helpful if it could be done conveniently and in conjunction with other processes that might already be taking place for other reasons.

Summary of the invention

In a first embodiment, electrodes are coupled to a surface at first, second, and third locations, the first location being further from the third location than from the second location. Impedance is measured at distinct frequencies between pairs of the electrodes. As a result, impedance is measured at differing regions below the surface, one region being deeper below the surface than the other region. In a second embodiment, a microfluidic device carries out an analysis. The analysis may be within a flexible patch adhered to a surface, or may be in a solid device implanted in a body of liquid surrounded by tissue. The analysis may involve pumping a fluid or may involve drawing an analyte electrophoretically through a microfluidic channel.

Figures

FIG. 1 illustrates various components associated with a first measuring device;

FIG. 2a illustrates various components associated with a second measuring device;

FIG. 2b illustrates various components associated with multiple measuring devices; and

FIG. 3 illustrates an electrophoretic approach in a measuring device.

Detailed description

A medical device and method for measuring physiologic parameters is provided. The medical device and method may be practiced independently and/or associated with other device(s), components, and method(s). One example of integration with a device is integration with a receiver, e.g., a receiver of RFID signals and/or conduction signals. One example of a receiver of

conduction signals is an ingestible event marker receiver device, as disclosed in U.S. patent application number 61/160,289 entitled "Body-Associated Signal Receiver" filed March 13, 2009. The foregoing is hereby incorporated by reference in its entirety.

One example of such a device is a microfluidic device such as a bandage-type patch designed to be temporarily or permanently attachable to the skin or implanted into the body. Another such example is one or more removably attachable or implantable devices having electrodes for measurement of various physiologic parameters. In certain aspects, the medical device may be an independently configure device or associated, e.g., wholly or partially integrated with other device(s).

In various aspects, a version of the aforementioned technique is created on the skin where the effluent is so small it simply evaporates. A reservoir liquid that represents a control liquid such as pure water may be stored on the patch and, using a microfluidic pump, the ions are pumped through the column. A sample of a patient's bodily fluid, such as sweat, is injected into the column. Other techniques such as microsuction, electrophoresis, etc., may be used as well.

Electrophoresis generally involves putting a voltage between the skin and the column to pull ions and other types of biological materials through the skin using electrophoresion and into the sampling column to be introduced into the chromatography column. The column may be flushed at a certain rate with a background fluid or carrier fluid, for example water, and as different ions diffuse through the fluid at a different rate, the ions are separated from one another and are collected at the distal end of the column by using electrical or optical means.

Another aspect includes application of electrophoretic voltage across the column, e.g., the length of the column, the end of the column, switched in and out, etc. For example, one segment of the column can be used to view simple diffusion to separate molecules and a valve may be used to control and or regulate the samples or a cross-channel may be activated which takes a certain amount of material which may be further separated using, for example, electrophoresis.

Aspects may be used to perform chemical analyses, physiologic analysis, and other pursuits. Examples include analysis of sweat, urine, blood etc. In some aspects, a device utilizing microfluidic principles such as the aforedescribed may be implanted, e.g., inside a bladder. Various aspects include miniaturized devices, components, subcomponents, etc., as deemed suitable for such

pursuits.

In some aspects, reagent(s) may be used. Generally, such reagents react chemically with the ions in some way to change the rate of diffusion or change their rate of electro-phoretic advancement.

To illustrate, and as depicted in FIG. 1, a first measuring device 100 such as a patch device is associated with a patient. The patch device has a column 102 and may have a reservoir which may include one or more fluids and a valve for regulating intake of the sample. The reservoir may be an independent component or integrated with one or more other components, e.g., the column. As the fluids leave a column 102 at outlet 108, they creep off the patient's skin or are released into the air and essentially evaporate because the quantities, e.g., amounts of fluids, are so low that they would be virtually non-noticeable. The sample intake is facilitated by a pump 104. The reservoir, e.g., a serpentine column, with a valve, and other components such as the pump 104 may be micro-fabricated. The liquid goes through the reservoir and through a detector device, e.g., an array of sensors, such as detector array 106 and is discharged through an outlet 108 as described in the art of ion chromatography. Coming out the detector array 106 is the column 102, which may empty the fluid. Typically, such a small quantity of fluid would be emptied that the fluid may be absorbed, e.g., by a material such as cotton that may be associated with the patch, and / or may evaporate over time.

