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(54) **SHIELDED OPTICAL PROBE HAVING AN ELECTRICAL CONNECTOR**

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6,280,213, which is a continuation of application No. 09/318,563, filed on May 26, 1999, now abandoned, which is a continuation of application No. 08/838,392, filed on Apr. 9, 1997, now Pat. No. 5,934,925, which is a continuation of application No. 08/543,297, filed on Oct. 16, 1995, now Pat. No. 5,645,440.

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See application file for complete search history.

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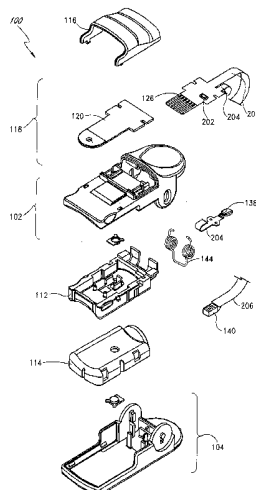
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(57) **ABSTRACT**

A noninvasive optical probe has an electrical connector for connecting the optical probe to a cable connector. According to one embodiment, the electrical connector includes a durable flexible tab suspended between the housing of the optical probe and a protective cover. The electrical connector also advantageously forms, according to various embodiments, a flexible, plugable, lockable, removable, and sealable electrical connection.

17 Claims, 7 Drawing Sheets



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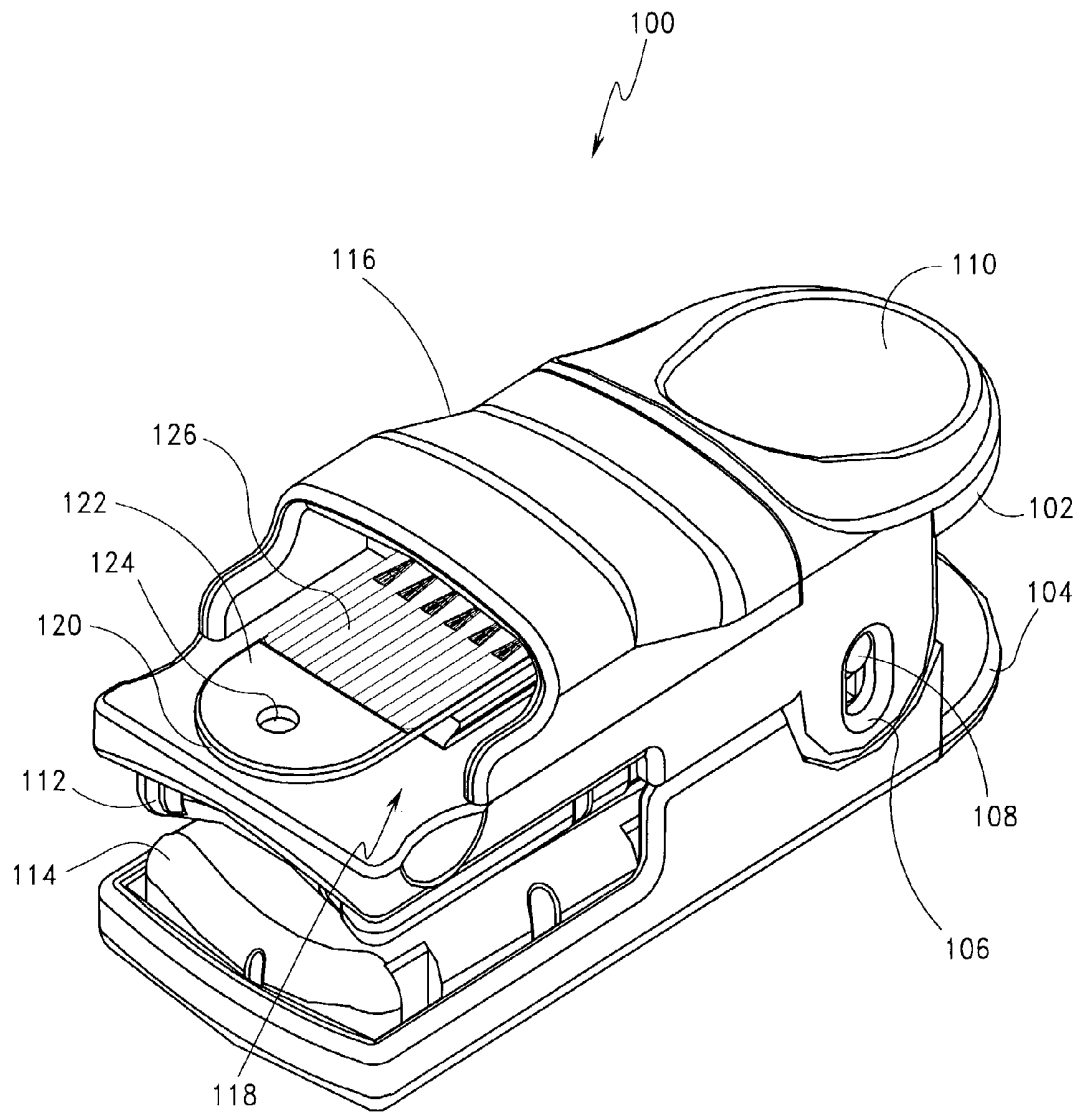
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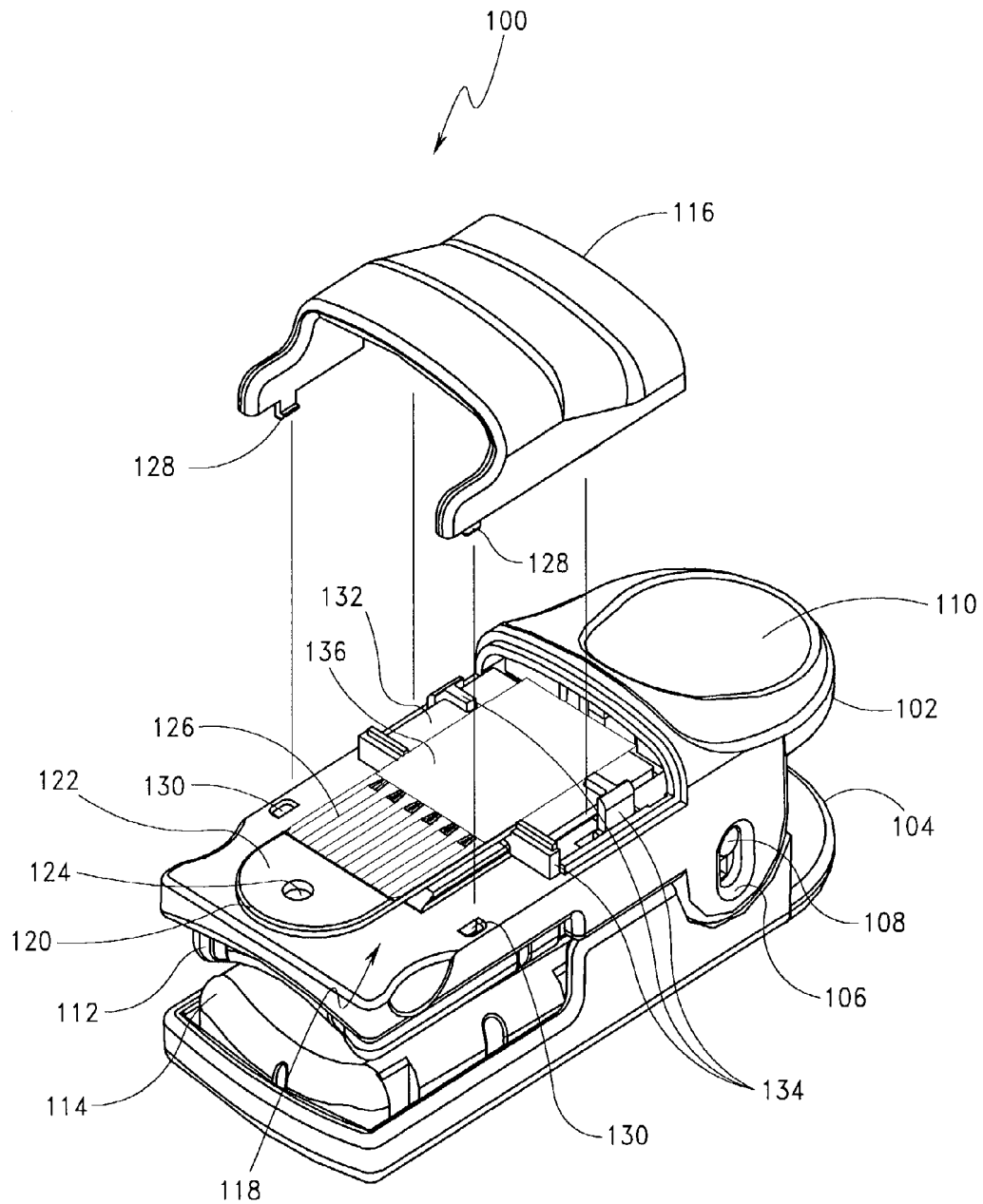
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*Fig. 1*

