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(54) **PULSE OXIMETRY METHODS AND APPARATUS FOR USE WITHIN AN AUDITORY CANAL**

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(52) **U.S. Cl.** ..... **600/340; 600/502**

(58) **Field of Classification Search** ..... **600/310, 600/322, 323, 340, 344, 500, 502, 549**

See application file for complete search history.

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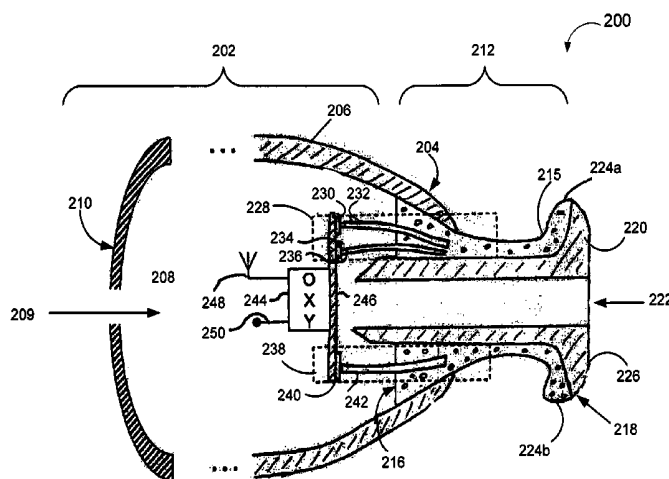
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(57) **ABSTRACT**

Methods and apparatus for detecting oxygen saturation levels in blood from within an auditory canal of a living being proximal to a tympanic membrane are disclosed. The auditory canal is lined with tissue and includes a proximal bend and a distal bend located between the proximal bend and the tympanic membrane. Oxygen levels are detected by emitting one or more wavelengths of light into a first position on the tissue of the auditory canal in a first region defined by the distal bend and the tympanic membrane. The wavelengths of light are then sensed at a second position on the tissue of the auditory canal in the first region. A blood oxygen saturation level and/or pulse rate is then calculated responsive to intensity information corresponding to the wavelengths of light detected at the second position.

**18 Claims, 6 Drawing Sheets**



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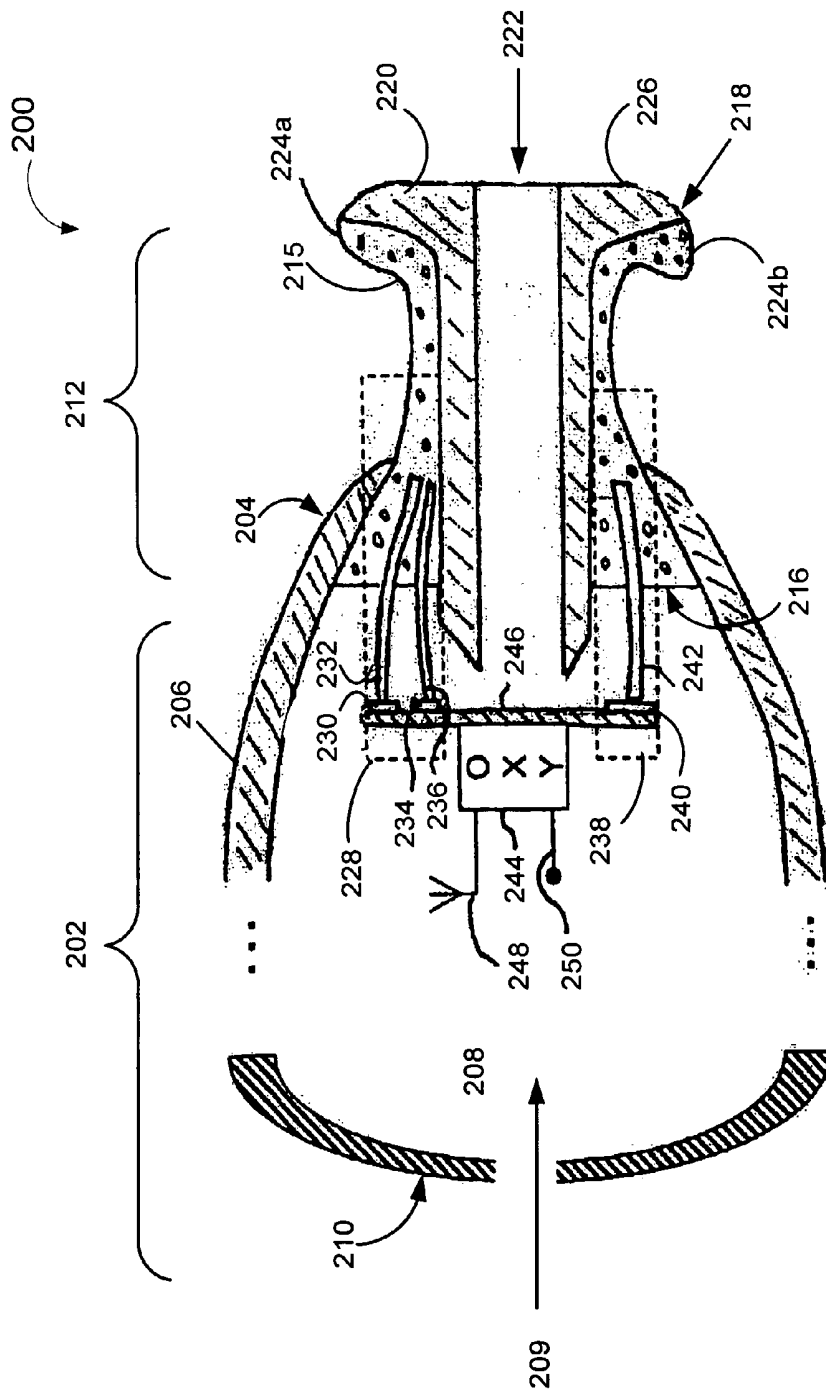