The device 100 is controlled by a microcontroller 112 powered for example by electrochemical cell 110. A wireless communications link 114 may be employed to permit the microcontroller 112 to communicate sensed information to equipment external to the device 100. The microcontroller 112 controls the pump 104 and receives signals from the sensor 106. Importantly, the device 100 is not powered by any equipment external to the device 100 but is self-powered. The cell 110 may be self-contained, or may get its electrolyte from surrounding liquid or moisture.

A variant is shown in Fig. 3. In Fig. 3, instead of a pump 104, we see a power supply 118. The power supply 118 develops an electrical potential between a region 120 of nearby tissue or liquid 116 and the far end of the column at 122. The electrical potential draws an analyte (typically ions of interest) through the column 102 for analysis in the sensor 106.

The chief application described herein is a patch applied to the skin. The patch receives for example perspiration from the skin and detects for example glucose. But the alternative application

is to implant the device in a body of liquid surrounded by, for example, an organ wall. In such an application, the device draws fluid from the body of liquid by means of a pump and passes it by a sensor. Alternatively the device draws an analyte (such as ions of interest) electrophoretically from the body of liquid.

In various aspects, devices may be configured to make such measurements at predetermined intervals, e.g., once a day or twice a day, and at different points in time when samples are required to be taken. In various aspects, the amounts of fluid, e.g., water, may be determined by the geometry of the column. One such example is a column having a very, very small diameter. Some examples include channel diameters of 50 nanometers, 100 nanometers, 50 micrometers, 100 micrometers, etc. Other diameters are possible as well.

Other applications include identification of various substances, e.g., glucose. For example, a sample may be electrophoretically pulled from the skin into the column and then glucose may be separated from the other constituents by passing it through the diffusion column.

It also may be possible to add a reagent to the sample and look for the change, e.g., look for the products, that would be a measure of the glucose concentration, glucose oxidation, etc. For example, hydrogen peroxide may be produced that can be measured with an electrometer. In another example, a reagent may be added to a sample to look for indications of pregnancy, etc.

Various aspects include a variety of different types of chemical analysis equipment, some or all of which may be miniaturized.

In various aspects, fluids may be sampled from various locations of the body. In one example, the fluid is sampled from within the body, e.g., using an implantable device. The implantable device may be implanted into various locations, e.g., a bladder, kidney, stomach, etc. To illustrate, the implantable device may be implanted into the bladder and sample urine to measure or identify glucose. Because glucose tends to reduce the conductivity as compared to salt, salt makes a fluid more conductive and glucose makes it less conductive. A measurement of glucose going into the bladder and the volume of the bladder may be determined by sampling of fluid associate, e.g., insert or implant a device inside the bladder. Measuring the concentration of glucose in the bladder might be a way of measuring glucose in the blood, i.e., may be a proxy for measuring glucose in the blood.

Another aspect includes a device that measures fluid content, e.g., water content of patient's skin. This approach may be similar to an approach described in U.S. patent application number 61/160,265, entitled "Volume Sensing Device, System, and Method" and filed March 13, 2009, herein incorporated by reference in its entirety. In this application, the approach may be used for measuring the amount of blood in the heart where the blood-to-tissue ratio is determined by measuring the impedance at two points at two different frequencies. A comparison of a ratio of the first impedance measurement at a point in time to the second impedance measurement at a corresponding point in time may be made to determine the blood volume-related value associated with an area located between the first tissue location and the second tissue location.

Various aspects facilitate measurement of various fluids and determinations inferred from those measurements, e.g., the moisture in skin, the level of dehydration, the amount of blood volume of the patient, etc. For example heart-failure patients may be susceptible to volume overload, insufficient hydration, and other serious issues. Measurement of various fluids and determinations inferred from those measurements may provide notice of such pending or actual condition.