*Fig. 2*

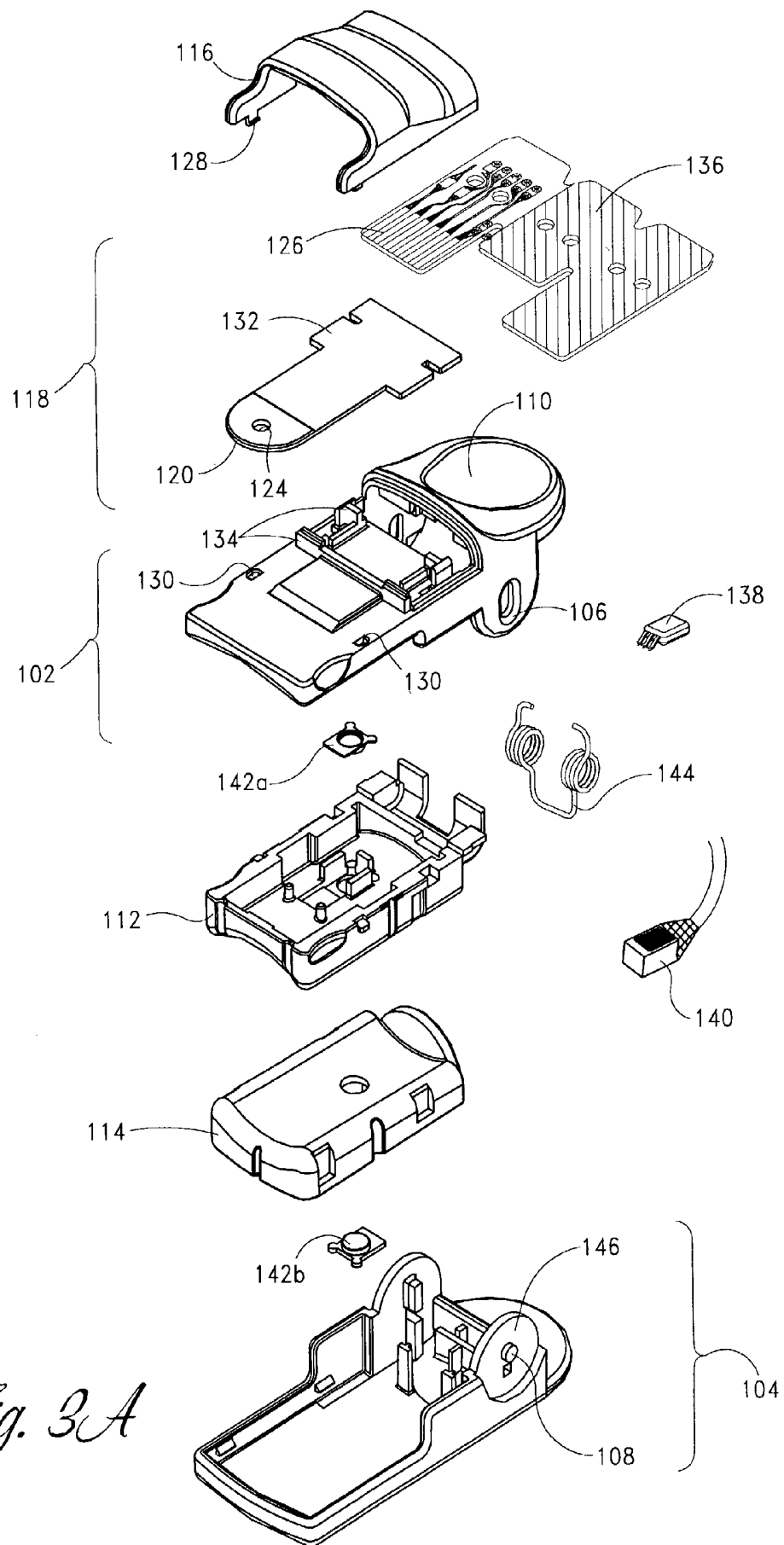


Fig. 3A

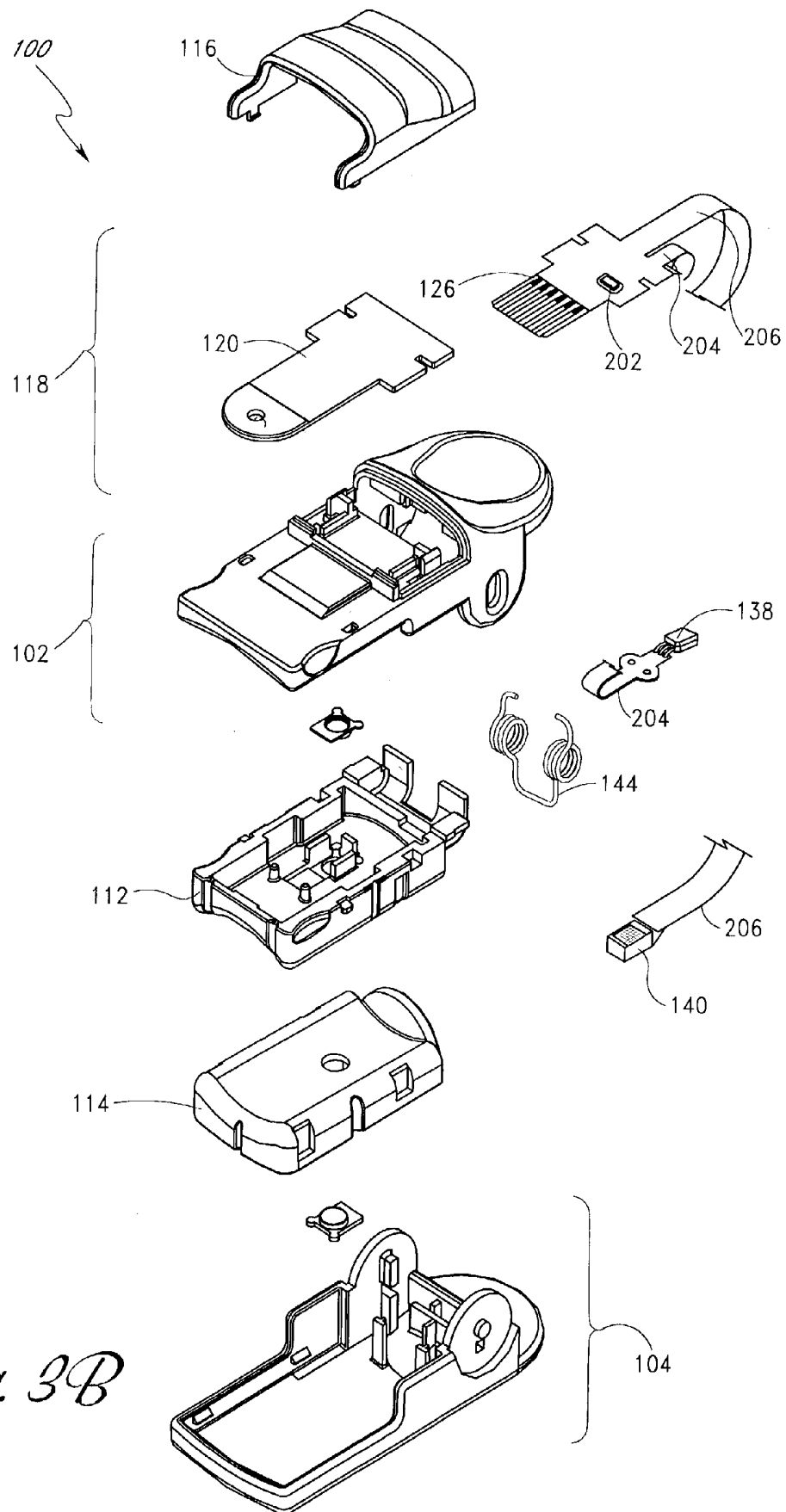


Fig. 3B

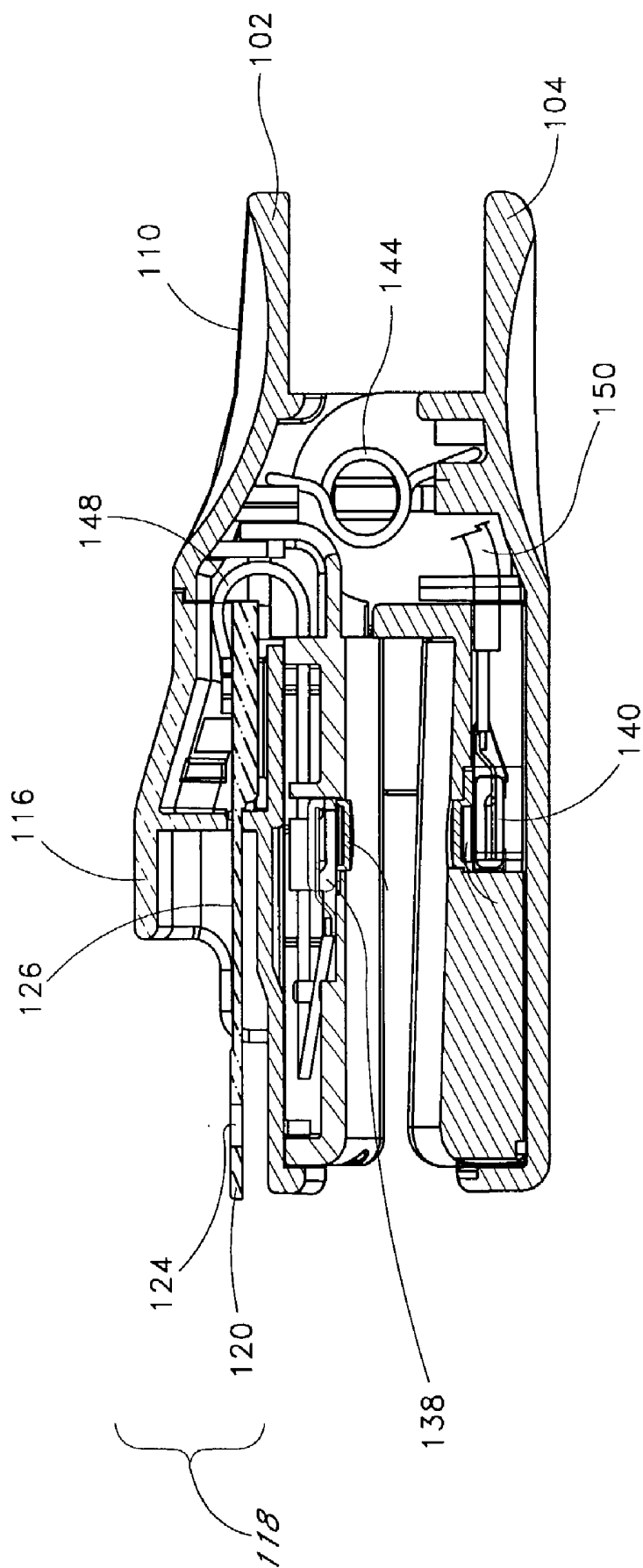


Fig. 4

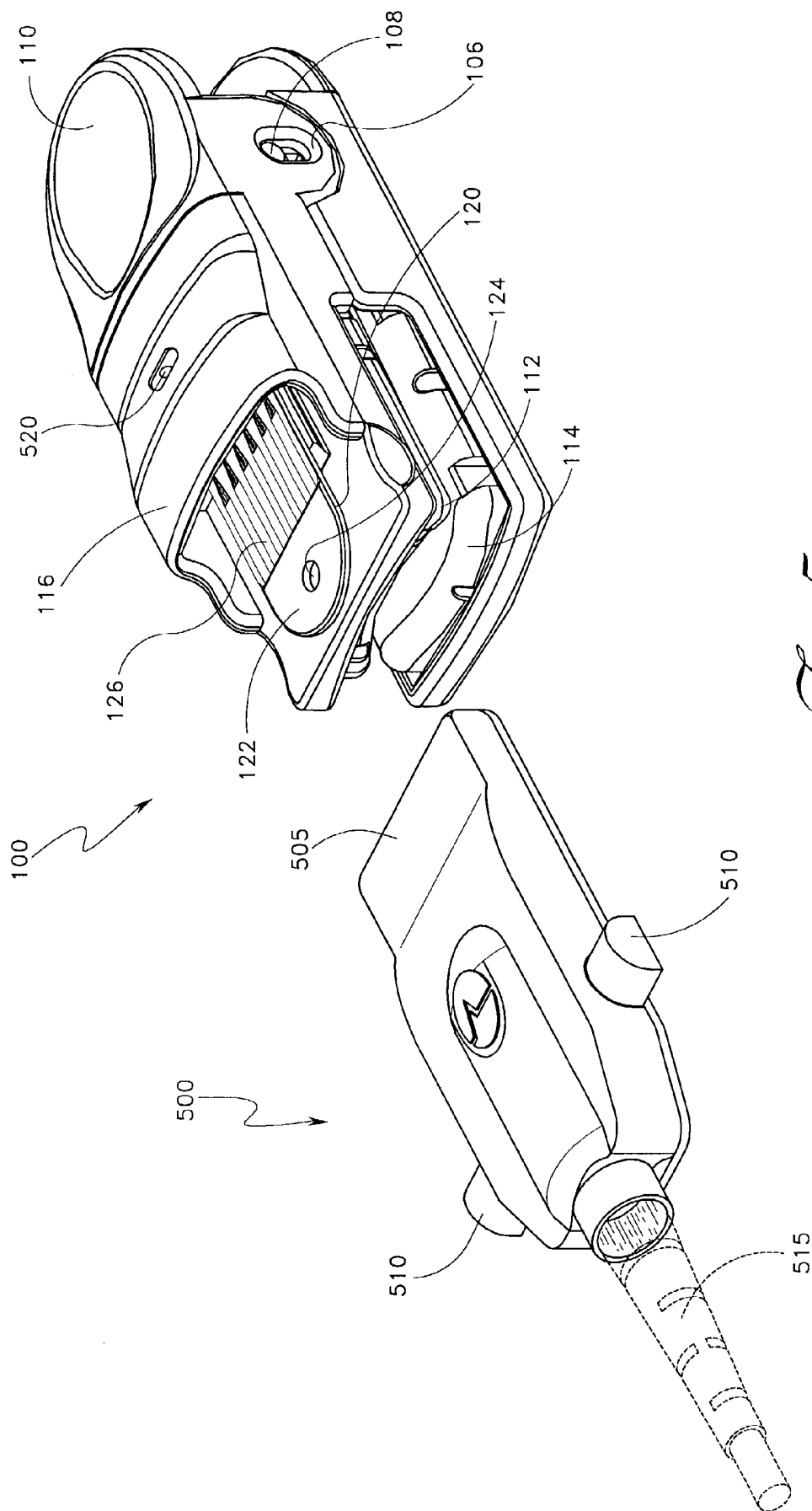


Fig. 5

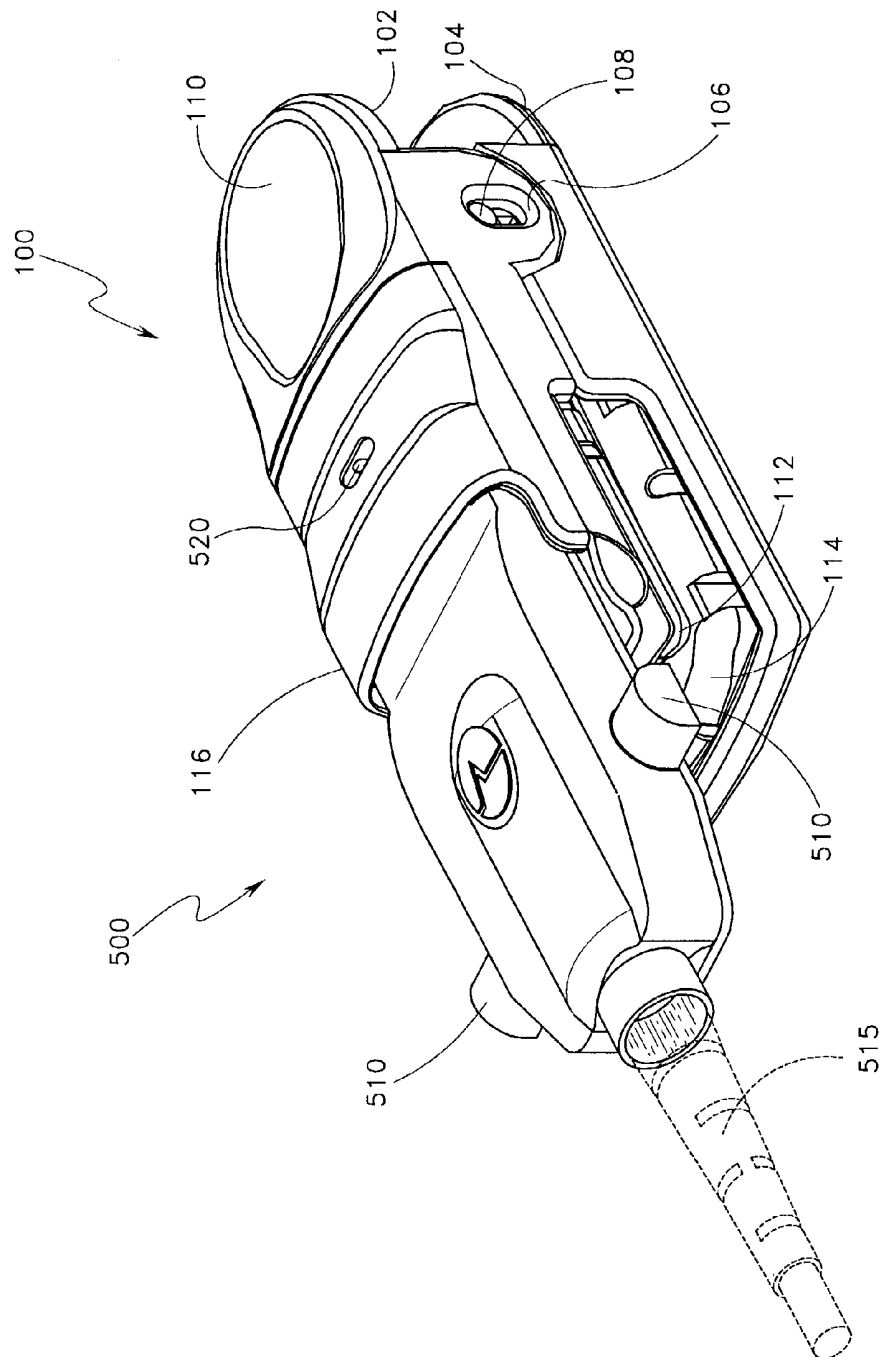


Fig. 6

SHIELDED OPTICAL PROBE HAVING AN ELECTRICAL CONNECTOR

REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. § 122 to the following patent applications, all of which are incorporated herein by reference. The present application is a continuation of U.S. patent application Ser. No. 09/770,757, filed Jan. 25, 2001 now U.S. Pat. No. 6,541,756, entitled "SHIELDED OPTICAL PROBE HAVING AN ELECTRICAL CONNECTOR," which is a continuation-in-part of U.S. patent application Ser. No. 09/420,544, filed Oct. 19, 1999 now U.S. Pat. No. 6,580,086, entitled "SHIELDED OPTICAL PROBE AND METHOD." The present application is also continuation-in-part of U.S. patent application Ser. No. 09/094,202, filed Jun. 9, 1998, entitled "LOW-NOISE OPTICAL PROBES," now U.S. Pat. No. 6,256,523, which is a continuation of U.S. patent application Ser. No. 08/543,789, filed Oct. 16, 1995, entitled "LOW-NOISE OPTICAL PROBES," now U.S. Pat. No. 5,782,757, which is a continuation-in-part of U.S. patent application Ser. No. 08/333,132, filed Nov. 1, 1994, entitled "LOW-NOISE OPTICAL PROBE," now U.S. Pat. No. 5,638,818, which is a continuation-in-part of U.S. patent application Ser. No. 07/672,890, filed Mar. 21, 1991, entitled "LOW NOISE OPTICAL PROBE," now abandoned. Further, the present application is a continuation-in-part of U.S. patent application Ser. No. 09/404,060, filed Sep. 23, 1999, entitled "PULSE OXIMETRY SENSOR ADAPTER," now U.S. Pat. No. 6,349,228, which is a continuation of U.S. patent application Ser. No. 09/021,957, filed Feb. 11, 1998, entitled "PULSE OXIMETRY SENSOR ADAPTER," now U.S. Pat. No. 5,995,855. In addition, the present application is a continuation-in-part of U.S. patent application Ser. No. 09/708,251, filed Nov. 7, 