FIG. 2

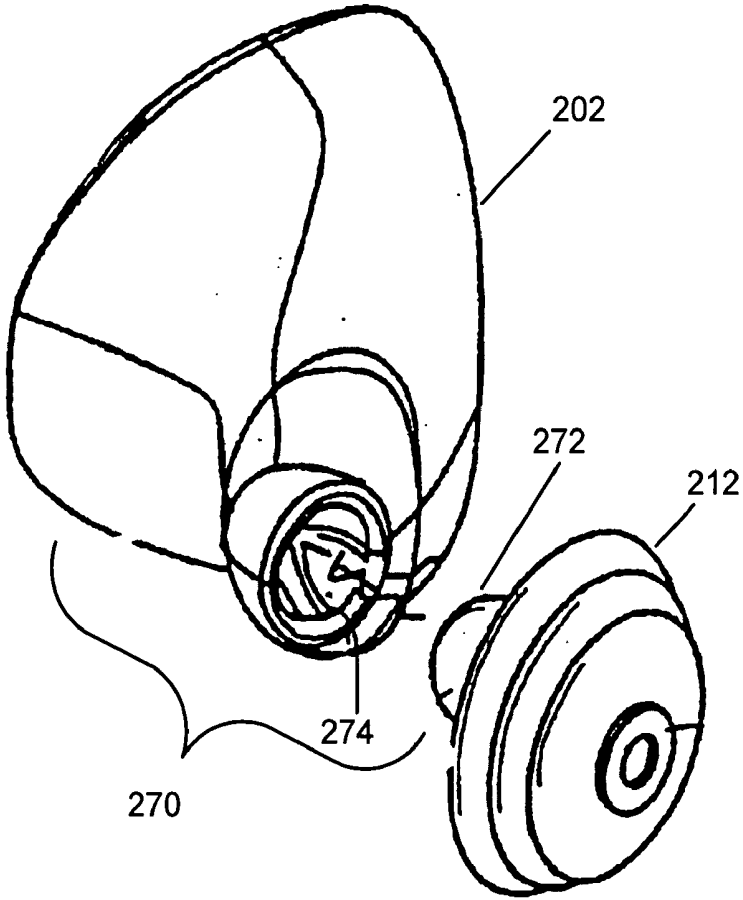


FIG. 2A

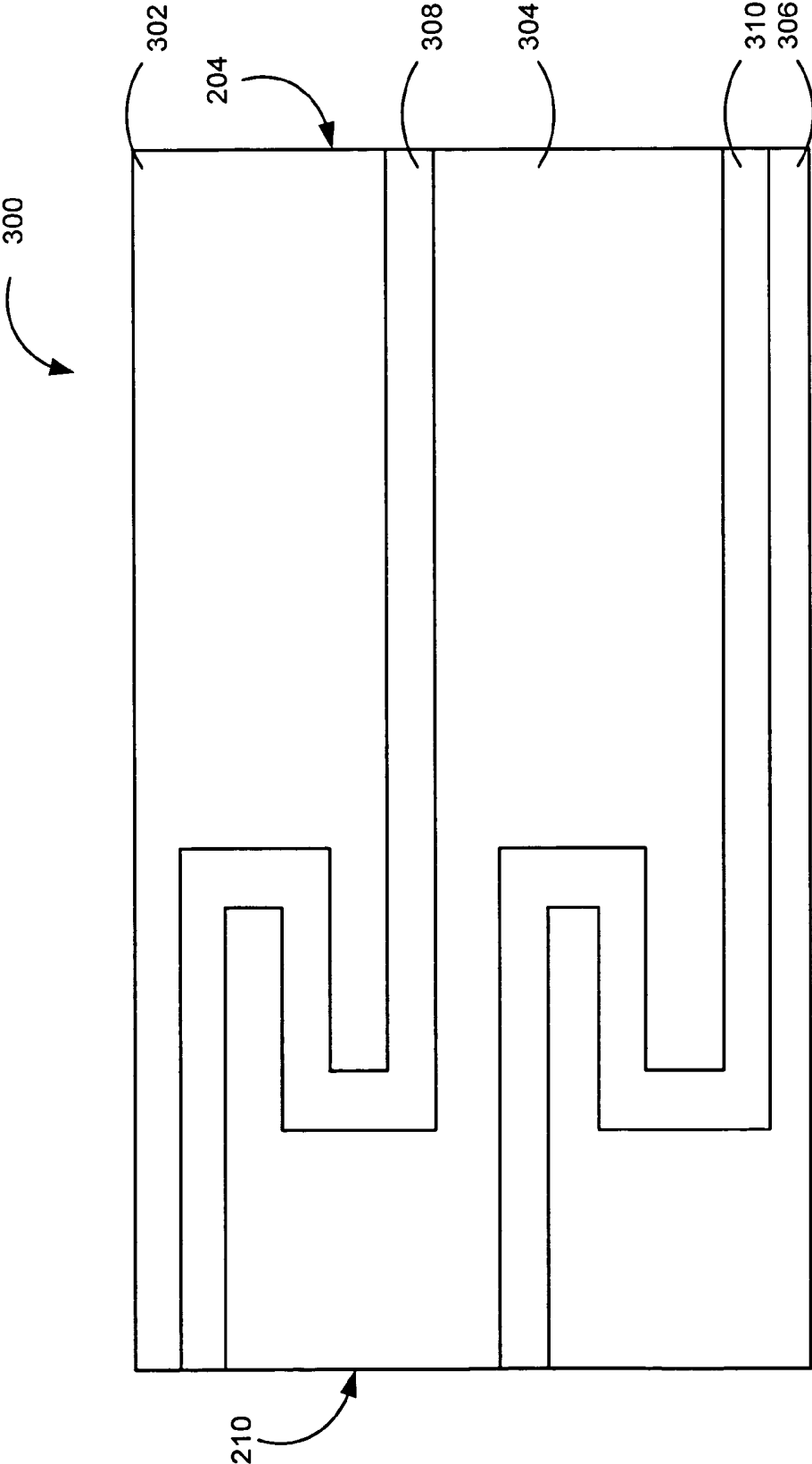