Continuing with this approach, comparison of these to pure saline would result in no difference and comparison to pure tissue would result in a maximum difference. Thus, the amount of fluid in the tissue is a function of what is produced, so the ratio of those two frequencies is function of the amount of fluid in the tissue. In a typical case the tissue being studied is tissue perfused with blood.

To illustrate and with reference to FIG. 2a, a second medical device 200 includes at least two electrodes 202, e.g., an array of electrodes. Alternatively, and with respect to FIG. 2b, each of the at least two electrodes may be associated with a multiple (respective) devices 206, 208. The devices may be configured variously and exhibit various form factors, e.g., two adhesive patches, each adhesive patch having one or more electrodes 202. The amount of tissue sampled is determined by the relative position of the electrodes 202. The bulk of the current 204 will flow between the two electrodes 202. There may be some current that goes at a farther distance and at a greater distance into the tissue, and the depth will be related to the distance apart of the two electrodes 202.

For example, if just the area of tissue near the surface of the skin is to be sampled, the electrodes may be positioned relatively close to each other. If sampling is directed to deeper within the tissue, then the electrodes may be positioned relatively far apart from each other. To illustrate, if sampling

is directed to the blood tissue ratio of a person's leg, one electrode may be positioned in the heel region and the other electrode may be positioned in the groin region.

A patch that attaches to the skin on the torso thus might have an array of electrodes at different spacings and, in so doing, might be able to characterize the relative amount of liquid at various depths in the skin. The two closest ones would be sampling the nearest tissues, the ones closest to the surface, and the ones spaced farthest apart would be sampling more of the in-depth tissue and looking at the tissue right there. So one could construct a simple mathematical model of the amount of fluid as a function of distance into the tissue.

One may have a two-dimensional array which may be used, among other things, to construct maps of blood-tissue ratios and start imaging or looking for various tissue types and configurations, including cysts and tumors.

Additional uses include athletic-related uses. For example, an athlete engaging in exercising, riding a bicycle, or running across a soccer field or football field may tend to dehydrate at a faster rate than an individual at rest. To monitor and guard against this condition, the fluid amount may be measured and the athlete's fluid intake may be adjusted accordingly. In addition, hydration may be monitored to ensure that the athlete does not drink too much fluid during the exercise period. In various aspects, the device may provide or trigger alert(s), e.g., audible alert to the wearer, electronic trigger to a designated device, etc. The alert may be conditioned on various predetermined parameters such as fluid level too low, too high, etc.

Further uses include monitoring multiple patients, e.g., residents in a nursing home or hospital where are a large number patients and relatively low number of nurses. Alerts may be sent, for example, to the nursing station, etc.

Another use includes monitoring an accident victim, e.g., an accident victim with a head injury, the goal being to monitor swelling, lack of fluids leading to shock, etc. Combinations of parameters can also be monitored, e.g., heart rate, heart rate variability, and fluid levels through a variable connection, dual frequency measurement. In one aspect, the medical device is configured as an implantable lead. Alternatively, the device may be configured as an external device, e.g., an adhesive patch applied over the heart region of the body to determine cardiac volume, heart rate, etc.

For dehydration applications, various aspects may be employed by desert travelers, sports players, military personnel, athletes, acupuncturists, and in agricultural pursuits, e.g., determining if steers or other animals are hydrated to a level necessary for optimum market consideration.

For various applications, e.g., application to the thorax region, multiple electrodes may be variously located on the thorax to observe changes in the region's impedance and to indicate how much blood is in the thorax as when sampled, for example, at three or four electrode contact points. A matrix may be derived from such a sampling.

Another application includes an implantable device comprising at least two electrodes for implantation into various locations, e.g., a bladder, is provided. In one example, the implantable device may measure or identify glucose. Because glucose tends to reduce the conductivity as compared to salt, salt makes a fluid more conductive and glucose makes it less conductive. A measurement of glucose going into the bladder and the volume of the bladder may be determined by putting a device inside the bladder. Measuring the concentration of glucose in the bladder might be a way of measuring glucose in the blood, i.e., may be a proxy for measuring glucose in the blood.