2000, entitled "PATIENT CABLE CONNECTOR," now U.S. Pat. No. 6,280,213, which is a continuation of U.S. patent application Ser. No. 09/318,563, filed May 26, 1999, entitled "PATIENT CABLE CONNECTOR," now abandoned, which is a continuation of U.S. patent application Ser. No. 08/838,392, filed Apr. 9, 1997, entitled "PATIENT CABLE CONNECTOR," now U.S. Pat. No. 5,934,925, which is a continuation of U.S. patent application Ser. No. 08/543,297, filed Oct. 16, 1995, entitled "PATIENT CABLE CONNECTOR," now U.S. Pat. No. 5,645,440.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates in general to low-noise optical probes which use optical energy to determine the characteristics of a medium, and in particular to optical probes having flexible, secure connectors for communicating signals to and from the probe.

2. Description of the Related Art

Electromagnetic, light or acoustic signals with known characteristics, when transmitted through or reflected in a medium, may reveal important information about that medium. In the field of medical testing and diagnosis, for example, light, heat or sound signals may be directed at a patient, transmitted or reflected through the patient's body, and received and compared with the original signal or wave. As a result, information about the patient's condition can be deduced without invasive testing, and information can be gathered continuously with minimal patient discomfort. For

example, during surgery, blood oxygen saturation can non-invasively be deduced and continuously monitored.

Typically, reusable and disposable optical probes are employed to measure an amount of transmitted or reflected light through an accessible part of the body, such as a finger, an earlobe, loose skin, a forehead, or the like. For example, reusable and disposable optical probes or sensors having the foregoing characteristics are disclosed and described in U.S. Pat. No. 5,782,757.