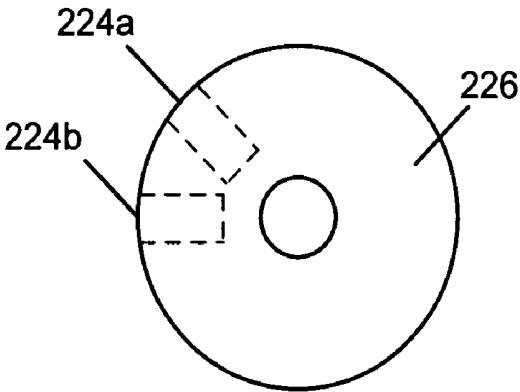
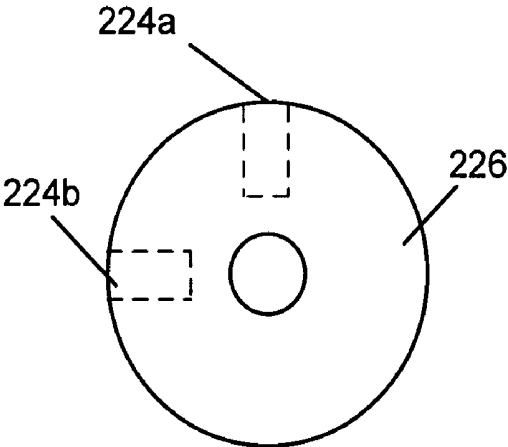
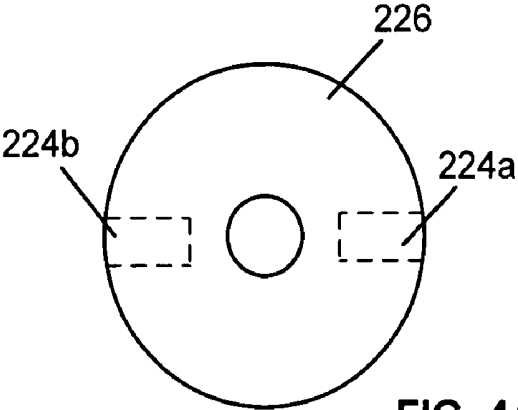