The foregoing examples are illustrative in nature and not determinative of scope. One skilled in the art will recognize that various alternatives, components, configurations, and steps may be used to carry out the invention described herein.

Claims

1. Apparatus comprising:

an adhesive patch disposed for adhesion to a surface;

the patch being flexible;

the patch comprising a microfluidic channel disposed to receive fluid from the surface;

the patch further comprising a pump connected with the channel, the pump responsive to a control signal for pumping fluid received from the surface along the microfluidic channel;

the patch further comprising a sensor positioned along the channel, the sensor disposed to sense a biochemical parameter of interest and responsive to the sensing to generate a data signal;

the patch unpowered by any power source external thereto and further comprising an electrochemical cell;

the patch wirelessly communicatively coupled to electronic equipment external thereto by means of a wireless communications link;

the patch further comprising a microcontroller controlling the pump by means of the control signal, the microcontroller receiving the data signal from the sensor, the microcontroller connected to the electrochemical cell to be powered thereby, the microcontroller electrically connected to the wireless communications link;

the patch being sterile;

the patch contained within a wrapper preserving said sterile condition.

2. The apparatus of claim 1 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

3. The apparatus of claim 2 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

4. The apparatus of claim 3 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

5. The apparatus of claim 1 wherein the biochemical parameter of interest is presence of glucose.

6. The apparatus of claim 1 further comprising a receiver disposed to receive a signal from a transmitter external to the apparatus.

7. The apparatus of claim 1 further comprising a reagent disposed to react with the fluid from the surface, the sensor disposed to sense a product of said reaction.

8. Apparatus comprising:

an adhesive patch disposed for adhesion to a surface;

the patch being flexible;

the patch comprising a microfluidic channel having first and second ends, the microfluidic channel at its first end disposed to receive fluid from the surface;

the patch further comprising a source of electrical potential, the source of electrical potential disposed to develop said electrical potential between the surface and the second end of the microfluidic channel;

the source of electrical potential responsive to a control signal;

the patch further comprising a sensor positioned along the channel, the sensor disposed to sense a biochemical parameter of interest and responsive to the sensing to generate a data signal;

the patch unpowered by any power source external thereto and further comprising an electrochemical cell;

the patch wirelessly communicatively coupled to electronic equipment external thereto by means of a wireless communications link;

the patch further comprising a microcontroller controlling the source of electrical potential by means of the control signal, the microcontroller receiving the data signal from the sensor, the microcontroller connected to the electrochemical cell to be powered thereby, the microcontroller electrically connected to the wireless communications link;

the patch being sterile;

the patch contained within a wrapper preserving said sterile condition.

9. The apparatus of claim 8 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

10. The apparatus of claim 9 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

11. The apparatus of claim 10 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

12. The apparatus of claim 8 wherein the biochemical parameter of interest is presence of glucose.

13. The apparatus of claim 8 further comprising a receiver disposed to receive a signal from a transmitter external to the apparatus.

14. The apparatus of claim 8 further comprising a reagent disposed to react with the fluid from the surface, the sensor disposed to sense a product of said reaction.

15. Apparatus comprising:

a solid device disposed for implantation within a body of liquid surrounded by tissue;

the device comprising a microfluidic channel disposed to receive fluid from the body of liquid;

the device further comprising a pump connected with the channel, the pump responsive to a control signal for pumping fluid received from the body of liquid along the microfluidic channel;

the device further comprising a sensor positioned along the channel, the sensor disposed to sense a biochemical parameter of interest and responsive to the sensing to generate a data signal;

the device unpowered by any power source external thereto and further comprising an electrochemical cell;

the device wirelessly communicatively coupled to electronic equipment external thereto by means of a wireless communications link;

the device further comprising a microcontroller controlling the pump by means of the control signal, the microcontroller receiving the data signal from the sensor, the microcontroller connected to the electrochemical cell to be powered thereby, the microcontroller electrically connected to the wireless communications link;

the device being sterile;

the device contained within a wrapper preserving said sterile condition.