The foregoing sensors typically incorporate a light source such as a light-emitting diode (LED) placed on one side of the body part, and a photodetector placed on an opposite side of the body part. The sensor may also connect to external monitoring equipment through a wire or cable. For example, reusable sensors often connect to external monitoring equipment through a permanent, plastic molded connection between the sensor and the cable.

The foregoing sensors suffer from at least several drawbacks. For example, the sensor is often limited to the useful life of the permanent plastic molded wire in that when the wire fails, the sensor is rendered inoperable despite its continuing functionality. Likewise, when the sensor fails, the wire or cable, the cost of which may not be trivial, is also rendered useless. In addition, existing reusable sensors do not have the capability to connect to monitoring equipment in a secure, reusable, yet flexible manner.

SUMMARY OF THE INVENTION

Based on at least the foregoing, there is a present need for an optical probe having an electrical connector designed to connect the sensor to external monitoring equipment in a secure, reusable, yet flexible manner. According to one embodiment, the optical probe is usable with a patient cable connector designed to engage disposable or reusable/disposable optical probes.

In one aspect of the invention, an improved optical probe assembly is disclosed which incorporates an electrical connector. The electrical connector includes a flexible plastic tab, on which is placed a flexible circuit. The plastic tab and circuit are typically at least partially enclosed in a protective housing. A separate patient cable connector attaches to the electrical connector via the flexible plastic tab, and a wire or other communications link connects the patient cable connector to external monitoring equipment. According to one embodiment, the electrical connector mates the patient cable connector in a manner that prevents incorrect engagement that may damage portions of the optical probe or patient cable connector.