FIG. 3



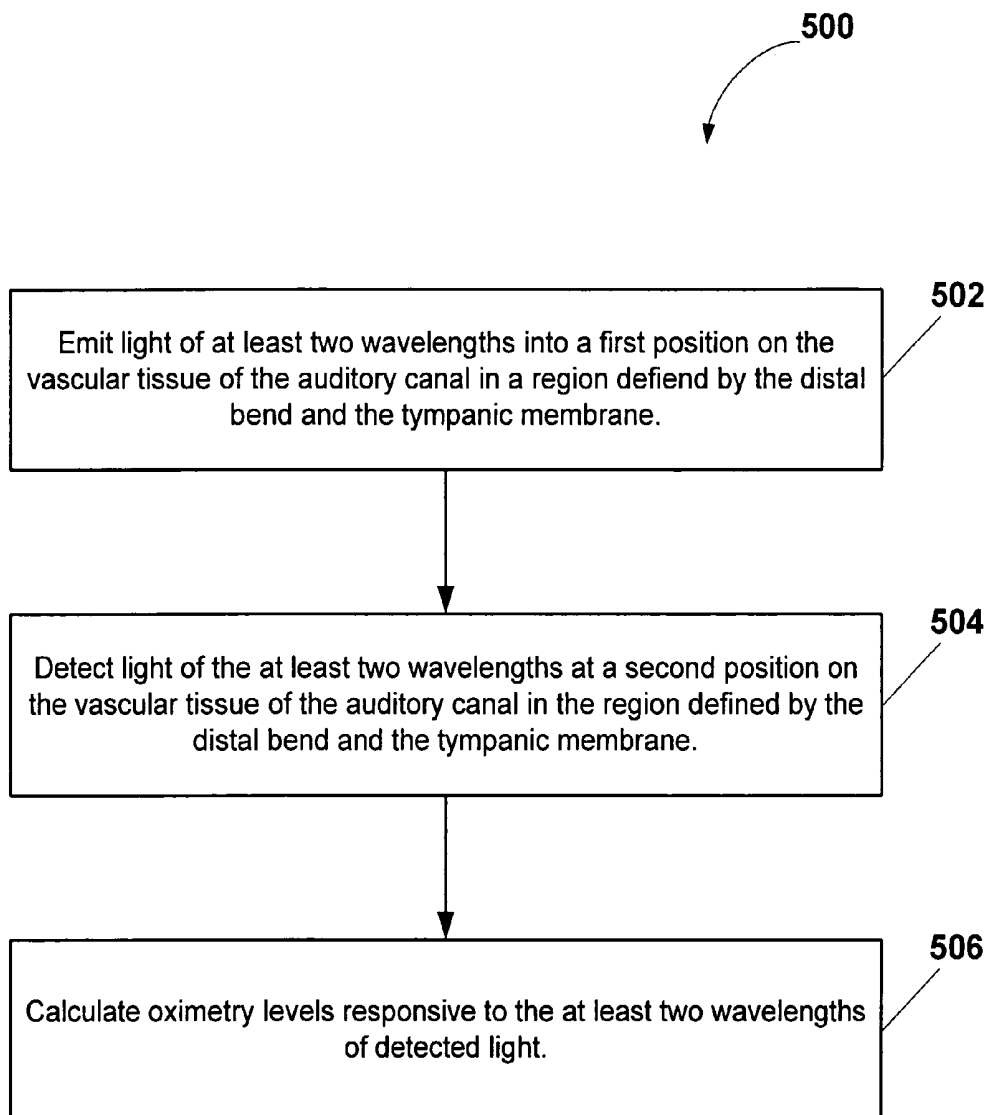


FIG. 5

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## PULSE OXIMETRY METHODS AND APPARATUS FOR USE WITHIN AN AUDITORY CANAL

### CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/497,890, filed Aug. 25, 2003, the contents of which are incorporated herein by reference.

### FIELD OF THE INVENTION

The present invention relates to the field of medical devices and, more particularly, to noninvasive pulse oximetry methods and apparatus for use inside an auditory canal of a living being.

### BACKGROUND OF THE INVENTION

An oximeter calculates blood oxygen saturation levels within a living being from the different rates at which oxygenated hemoglobin (oxyhemoglobin) and reduced hemoglobin (deoxyhemoglobin) within vascular tissue of the living being absorb light of different wavelengths. Typically, two wavelengths of light are used where one wavelength is much less sensitive to blood oxygen saturation levels than the other. The wavelength of light that is less sensitive to oxygen saturation levels serves as a constant against which the wavelength of light that is more sensitive to oxygen saturation levels is compared in order to calculate blood oxygen saturation levels.