16. The apparatus of claim 15 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

17. The apparatus of claim 16 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

18. The apparatus of claim 17 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

19. The apparatus of claim 15 wherein the biochemical parameter of interest is presence of glucose.

20. The apparatus of claim 15 further comprising a receiver disposed to receive a signal from a transmitter located external to the apparatus.

21. The apparatus of claim 15 further comprising a reagent disposed to react with the fluid from the body of liquid, the sensor disposed to sense a product of said reaction.

22. Apparatus comprising:

a solid device disposed for implantation within a body of liquid surrounded by tissue;

the device comprising a microfluidic channel having first and second ends, the microfluidic channel at its first end disposed to receive fluid from the body of liquid;

the device further comprising a source of electrical potential, the source of electrical potential disposed to develop said electrical potential between the body of liquid and the second end of the microfluidic channel;

the source of electrical potential responsive to a control signal;

the device further comprising a sensor positioned along the channel, the sensor disposed to sense a biochemical parameter of interest and responsive to the sensing to generate a data signal;

the device unpowered by any power source external thereto and further comprising an electrochemical cell;

the device wirelessly communicatively coupled to electronic equipment external thereto by means of a wireless communications link;

the device further comprising a microcontroller controlling the source of electrical potential by means of the control signal, the microcontroller receiving the data signal from the sensor, the microcontroller connected to the electrochemical cell to be powered thereby, the microcontroller electrically connected to the wireless communications link;

the device being sterile;

the device contained within a wrapper preserving said sterile condition.

23. The apparatus of claim 22 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

24. The apparatus of claim 23 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

25. The apparatus of claim 24 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

26. The apparatus of claim 22 wherein the biochemical parameter of interest is presence of glucose.

27. The apparatus of claim 22 further comprising a reagent disposed to react with the fluid from the body of liquid, the sensor disposed to sense a product of said reaction.

28. A method comprising the steps of:

removing a sterile flexible adhesive patch from a sterile wrapper;

adhering the patch to a surface;

under control of a microcontroller within the patch, controlling a pump within the patch to pump fluid received from the surface into a microfluidic channel;

under control of the microcontroller, receiving a data signal from a sensor positioned along the channel, the data signal indicative of a sensed biochemical parameter of interest regarding the pumped fluid;

under control of the microcontroller, communicating information indicative of the data signal to electronic equipment external thereto by means of a wireless communications link.

29. The method of claim 28, further characterized in that the controlling, the pumping, the sensing,

and the communicating is unpowered by any power source external thereto.

30. The method of claim 29, further characterized in that the controlling, the pumping, the sensing, and the communicating is powered by operation of an electrochemical cell.

31. The method of claim 28 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

32. The method of claim 31 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

33. The method of claim 32 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

34. The method of claim 28 wherein the biochemical parameter of interest is presence of glucose.

35. The method of claim 28 further characterized in that there is provided a reagent disposed to react with the fluid from the surface, the sensor disposed to sense a product of said reaction.

36. A method comprising the steps of:

removing a sterile flexible adhesive patch from a sterile wrapper;

adhering the patch to a surface, thereby bringing a first end of a microfluidic channel nearby to the surface;

under control of a microcontroller within the patch, developing an electrical potential between the surface and a second end of the microfluidic channel, thereby drawing an analyte through the microfluidic channel;

under control of the microcontroller, receiving a data signal from a sensor positioned along the channel, the data signal indicative of a sensed biochemical parameter of interest regarding the analyte;

under control of the microcontroller, communicating information indicative of the data signal to electronic equipment external thereto by means of a wireless communications link.

37. The method of claim 36, further characterized in that the controlling, the developing, the sensing, and the communicating is unpowered by any power source external thereto.

38. The method of claim 37, further characterized in that the controlling, the developing, the sensing, and the communicating is powered by operation of an electrochemical cell.