In another aspect of the invention, an improved optical probe is disclosed having an electrical connector. According to one embodiment, once the patient cable connector has been connected to the electrical connector, the flexible plastic tab is locked into place within the patient cable connector via a locking aperture on the flexible plastic tab. The resulting connection is flexible, but electrically secure.

In another aspect of the invention, an improved optical probe assembly is disclosed with an electrical connector designed to accept connections to various external monitoring equipment and may accept connections using various types of wires. Thus, the patient cable connector may be connected to, for example, a wireless transmitter and/or battery, eliminating the need for a wire at all. Additionally, the type of wire may be varied based on patient needs, and the replacement of wires and patient cable connectors may take place separately as needed from the replacement of optical probes.

In another aspect of the invention, an improved optical probe assembly is disclosed having an electrical connector adaptable for use with patient cable connectors designed for disposable, reusable, durable, and combination reusable/disposable sensors. Through the use of a standardized or universal patient cable connectors, optical sensors are advantageously used interchangeably and easily adapted to different monitoring equipment and patient conditions.

In another aspect of the invention, an improved optical probe assembly is disclosed with an electrical connector which is protected from fluids and the environment surrounding the sensor. Additionally, both a patient cable connector and protective housing over the electrical connector include shielding to prevent leakage of electromagnetic radiation which otherwise might interfere with operation of the optical probe.

In yet another aspect of the invention, an improved optical probe is disclosed with an electrical connector. The optical probe includes an improved pivoting mechanism around the finger such that the internal geometry of the light source, finger material, and photodetector are subject to less variation from finger movement. In addition, the optical probe provides more consistent pressure on the finger throughout the mechanism, uses fewer parts, includes a more straightforward assembly, and is less expensive to achieve appropriate geometry and pressure results.

Therefore, an aspect of the invention is an optical probe for irradiating tissue and producing a signal indicative of a physiological parameter of the tissue. The optical probe comprises a housing substantially securing a light source and a detector to tissue at a measurement site, thereby allowing the detector to produce a signal indicative of at least one physiological parameter of the tissue. The optical probe also comprises a plugable electrical connector forming a releasable connection with a cable connector, wherein the electrical connector includes a plurality of conductive paths electrically communicating with the light source and the detector. The cable connector electrically communicates with external monitoring equipment.

Another aspect of the invention is a reusable pulse oximetry sensor for producing a signal indicative of at least one physiological parameter of tissue. The sensor comprises an upper housing having a first circuit element comprising one of a light source and a detector, and a first wire connected to the first circuit element. The sensor also comprises a lower housing having a second circuit element comprising the other of the light source and the detector, and a second wire connected to the second circuit element. The sensor also comprises a hinge-like joint adjustably coupling the upper housing and lower housing and an electrical connector having a tab and a flexible circuit mounted on the tab and comprising a plurality of conductive paths. One of the conductive paths electrically connects to the first wire while another of the conductive paths electrically connects to the second wire, thereby providing an electrical connection from the conductive paths of the electrical connector to the light source and the detector.

Another aspect of the invention is a reusable pulse oximetry sensor for producing a signal indicative of at least one physiological parameter of tissue. The sensor comprises an upper housing having a first circuit element comprising one of a light source and a detector, and a lower housing having a second circuit element comprising the other of the light source and the detector. The sensor also comprises a hinge-like joint adjustably coupling the upper housing and lower housing, and an electrical connector having a tab, and a flexible circuit mounted on the tab and comprising a plu-

ality of conductive paths. One of the conductive paths electrically connects to the detector while another of the conductive paths electrically connects to the light source.

Another aspect of the invention is an optical probe for non-invasively collecting a signal indicative of a physiological parameter of tissue. The optical probe comprises a light source, a detector, a connector having a flexible circuit mounted on a durable tab, and a protective housing at least partially covering the flexible circuit mounted on the durable tab.

Another aspect of the invention is a method of determining a physiological parameter of tissue using a non-invasive optical probe. The method comprises positioning a light source of a non-invasive optical probe to irradiate a measurement site with light, and positioning a detector of the probe to detect light which interacts with the measurement site. The method also comprises releasably connecting an external monitoring equipment cable to the probe through a flexible circuit mounted on a durable tab having a protective cover. Also, at least one the conductive paths electrically communicates with the light source and at least one of the conductive paths electrically communicates with the detector.

Another aspect of the invention is an electrical connector, comprising a flexible durable tab configured to guide a cable connector around the tab, thereby engaging the electrical connector to the cable connector. The connector also comprises a flexible circuit mounted on the flexible tab and electrically communicating with electrical contacts of the cable connector. The connector also comprises a locking mechanism releasably locking the electrical connector to the cable connector, and a protective cover covering at least a portion of the flexible circuit.

For purposes of summarizing the invention, certain aspects, advantages and novel features of the invention have been described herein. It is to be understood that not necessarily all such aspects, advantages or features will be embodied in any particular embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an optical probe with an electrical connector according to aspects of one embodiment of the present invention.

FIG. 2 is a perspective view of the optical probe of FIG. 1 with a protective housing raised above the probe housing, according to aspects of an embodiment of the present invention.

FIG. 3A is an exploded view of the optical probe of FIG. 1, according to aspects of an embodiment of the present invention.

FIG. 3B is an exploded view of the optical probe of FIG. 1, according to aspects of another embodiment of the present invention.

FIG. 4 is a cross-sectional view of the optical probe of FIG. 1, according to aspects of an embodiment of the present invention.

FIG. 5 is a perspective view of the optical probe of FIG. 1 with a patient cable connector, according to aspects of an embodiment of the present invention.

FIG. 6 is a perspective view of the optical probe of FIG. 1 engaged to the patient cable connector of FIG. 5, according to aspects of an embodiment of the present invention.

DETAILED DESCRIPTION OF THE
PREFERRED EMBODIMENT

The invention is described in detail below with references to the figures, where like elements are referenced with like numerals throughout. The term probe and sensor are used interchangeably herein.

FIG. 1 illustrates an optical probe 100 according to one embodiment of the invention. As shown in FIG. 1, the optical probe 100 comprises an upper housing 102 and a lower housing 104. According to this embodiment, the upper housing 102 and the lower housing 104 oppose one another and are configured to include components designed to accept a measurement site for the tissue of a patient. For example, according to the embodiment shown in FIG. 1, the optical probe 100 is configured to accept a digit of a patient as a measurement site.

According to one embodiment, the upper and lower housings, 102 and 104, comprise injection moldable thermoplastic material or other suitable medium. As further illustrated in FIG. 1, the upper housing 102 comprises an aperture 106 while the lower housing 104 further comprises a pivoting element 108. According to one embodiment, the aperture 106 and the pivoting element 108 combine to form a hinge-like joint where the hinge-like joint allows the upper housing 102 to pivot from the lower housing 104 through a central axis defined, for example, by the pivoting element 108. Thus, according to this embodiment, an open end of optical probe 100 opens as the upper housing 102 pivots away from the lower housing 104, thereby providing an area designed to accept tissue to be measured. According to one embodiment, the upper housing 102 and the lower housing 104 may each advantageously include a finger recess surface 110 formed to provide a comfortable, securing edge where, for example, medical staff or the user may advantageously squeeze a pivoting end of the optical probe 100, thereby opening the open end thereof.

Although the foregoing is described with reference to preferred and alternative embodiments, a skilled artisan will recognize from the disclosure herein that the optical probe 100 may comprise a wide number of mechanical devices designed to substantially secure the upper housing 102 and the lower housing 104 to a measurement site in a manner sufficient for the optical probe 100 to perform reliable measurements. Such mechanical devices may replace or work in conjunction with the foregoing hinge-like joint.

According to yet another embodiment of the invention, the upper housing 102 further comprises an upper support surface 112, while the lower housing 104 further comprises a lower support surface 114. According to this embodiment, the upper support surface 112 and the lower support surface 114 provide additional supporting structure for tissue when the tissue is placed in the optical probe 100. For example, as shown in FIG. 1, the upper and lower support surfaces, 112 and 114, are configured to accept a digit in a manner that is comfortable for the patient, advantageously helps substantially secure the optical probe 100 to a measurement site on the digit, provides at least a partial seal against ambient light, and provides for relatively straightforward replacement, sterilization, or both.