The measurement of oxygen saturation levels ("oximetry") is a critical physiologic measurement for critical care patients. Presently, sensors for use with oximeters to measure oxygen saturation levels in vascular tissue are designed for placement on a finger, ear lobe, foot, or in an outer portion of the auditory canal. These sensors are subject to motion artifacts that may result in inaccurate measurements. Accordingly, improved oximetry methods and apparatus are needed that are not subject to this limitation. The present invention addresses this need among others.

### SUMMARY OF THE INVENTION

The present invention is embodied in methods and apparatus for detecting oxygen saturation levels in blood from within an auditory canal of a living being proximal to a tympanic membrane. The auditory canal is lined with tissue and includes a proximal bend and a distal bend located between the proximal bend and the tympanic membrane. Oxygen levels are measured by emitting one or more wavelengths of light into a first position on the tissue of the auditory canal in a first region defined by the distal bend and the tympanic membrane; sensing the wavelengths of light at a second position on the tissue of the auditory canal in the first region, the second position being spaced from the first position; and calculating at least one of (i) a blood oxygen saturation level and (ii) a pulse rate responsive to intensity information corresponding to the wavelengths of light detected at the second position.

### BRIEF DESCRIPTION OF THE DRAWINGS

The invention is best understood from the following detailed description when read in connection with the accompanying drawings, with like elements having the same

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reference numerals. This emphasizes that, according to common practice, the various features of the drawings are not drawn to scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. When a plurality of similar elements are present, a single reference numeral may be assigned to the plurality of similar elements with a small letter designation referring to specific elements. When referring to the elements collectively or to a non-specific one or more of the elements, the small letter designation may be dropped. Included in the drawings are the following figures:

FIG. 1 is a cross sectional anatomical illustration of an auditory canal and surrounding structure;

FIG. 2 is a cross-sectional view of an exemplary oximetry sensor in accordance with the present invention;

FIG. 2A is a perspective view of an alternative exemplary oximetry sensor in accordance with the present invention;

FIG. 3 is a surface view of a portion of an exemplary outer surface of the oximetry sensor of FIG. 2;

FIGS. 4A, 4B, and 4C are cross-sectional views of exemplary portions of the oximetry sensor; and

FIG. 5 is a flow chart of exemplary steps for determining oximetry levels in accordance with the present invention.

### DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 show a cross-sectional anatomical view of an auditory canal **100** in the transverse plane of a portion **102** of a head. The auditory canal **100** is generally S-shaped and can be described as having three regions. A first region **20** is the medial concha cavity, which is surrounded by cartilaginous tissue **22**. A second region **23**, which is separated from the first region **20** by a first bend **30** (the "proximal bend"), is also surrounded by cartilaginous tissue **22**. A third region **25**, which is separated from the second region **23** by a second bend **31** (the "distal bend"), defines the final auditory canal region near the tympanic membrane **26** and is surrounded by dense bony tissue **27**.

Vascular tissue **28** covering the first and second regions **20** and **23** is relatively thick and has a well developed subcutaneous layer that allows some expansion to occur. In contrast, vascular tissue **29** covering the third region **25** is relatively thin and, thus, little or no tolerance for expansion exists in this region.

Mandibular motion associated with activities such as talking, chewing, yawning, and biting deforms the first and second regions **20** and **23** of the auditory canal **100**. This deformation is generally caused by the asymmetric stresses from the actions of the mandibular condyle **33** on neighboring cartilaginous tissue **22**. These deformations have radial components, e.g. constrictions, and axial components, i.e. inward and outward motion, which may result in motion artifacts in known oximetry sensors positioned within the first or second regions **20** and **23**. The third region **25**, which is surrounded by bony tissue **27**, is less susceptible to deformation due to mandibular motion. Additional details regarding the auditory canal may be found in U.S. Pat. No. 5,701,348, which is incorporated fully herein by reference.

FIG. 2 depicts an exemplary oximetry sensor **200** and will be described with reference to the auditory canal **100** of FIG. 1. The oximetry sensor **200** is configured to measure oxygen saturation levels in the vascular tissue **29** within the third region **25** of the auditory canal **100**. A first portion **202** of the oximetry sensor **200** is configured for placement in the second region **23** of the auditory canal **100**, i.e., between the first bend **30** and the second bend **31**. The first portion **202**

includes a distal end **204** that extends toward the tympanic membrane **26** when the oximetry sensor **200** is positioned within the auditory canal **100**. In an exemplary embodiment, the first portion **202** includes an outer surface (shell) **206** that is relatively rigid and shaped to conform to the contours of the second region **23**.