39. The method of claim 36 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

40. The method of claim 39 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

41. The method of claim 40 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

42. The method of claim 36 wherein the biochemical parameter of interest is presence of glucose.

43. The method of claim 36 further characterized in that there is provided a reagent disposed to react with the analyte, the sensor disposed to sense a product of said reaction.

44. A method comprising the steps of:

removing a solid device from a sterile wrapper;

implanting the device within a body of liquid surrounded by tissue, thereby bringing a first end of a microfluidic channel to the body of liquid;

under control of a microcontroller within the device, operating a pump within the device to draw fluid from the body of liquid into the microfluidic channel;

under control of the microcontroller, receiving a data signal from a sensor positioned along the

channel, the data signal indicative of a sensed biochemical parameter of interest regarding the fluid;

under control of the microcontroller, communicating information indicative of the data signal to electronic equipment external thereto by means of a wireless communications link.

45. The method of claim 44, further characterized in that the controlling, the developing, the sensing, and the communicating is unpowered by any power source external thereto.

46. The method of claim 45, further characterized in that the controlling, the developing, the sensing, and the communicating is powered by operation of an electrochemical cell.

47. The method of claim 44 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

48. The method of claim 47 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

49. The method of claim 48 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

50. The method of claim 44 wherein the biochemical parameter of interest is presence of glucose.

51. The method of claim 44 further characterized in that there is provided a reagent disposed to react with the fluid, the sensor disposed to sense a product of said reaction.

52. A method comprising the steps of:

removing a solid device from a sterile wrapper;

implanting the device within a body of liquid surrounded by tissue, thereby bringing a first end of a microfluidic channel to the body of liquid;

under control of a microcontroller within the device, developing an electrical potential between the body of liquid and a second end of the microfluidic channel, thereby drawing an analyte through the

microfluidic channel;

under control of the microcontroller, receiving a data signal from a sensor positioned along the channel, the data signal indicative of a sensed biochemical parameter of interest regarding the analyte;

under control of the microcontroller, communicating information indicative of the data signal to electronic equipment external thereto by means of a wireless communications link.

53. The method of claim 52, further characterized in that the controlling, the developing, the sensing, and the communicating is unpowered by any power source external thereto.

54. The method of claim 53, further characterized in that the controlling, the developing, the sensing, and the communicating is powered by operation of an electrochemical cell.

55. The method of claim 52 wherein the channel diameter is in the range of 50 nanometers to 100 micrometers.

56. The method of claim 53 wherein the channel diameter is in the range of 50 nanometers to 50 micrometers.

57. The method of claim 54 wherein the channel diameter is in the range of 50 nanometers to 100 nanometers.

58. The method of claim 52 wherein the biochemical parameter of interest is presence of glucose.

59. The method of claim 52 further characterized in that there is provided a reagent disposed to react with the analyte, the sensor disposed to sense a product of said reaction.

60. Apparatus comprising:

a first electrode coupled to a surface of a material having a depth, the first electrode coupled to the surface of the material at a first location;

a second electrode coupled to the surface of the material at a second location;

a third electrode coupled to the surface of the material at a third location;

the first location being further away from the third location than from the second location;

the apparatus further comprising sensing electronics connected with the first electrode, the second electrode, and the third electrode;

the sensing electronics disposed to measure, between the first and the second electrodes, a ratio of conductivity of a first region of the material at two differing frequencies;

the sensing electronics disposed to measure, between the first and the third electrodes, a ratio of conductivity of a second region of the material at two differing frequencies.

61. The apparatus of claim 60 wherein the material is tissue perfused with blood, and wherein the second region is further from the surface than the first region, and wherein the ratios of conductivity are indicative of blood/tissue ratios.