According to one embodiment, the upper and lower support surfaces, 112 and 114, comprise injection moldable thermoplastic elastomer material or other suitable medium. FIG. 1 also illustrates the optical probe 100 having a protective housing 116 and an electrical connector 118, according to aspects of yet another embodiment of the invention. As shown in FIG. 1, the protective housing 116

comprises a raised surface at least partially covering the electrical connector 118. According to yet another embodiment, the protective housing 116 may advantageously protect a cable connector, which connects the optical probe 100 to external monitoring equipment. The foregoing cable connector is further disclosed with reference to FIGS. 5 and 6.

According to an embodiment of the invention, the protective housing 116 advantageously protects the electrical connector 118 from environmental conditions external to the sensor. For example, according to one embodiment, the protective housing 116 may advantageously substantially seal the electrical connector 118 to the foregoing cable connector, thereby protecting the engaged connectors from fluids, dirt, ordinary wear and tear, or the like.

According to yet another embodiment, when the protective housing 116 is formed at least partially to fit the shape of a known external connector, such as the patient cable connector described with reference to FIGS. 5 and 6, the protective housing 116 may advantageously assist in creating a secure but removable electrical connection, through, for example, a substantially sealable or friction fit relationship.

Although disclosed with respect to preferred and alternative embodiments, a skilled artisan will recognize from the disclosure herein that the protective housing 116 may advantageously be mounted in a reverse direction from that shown in FIG. 1, or placed on the lower housing 104. Moreover, a skilled artisan will recognize from the disclosure herein that the functions performed by the protective housing 116 may be performed by the upper housing 102 or lower housing 104, when the foregoing housings are appropriately shaped to carry the electrical connector 118. Thus, it is foreseen that the functions of the protective housing 116 may advantageously be performed by any of the housings of the optical probe 100 in a wide number of configurations.

According to one embodiment, the protective housing 116 generally comprises the same or similar material and is formed in the same or similar manner as that of the upper housing 102 or the lower housing 104.

According to one embodiment, the electrical connector 118 comprises a flexible plastic tab 120 having a connection tab protrusion 122 with a locking aperture 124 and a flexible circuit 126. According to one embodiment, the flexible plastic tab 120 is rectangular in shape with the elongated portion of the rectangle being aligned with an elongated axis of the optical probe 100. According to one embodiment, one end of the tab 120 terminates in a semicircular tongue, thereby forming the connection tab protrusion 122. The connection tab protrusion 122 includes the locking aperture 124.

According to another embodiment, the tab 120 provides a durable yet flexible mounting surface for at least a portion of the flexible circuit 126. By using flexible materials, the tab 120 serves a shock absorbing function for movement, for pushes and pulls on the optical probe 100, and for connections made to the electrical connector 118. In addition, the connection tab protrusion 122 and locking aperture 124 may advantageously serve as a tongue to substantially secure an electrical connection made between the electrical connector 118, and, for example, a patient cable connector. In addition, the locking aperture 124 provides a catch to prevent accidental unplugging of the electrical connector 118.

The foregoing tab 120 also advantageously guides a mating cable connector, such as those cables connectors connecting the optical probe 100 to external monitoring equipment, into secure, removable, electrical contact with

the electrical connector **118**. Through such connection, the tab **120** provides electrical communication between the external monitoring equipment and the light source or photodetector of the optical probe **100**. Accordingly, the tab **120** advantageously provides a secure, plugable, connection between the electrical components of the sensor and external monitoring equipment. Furthermore, the tab **120** provides a shock absorbing connection between the optical probe **100** and an external connection. At the same time, the locking aperture **124** and the connection tab protrusion **122** provide a latch opening for a secure but removable locking mechanism securing the electrical connector **118** of the optical probe **100** to an external patient cable connector. According to one embodiment, the tab **120** comprises injection moldable thermoplastic material or other suitable medium.

FIG. **2** illustrates the optical probe **100** with the protective housing **116** lifted from the upper housing **102**. The protective housing **116** is, in one embodiment, attached to the upper housing **102** through a tab and aperture mechanism. For example, as shown in FIG. **2**, the protective housing **116** may include securing tabs **128**, such as detents or latches, which lock into apertures **130** on the upper housing **102**. However, it is foreseen that the protective housing **116** may be attached by any commonly used means including plastic molding, locking components, screws, and the like. It is further foreseen that, in the absence of the protective housing **116**, the flexible plastic tab **120** may advantageously directly connect to the upper housing **102**.

FIG. **2** also shows one embodiment of the attachment of the electrical connector **118** to the optical probe **100**. For example, in one embodiment of the electrical connector **118**, the flexible plastic tab **120** comprises locking protrusions **132** protruding perpendicularly to the general elongated shape of the tab **120**. In addition, the upper housing **102** includes locking slots **134** designed to mate with the locking protrusions **132**, thereby substantially securing the tab **120** to the upper housing **102**. According to one embodiment, optical probe **100** includes multiple locking protrusions **132** and multiple corresponding locking slots **134**, thereby decreasing potential lateral movement of the plastic tab **120** during electrical connection of electrical connector **118** to external monitoring equipment. A skilled artisan will recognize from the disclosure herein that the locking slots **134** may comprise a wide number of connection mechanisms, including, for example, plastic molding, locking components, screws, adhesive, staples, and the like.

According to yet another embodiment, the electrical connector **118**, including the flexible plastic tab **120**, may advantageously be at least partially raised or suspended between the upper housing **102** and the protective housing **116**. Thus, the upper housing **102** and the protective housing **116** may advantageously together form a pocket or guide, within which the tab **120** protrudes to connect to appropriately shaped electrical mating devices. A skilled artisan will recognize that the electrical connector **118** may also be suspended within the upper housing **102** when the upper housing **102** is altered to perform the function of the protective housing **116**.

Advantageously, the attachment of the electrical connector **118** to the upper housing **102** (or another housing) of the optical probe **100** allows the electrical connector **118** to serve as a secure but removable electrical connection between the optical probe **100** and external monitoring devices, while at the same time allowing the electrical connector **118** to include a shock absorbing function against patient movement or other agitation of the optical probe **100**.

Advantageously, the electrical connector **118** of FIG. **2** is connectable to cables provided, for example, for use with disposable optical probes. Thus, the electrical connector **118** allows users to choose the optical probe most suitable for a specific condition. For example, when a patient may have a particularly fluid or soiled condition, such as, for example, a burn victim, a health care provider may wish to use typically more expensive disposable optical probes. Once the patient has recovered to a less infecting or electronically damaging environment, the health care provider may advantageously change to the typically less expensive reusable probes without changing the cables connected to the external monitoring equipment.

FIG. **2** also shows the electrical connector **118**, and in particular, the flexible circuit **126** partially covered by one or more protective flaps **136**. According to one embodiment of the invention, the flexible circuit **126** includes a number of conductive paths, each conductive path electrically connected to one or more electrical components, such as a light source or a detector. The conductive paths of the circuit may be made from any known conductor, such as silver, copper, and the like. As the conductive paths change from the pattern represented in the portion mating with an external monitoring equipment connector, to patterns designed to provide contacts with the various electrical components, the conductive paths, and therefore, the flexible circuit **126**, are covered by the protective flaps **136**. Accordingly, the protective flaps **136** advantageously guard against damage or electrical shorts in the conductive paths.

FIG. **3A** shows an exploded view of the optical probe **100** including the electrical connector **118**. For example, FIG. **3A** emphasizes an embodiment of the protective flaps **136** and how, according to that embodiment, the protective flaps **136** may be folded to create a faraday shield for the flexible circuit **126**, thus protecting it from electromagnetic interference.

Advantageously, electrical power and signals can be transmitted between the optical probe **100** and external monitoring devices via the electrical connector **118** in a secure, interchangeable, replaceable, shock absorbing, and universal manner. For example, the optical probe **100**, an external cable connector or another compatible connector, and in one embodiment the electrical connector **118**, may advantageously be independently replaceable, such that failure or wear of one component does not require replacement of other related components.