In an exemplary embodiment, the outer surface **206** of the first portion **202** is substantially smooth and the first portion **202** further includes a hollow body portion **208** that extends from the distal end **204** to an outer end **210** that is substantially opposite the distal end **204**. The hollow body portion **208** defines an elongated passage **209** that extends between the outer end **210** and the distal end **204** of the first portion **202** for communication of acoustic signals through the first portion **202**. The hollow body portion **208** may be configured such that light is not passed by the hollow passage to the vascular tissue **29** in the third region **25**.

In an alternative exemplary embodiment, the outer surface **206** of the first portion **202** includes one or more protrusions (fins, bumps, etc.) that form channels extending from the outer end **210** to the distal end **204** of the first portion **202** in addition to, or instead of, the hollow body portion **208**. FIG. 3 represents an exemplary portion **300** of the outer surface **206** (FIG. 2) between the outer end **210** and the distal end **204**. The exemplary portion **300** includes protrusions (represented by a first protrusion **302**, a second protrusion **304**, and a third protrusion **306**). The illustrated first and second protrusions **302** and **304** define a first channel **308** and the second and third protrusions **304** and **306** define a second channel **310**. The channels **308** and **310** each have a “maze-like” configuration that doubles back on itself between the outer end **210** and the distal end **204** to allow acoustic signals to pass through the second region **23** (FIG. 1) to a second portion **212** (FIG. 2) while blocking light from reaching the vascular tissue **29** in the third region **25**.

In an exemplary embodiment, the protrusions are sized to comfortably support the first portion **202** within the auditory canal **100** while allowing air (sound) to flow freely past the first portion **202**. The protrusions act to centrally hold the first portion **202** in the second region **23** of the auditory canal **100** and comfortably touch the vascular tissue **28** of the auditory canal **100**. Each protrusion may have a flat surface where it contacts the vascular tissue **28** to minimize discomfort. Although three protrusions are illustrated, fewer or more protrusions may be formed on the outer surface **206**. Positioning a device within the auditory canal **100** negatively affect hearing, however, a hole larger than 2 mm, or an effective passage(s) having an area equivalent to a 2 mm hole or larger will substantially pass most low to high audio frequencies.

Referring back to FIG. 2, a second portion **212** of the oximetry sensor **200** is configured for placement in the third region **25** of the auditory canal **100**, i.e., between the second bend **31** and the tympanic membrane **26**. The second portion **212** includes optically transparent portions **224** and optically blocking portions **226** for use in measuring oximetry levels within the vascular tissue **29** of the third region **25**, which is described in further detail below. The optically transparent portions **224** form channels and/or islands within the optically blocking portions **226**. An outer surface **214** of the second portion **212** is configured to abut at least a portion of the vascular tissue **29** lining the auditory canal **100** in the third region **25**. Due to the dense bony tissue **27** surrounding the third region **25**, positioning the second portion **212** within the third region **25** effectively isolates the second portion **212** from being directly affected by mandibular

motion, thereby reducing oximetry false alarms associated with motion artifacts. Additionally, positioning the second portion **212** past the second bend **31** tends to “lock” the oximetry sensor **200** in position.

In an exemplary embodiment, the second portion **212** is movably coupled to the first portion **202**. The second portion **212** includes a proximal end **216** and a tympanic end **218** that extends toward the tympanic membrane **26** when the oximetry sensor **200** is positioned within the auditory canal **100**. Although positioning the second portion **212** within the third region **25** effectively isolates the second portion from being directly affected by mandibular motion, the second portion **212** may be indirectly affected by mandibular motion transferred to the second portion **212** through the first portion **202**. Movably coupling the second portion **212** to the first portion **202** reduces the effect of this indirect mandibular motion on the second portion **212**, thereby further reducing oximetry measurement false alarms due to motion artifacts.

In an exemplary embodiment, the second portion **212** further includes a hollow body portion **220** that defines an elongated passage **222** extending between the proximal end **216** and the tympanic end **218** of the second portion **212**. The hollow body portion **220** is configured to communicate acoustic signals through the second portion **212** between the first portion **202** and the tympanic membrane **26**. If each of the first and second portions **202** and **212** include elongated passages (e.g., elongated passages **209** and **222**), acoustic signals originating from outside the auditory canal **100** may pass to the tympanic membrane **26**.