62. A method for use with apparatus comprising a first electrode, a second electrode, and a third electrode, each electrode disposed for coupling to a surface of a material having a depth, and sensing electronics disposed to measure, between pairs of electrodes, a ratio of conductivity of regions of the material at two differing frequencies; the method comprising the steps of:

coupling the first electrode to the surface of the material at a first location;

coupling the second electrode to the surface of the material at a second location;

coupling the third electrode to the surface of the material at a third location;

the first location being further away from the third location than from the second location;

by means of the sensing electronics measuring, between the first and the second electrodes, a ratio of conductivity of a first region of the material at two differing frequencies;

by means of the sensing electronics measuring, between the first and the third electrodes, a ratio of conductivity of a second region of the material at two differing frequencies.

63. The method of claim 62 wherein the second region is further from the surface than the first region, and wherein the ratios of conductivity are indicative of blood/tissue ratios.

64. The method of claim 62 further comprising the step of communicating information indicative of the ratios by means of a wireless communications link.

FIG. 1

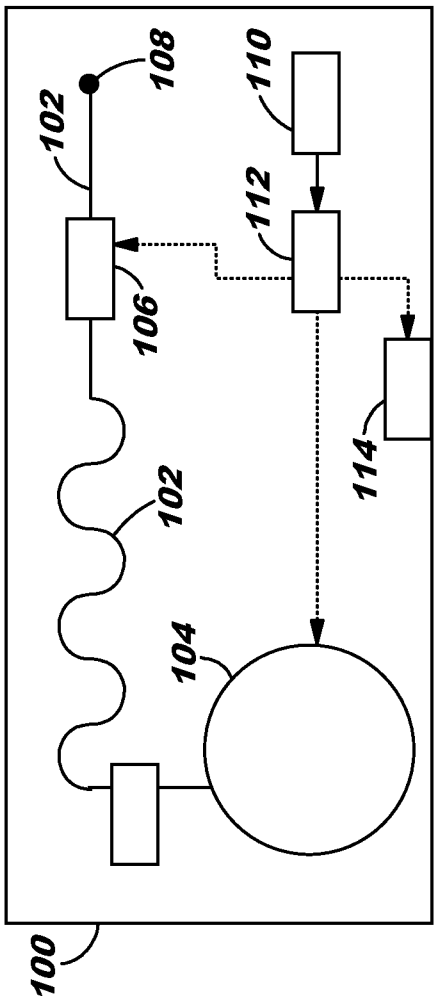

FIG. 2B

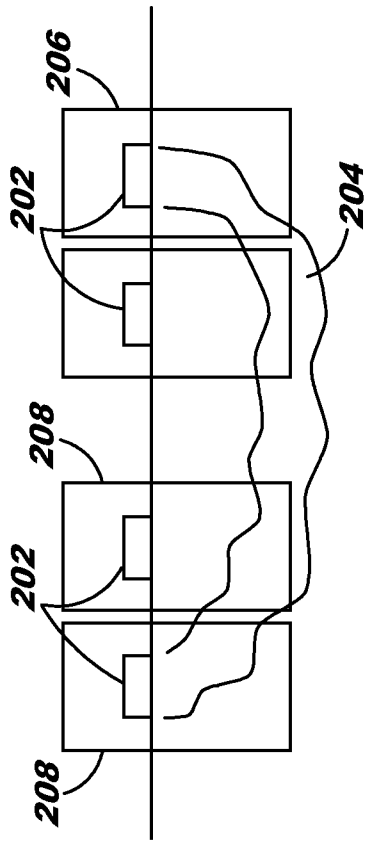

FIG. 2A

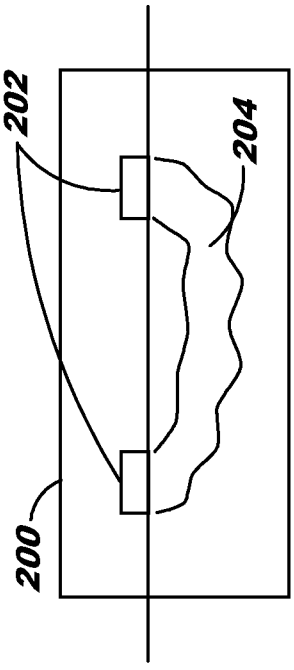

FIG. 3