FIG. **3A** also shows the optical probe **100**, and in particular, the upper housing **102**, comprising one or more light emitting diodes (LEDs) **138**, although it will be appreciated that other light generating devices may be used. The LEDs **138** provide a light source for the optical probe **100** and are electrically connected to the flexible circuit **126** through the conductive path and one or more wires. The construction and operation of the LEDs **138** and their drive circuitry is described in U.S. Pat. No. 5,758,644, which is incorporated herein by reference.

FIG. **3A** also shows the optical probe **100**, and in particular, the lower housing **104**, comprising a detector **140**, such as a photodetector, designed to detect an amount of light energy passed from the LEDs **138**, through the tissue at the measurement site. For example, the LEDs **138** may shine light energy through an aperture in the upper housing **102**, through the patient tissue, through an aperture in the lower housing **104** and onto the detector **140**. Alternatively, a skilled artisan will recognize from the disclosure herein that the optical probe **100** may incorporate housing adapted for a reflective detector. However, the detector **140** shown in

FIG. 3A, is attached to internal wiring eventually electrically communicating with one or more of the conductive paths on the flexible circuit 126.

FIG. 3A also illustrates the optical probe 100 having multiple transparent covers 142A and 142B, preferably comprising transparent polymer, which act as protection for the LEDs 138 and for the detector 140. The construction and operation of the covers 142, including the potential of including physical and optical properties or characteristics therein, is described in U.S. patent application Ser. No. 09/420,544, which is incorporated herein by reference.

According to yet another embodiment, the optical probe 100 includes a biasing spring 144 preloaded or partially wound so as to bias the upper housing 102 against the lower housing 104, thereby biasing the open end of the optical probe 100 into a closed position around the tissue at the measurement site, for example, around the digit of a patient. In this manner, the finger recesses 110 allow a user to grasp the optical probe 100 between their fingers and apply force counter to the biasing spring 144, thereby opening the open end of the optical probe 100 for insertion of, for example, the distal end of a digit.

According to yet another embodiment, the lower housing 104 also comprises opposing vertical risers 146, each including at least one of the pivoting elements 108. As discussed above when the lower housing 104 and the upper housing 102 are coupled, the pivoting element 108 and the aperture 106 form a pivoting hinge-like joint, which allows the optical sensor to comfortably adjust position while maintaining the proper geometry between the patient tissue, the light source, and the photodetector.

FIG. 3B shows an exploded view of another embodiment of the optical probe 100 including the electrical connector 118. In one embodiment of the optical probe 100 illustrated in FIG. 3B, the flexible circuit 126 includes flexible circuit extensions 204 and 206. The first flexible circuit extension 204 extends the flexible circuit 126 to the LED 138. Similarly, the second flexible circuit extension 206 extends the flexible circuit 126 to the detector 140. The flexible circuit extensions 204 and 206 are part of the flexible circuit 126, and are constructed from the same or similar materials.

Advantageously, the flexible circuit extensions 204 and 206 reduce the construction cost of the optical probe 100 by removing the need for any number of wires to be added and connected to any number of sensor elements. In addition, the substantially flat flexible circuit extensions 204 and 206 do not hinder the flexibility of the optical sensor at the hinge-like joint.

Furthermore, the flexible circuit 126 in one embodiment includes a coding resistor 202 in parallel with the LED 138. The coding resistor 202 can be used, for example, to indicate the type of optical probe 100. In other words, the value of the coding resistor 202 can be selected to indicate that the optical probe 100 is an adult probe, a pediatric probe, a neonatal probe, a disposable probe, a reusable probe, or the like. The coding resistor 202 can also be utilized for security purposes. In other words, the value of the coding resistor 202 can be used to indicate that the optical probe 100 is from an authorized sensor supplier. This permits control over safety, quality, and performance concerns which can arise with unauthorized sensors. In addition, the coding resistor 202 can be used to indicate physical or operating characteristics of the optical probe 100, such as the wavelengths of the LEDs 138. Additional disclosure related to uses and specific embodiments of the coding resistor 202 can be found in U.S. Patent application Ser. No. 09/404,060, filed Sep. 23, 1999, entitled "PULSE OXIMETRY SENSOR ADAPTER," now

U.S. Pat. No. 6,349,228, which is incorporated herein by reference. The coding resistor 202 can be read by an external monitoring system, such as that described in U.S. Patent application Ser. No. 08/478,493, filed Jun. 7, 1995, entitled "MANUAL AND AUTOMATIC PROBE CALIBRATION," now U.S. Pat. No. 5,758,644, which is incorporated herein by reference.

FIG. 4 shows a cross sectional view of one embodiment of the optical probe 100 with the electrical connector 118. As shown in FIG. 4, the flexible plastic tab 120 is housed between the protective housing 116 and the upper housing 102. According to this embodiment, the connection tab protrusion 122 and the locking aperture 124 of the flexible plastic tab 120 are advantageously accessible to the environment outside of the optical probe 100.

As illustrated in FIG. 4, one or more of the conductive paths on the flexible circuit 126 are connected by a first internal wire 148 to the LEDs 138 housed within the upper housing 102. In addition, FIG. 4 shows one or more of the conductive paths on the flexible circuit 126 being connected by a second internal wire 150 to the detector 140 housed within the lower housing 104. Moreover, the cross sectional view of FIG. 4 illustrates the biasing spring 144 being positioned and biased between the upper housing 102 and the lower housing 104 to provide resistance and tension as discussed above.

FIG. 4 also illustrates the protective housing 116, in one embodiment, partially protecting the electrical connector 118 as the electrical connector 118 is at least partially suspended between the protective housing 116 and upper housing 102, thereby providing ease of connectability, along with 360 degrees of support for the connection. For example, the connection is supported from beneath by the cable connector being in contact with the upper housing 102, from the sides and from above by contact with the protective housing 116, and from the center by the electrical connector 118. In addition to the foregoing, skilled artisans can foresee from the disclosure herein alternative embodiments such as alternative orientations or placements of the electrical connector 118, such as, for example, in the lower housing 104.

FIG. 5 shows the optical probe 100 including the electrical connector 118 in one embodiment where an external plug, such as, for example, a patient cable connector 500 is adapted to securely and releasably form a plugable electrical connection. For example, FIG. 5 shows the patient cable connector 500 having a receptor end 505, a releasing mechanism 510, and external wire 515. According to one embodiment, the receptor end 505 is designed to electrically mate with the electrical connector 118. For example, the receptor end 505 may advantageously include electrical contacts that, when the patient cable connector 500 engages the optical probe 100, the electrical contacts line up and electrically communicate with conductive paths on the flexible circuit 126. The electrical contacts in the patient cable connector 500 then communicate with the external wire 515 to communicate signals to and from external monitoring equipment (not shown). The construction and operation of the patient cable connector 500, its electrical contacts and circuitry, as well as the release mechanism 510, are described in U.S. Pat. Nos. 5,645,440, 5,934,925, and U.S. Pat. No. 6,280,213, which are incorporated herein by reference.

According to one embodiment, the shape of the connection tab protrusion 122 is adjusted to fit snugly with the patient cable connector 500, and the internal shape (in this case, concave) of the protective housing 116 is adapted to snugly fit the external surface of the patient cable connector 500. According to one embodiment, the protective housing

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116, the tab 120, and the contacts of the patient cable connector 500 work together to form a friction fit relationship firmly securing the connector 500 to the optical probe 100.

According to one embodiment, once the patient cable connector 500 has been connected to the electrical connector 118, the flexible plastic tab 120 is locked into place within the connector 500 via the locking aperture 124 on the tab 120. The resulting connection is advantageously flexible, but electrically secure. For example, the foregoing connection prohibits accidental pulls or patient agitation from dislodging the electrical connection while maintaining relatively easy release of the connection through the locking mechanism. Thus, the foregoing connection provides a flexible but secure connection, thereby ensuring jolts, accidental pulls, or patient agitation have a reduced impact on the secure operation of the optical probe 100.