In an exemplary embodiment, the second portion **212** is made of a flexible elastomer, which renders the second portion **212** movable with respect to the first portion **202**. The flexible elastomer facilitates the navigation of the typical, nominally S-shaped centerline path of the auditory canal **100**. The second portion **212** may be constructed of a low modulus, low durometer material to provide a high level of comfort for the user even when it is inserted into the third region **25** of the auditory canal **100**. In addition, the hollow body portion **220** may be substantially tubular in shape and elongated to permit a continuum of deformations along its length so that its axis can conform to the axis of the auditory canal in the third region **25**.

In an alternative exemplary embodiment, as depicted in FIG. 2A, a mechanical joint **270** may be positioned between the first portion **202** and the second portion **212** to render the second portion **212** movable relative to the first portion **202**. The illustrated mechanical joint **270** includes a ball portion **272** and a ball receiving portion **274** configured to movably engage the ball portion **272**. Examples of suitable mechanical joints may be found in U.S. Pat. No. 6,205,227 to Mahoney et al. titled PERITYMPANIC HEARING INSTRUMENT, which is commonly assigned with the present application and incorporated fully herein by reference.

Referring back to FIG. 2, an emitter **228** is positioned within the oximetry sensor **200** to emit light of two or more wavelengths from a first optically transparent portion **224a** of the second portion **212** into a corresponding first position of the vascular tissue **29** when the oximetry sensor **200** is positioned within the auditory canal **100**. The illustrated emitter **228** includes a first light source **230**, a first light channel **232**, a second light source **234**, and a second light channel **236**. In an exemplary embodiment, the first and second light sources **230** and **234** are positioned within the first portion **202** and the first and second light channels **232** and **234** are configured to direct light from the first and

second light sources, respectively, to the first optically transparent portion 224a. In an alternative embodiment, the light sources 230 and 234 may be positioned within the second portion 212 with leads (not shown) for powering the light sources extending from a power source (not shown) in the first portion 202 to the first and second light sources in the second portion 212. The first and second light sources 230 and 234 may be light emitting diodes (LEDs, e.g., a 660 nm LED and an 805 nm LED) and the first and second light channels 232 and 236 may be optical fibers.

A detector 238 is positioned within the oximetry sensor 200 to detect light of the two or more wavelengths out of a second position of the vascular tissue 29 impinging a corresponding second optically transparent portion 224b of the second portion 212 when the oximetry sensor 200 is positioned within the auditory canal 100. The illustrated detector 238 includes a photodetector 240 (e.g., a photo diode) and a third light channel 242 (e.g., an optical fiber). In an exemplary embodiment, the photodetector 240 is positioned within the first portion 202 and the third light channel 242 is configured to direct light impinging the second optically transparent portion 224b of the second portion 212 through the second portion 212 to the photodetector 240 in the first portion 202. In an alternative exemplary embodiment, the photodetector 240 may be positioned within the second portion 212 with a lead (not shown) extending from the photodetector 240 to oximetry circuitry 244 in the first portion 202. The first and second optically transparent portions 224a and 224b may form channels on the surface of the second portion 212 for respectively emitting and detecting light along the channels to maximize coupling and to limit the effects of blockage do to wax build-up.

FIGS. 4A, 4B, and 4C depict cross sectional views of exemplary second portions 212 for delivering light to the first and second positions of the vascular tissue in the third region 25. The cross sectional views each include an optically blocking portion 226 and optically transparent portions 224. The illustrated cross sectional second portions each include two transparent portions 224—a light emitting optically transparent portion 224a and a light receiving optically transparent portion 224b. The light emitting portion 224a is coupled to the first and second light sources 230 and 234 (FIG. 2) and the light receiving portion 224b is coupled to the photodetector 240, e.g., via optical fibers 232, 236, and 242. The light emitting portion 224a emits light from the light sources to the first position of the vascular tissue 29 when the oximetry sensor 200 is positioned within the auditory canal and the light receiving portion 224b collects light from the second position of the vascular tissue 29 when the oximetry sensor 200 is positioned within the auditory canal.

In FIG. 4A, the light emitting portion 224a and the light receiving portion 224b are radially positioned substantially opposite one another, e.g., about 180 degrees apart, such that the first and second positions on the vascular tissue are on opposite sides of the second portion 212 (FIG. 2). In FIG. 4B, the light emitting portion 224a and the light receiving portion 224b are radially positioned approximately 90 degrees with respect to one another. In FIG. 4C, the light emitting portion 224a and the light receiving portion 224b are radially positioned approximately 45 degrees with respect to one another. In an exemplary embodiment, the light emitting portion 224a and the light receiving portion 224b are radially positioned relative to one another between about 5 degrees and 180 degrees. In an alternative exemplary embodiment, the light emitting portion and the light

receiving portion may radially overlap, but be separated in a longitudinal direction by the optically blocking portion 226, e.g., along the length of the elongated passage 222 (FIG. 2) extending through the second portion 212.