FIG. 5 also shows a sensor life indicator 520, according to additional embodiments of the invention. For example, the indicator 520 may advantageously comprise one or more LEDs designed to indicate to the user that the useful life of the optical probe 100 has expired, due to wear, overuse, malfunction, or the like. According to one embodiment, the determination of the useful life is made within circuitry of the optical probe 100. For example, the optical probe 100 may advantageously include one or more memory registers or counters for storing an indication of the use of the optical probe 100. For example, the memory registers may count the number of drive pulses received by the optical probe 100, the number of return signals generated by the detector 140, or the like. In addition, the optical probe 100 may use any number of known oscillators or oscillating circuits to generate a measure of time or use. According to this embodiment, once the data stored in the memory registers reaches a predetermined threshold, the sensor life indicator 520 is activated, such as, for example, the emission of a constant or blinking light, such as, for example, a red light.

According to one embodiment, the determination of the useful life of the optical probe 100 may advantageously be made using the external monitoring equipment, or a combination of the optical probe 100 and the external monitoring equipment. In such embodiments, a signal may advantageously be passed from the external monitoring equipment to the sensor life indicator 520 for activation thereof. Additional disclosure and specific embodiments of the sensor life indicator 520 may advantageously be found in U.S. patent application Ser. No. 09/502,032 filed Feb. 10, 2000, entitled "SENSOR LIFE MONITOR SYSTEM," which is incorporated herein by reference.

A skilled artisan will recognize from the disclosure herein that the sensor life indicator 520 can be implemented in a number of alternative embodiments. For example, the sensor life indicator 520 can be visible through an aperture on the patient cable connector 500 or can be integrated with the flexible circuit 126. In addition, the sensor life indicator 520 may advantageously be placed on virtually any housing or extension of the optical probe 100. Moreover, the sensor life indicator 520 may advantageously provide an indication of proper use, continued usefulness, proper application, or the like, through the use of another signal, such as, for example, a green light.

As discussed above, the sensor life indicator 520 advantageously permits a user of the optical probe 100 to recognize when the useful life of the probe's components is near an end due to wear, overuse, or the like. Without the sensor life indicator 520, the user can only approximate or guess

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when the optical probe 100 should be replaced, or wait until the optical probe 100 ceases to function properly.

FIG. 6 shows the patient cable connector 500 engaged with or attached to the optical probe 100, according to one embodiment of the invention. The optical probe 100, in one embodiment, includes the sensor life indicator 520. According to one embodiment, the patient cable connector 500 may advantageously be locked in an engaged position through the locking aperture 124. According to yet another embodiment of the invention, the patient cable connector 500 and the optical probe 100 form a substantially secure, yet releasable, seal. According to one embodiment, the seal may be resistant to fluids or the like.

The probe 100 may be employed in any circumstance where a measurement of transmitted or reflected energies is to be made, including but not limited to, measurements taken on a finger, an earlobe, a lip or a forehead and the like. Similarly, a skilled artisan will recognize from the disclosure herein that the electrical connector 118 may be adjusted to any number of embodiments. For example, a skilled artisan will recognize from the disclosure herein that the electrical connector 118 may be attached to the lower housing 104, may be secured in an opposite or rotatable manner via a wide number of securement mechanisms, including those disclosed herein, hook-and-loop material, releasable or other latches, rotating securement mechanisms, or the like. Moreover, a skilled artisan will recognize from the disclosure herein the option of reversing components, for example, placing various components of the electrical connector 118 on the patient cable connector 500 and vice versa. In addition, the locking mechanism may include any number of a wide variety of known devices, such as, for example, thumb screws, hook-and-latch materials, straps, press or friction fit mechanisms, or the like.

In addition, a skilled artisan will recognize a wide number of other embodiments from the disclosure herein, including but not limited to, changes in the shape of the optical probe 100 and its components, changes in the shape of the flexible circuit 126, or the like. In addition, different placement of the flexible circuit 126 upon the device and different shapes or positions of the protective housing 116, when the protective housing 116 is used at all, are foreseen. Moreover, the described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention therefore is indicated by the appended claims rather than by the foregoing description.

What is claimed is:

1. A pulse oximetry system including a reusable pulse oximetry sensor capable of being separated from a cable, the sensor further comprising:

- a reusable upper housing including one of a detector capable of detecting light attenuated by body tissue and a plurality of emitters capable of emitting light;
- a reusable lower housing including the other of the detector and the plurality of emitters; and
- a reusable hinge-like joint adjustably connecting the upper and lower housings to form an enclosure such that application of pressure to a first end of the upper and lower housings activates the hinge-like joint causing a second end of the upper and lower housings to separate and receive a digit of a wearer of the sensor, the hinge-like joint including a biasing member biasing the first end of the upper and lower housings toward one another,

wherein one of the upper and lower housings further comprises a sensor connector including first conductors electrically communicating with the plurality of emit-

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- ters, second conductors electrically communicating with the detector, and a durable guide comprising a durable tab, the durable guide configured to align the first and second conductors with appropriate conductors of a matable cable connector when the instable cable connector is plugged into the sensor connector. 5
2. The system of claim 1, wherein the sensor connector further includes a locking mechanism.
3. The system of claim 1, wherein the durable guide includes a locking mechanism. 10
4. The system of claim 3, wherein the locking mechanism comprises an aperture in a durable tab.
5. The system of claim 1, wherein the durable tab further comprises a flexible circuit including the first and second conductors. 15
6. The system of claim 1, wherein the sensor connector forms a protective housing at least partially covering the first and second conductors.
7. The system of claim 6, wherein the protective housing is capable of substantially sealing the temporary connection between the first and second conductors and the conductors of the matable cable connector against external environmental conditions. 20
8. The system of claim 1, further comprising a pulse oximeter configured to communicate with the sensor to determine one or more physiological parameters of the wearer of the sensor. 25
9. The system of claim 1, further comprising a cable.
10. The system of claim 1, further comprising an indicator configured to indicate when the sensor should be replaced. 30
11. The system of claim 1, wherein the sensor further comprises an information element.
12. The system of claim 11, wherein the information element comprises a coding resistor.
13. The system of claim 1, wherein the upper and lower housings comprise an Injection moldable Thermoplastic material. 35
14. The system of claim 1, wherein the first and second conductors comprise conductive paths of a flexible circuit, the conductive paths comprising silver or copper. 40
15. A method of assembling a pulse oximeter system for determining one or more parameters of a patient, the method comprising:
- providing a pulse oximeter capable of outputting emitter drive signals and receiving detector signals indicative of one or more parameters of a patient; 45
- providing a reusable sensor, the reusable sensor including an enclosure including a pivot mechanism between an upper housing and a lower housing, the pivot mechanism biased in a position to form the enclosure 50
- while application of pressure to one end of the upper

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- and lower housings causes the pivot mechanism to open to accept human tissue, the upper housing including a plurality of emitters capable of emitting light and the lower housing including a detector capable of detecting light attenuated by body tissue, wherein one of the upper and lower housings further comprises a sensor connector including (i) first conductors electrically communicating with the plurality of emitters, (ii) second conductors electrically communicating with the detector, and (iii) a durable guide comprising a durable tab, the durable guide configured to align the first and second conductors with appropriate conductors of a matable cable connector when the instable cable connector is plugged into the sensor connector; and
- providing one or more cables electrically connecting the pulse oximeter to the reusable sensor.
16. The method of claim 15, further comprising:
- connecting the one or more cables to the pulse oximeter; and connecting the one or more cables to the reusable sensor by aligning the cable connector with the durable guide and mating the instable cable connector with the sensor connector.
17. A pulse oximetry system including a reusable pulse oximetry sensor capable of being separated from a cable, the sensor further comprising:
- a upper housing including one of a detector capable of detecting light attenuated by body tissue and a plurality of emitters capable of emitting light;
- a lower housing including the other of the detector and the plurality of emitters; and
- a rotatable joint comprising an aperture end and a pivoting element adjustably connecting the upper and lower housings to form an enclosure such that application of pressure to a first end of the upper and lower housings activates the hingelike joint causing a second end of the upper and lower housings to separate and receive a digit of a wearer of the sensor, the hinge-like joint including a biasing member biasing the first end of the upper and lower housings toward one another,
- wherein one of the upper and lower housings further comprises a sensor connector including first conductors electrically communicating with the plurality of emitters, second conductors electrically communicating with the detector, and a durable guide configured to align the first and second conductors with appropriate conductors of a instable cable connector when the instable cable connector is plugged into the sensor connector.

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