Referring back to FIG. 2, the oximetry circuitry 244 is configured to process information corresponding to the two or more wavelengths of light received by the detector 238. In addition, the oximetry circuitry 244 may be configured to control the emitter 228. The oximetry circuitry 244 may be coupled to the emitter 228 and the detector 238 via traces of a circuit board 246. The oximetry circuitry 244 may be configured to calculate an oximetry value based on the received two or more wavelengths of light. In addition, the oximetry circuitry 244 may be configured to calculate pulse rate. Suitable methods for calculating oximetry levels and pulse rates will be understood by those of skill in the art.

The exemplary oximetry circuitry 244 further includes an emitter 248 for wireless transmission of information related to the two or more wavelengths of light and/or a port 250 for wired transmission of information related to the two or more wavelength of light. The information related to the two or more wavelengths of light may be values calculated by the oximetry circuitry 244 or raw data detected by the detector 238. A suitable oximetry circuit for use in the present invention will be understood by those of skill in the art.

FIG. 5 depicts a flow chart 500 of exemplary steps for detecting oxygen saturation levels in blood from within an auditory canal of a living being. The steps are described with reference to FIGS. 1 and 2.

At block 502, the emitter 228 emits light of two or more wavelengths into a first position on the vascular tissue 29 of the auditory canal 100 in the third region 25, which is defined by the distal bend 31 and the tympanic membrane 26. At least one of the wavelengths of light is much less sensitive to blood oxygen saturation levels than at least one of the other wavelengths of light. The wavelength of light that is sensitive to blood oxygen saturation levels may be the isobestic wavelength, which for oxygenated blood is 805 nm, e.g., infrared light. After the oximetry sensor 200 is positioned within the auditory canal 100, the emitter 204 emits the two or more wavelengths of light, e.g., from light sources 230 and 234, responsive to the oximetry circuitry 244.

In an exemplary embodiment, the oximetry circuitry 244 is configured to modulate the emitter 228 to cause a first light source, e.g., light source 230, to emit light for one-third ( $\frac{1}{3}$ ) of a proposed cycle time; to cause a second light source, e.g., light source 234, to emit light during a second one-third of the cycle time; and to cause no light to be emitted during a final one-third of the cycle time. During the period of time in which no light is emitted, the detector 238 may measure background light intensity levels for subtraction from the measure light intensity signals when light is being emitted to increase accuracy.

In an exemplary embodiment, the wavelengths of light are generated in the first portion 202 and are passed to the emitting optically transparent portion 224a of the second portion 212, e.g., via optical fibers 232 and 234, where they are emitted into the first position on the vascular tissue 29. In an alternative exemplary embodiment, the wavelengths of light originate in the second portion 212 responsive to electrical signal from the oximetry circuitry 244.

At block 504, the detector 238 detects the intensity of the two or more frequencies of light at a second position on the vascular tissue 29 of the auditory canal 100 in the third region 25. The second position is spaced from the first position and the light detected by the detector 228 is light

that has passed through the vascular tissue **29** from the first position to the second position. In an exemplary embodiment, the detector **238** sequentially detects the light as emitted by the emitter **228**.

In an exemplary embodiment, light from the second position of the vascular tissue **29** impinges upon the optically transparent portion **224b** of the second portion **212** and is passed to the photo detector **240** in the first portion **202**, e.g., via an optical fiber **242**, for detection and communication to the oximetry circuitry **244**. In an alternative exemplary embodiment, the light is detected in the second portion and an electrical signal including intensity information corresponding to the detected light is passed to the first portion, e.g., via a transmission line.

As used herein, the phrase “intensity information corresponding to the two or more frequencies of light” detected in the third region **25** may be used to refer to the actual light or to an electrical signal representing the actual light. In an exemplary embodiment, this information passes from the third region **25** to another region (e.g., within the auditory canal or outside of the auditory canal) distinct from the third region **25** through a flexible coupling (e.g., a flexible second portion **202** coupled to the first portion **212** or a mechanical joint connecting the first and second portions **202** and **212**).

At block **506**, the oximetry circuitry **244** calculates a blood oxygen saturation level responsive to the intensity information corresponding to the two or more wavelengths of light detected at the second position. Since one of the frequencies of light is less sensitive to oxygen saturation levels than the other, this frequency of light provides a “base-line” against which a frequency of light that is more sensitive to oxygen saturation can be compared in order to calculate blood oxygen saturation levels in a manner that will be understood by those of skill in the art. The oximetry circuitry **244** may alternatively or additionally calculate pulse rate responsive to the information in a manner that will also be understood by those of skill in the art. The absolute strength of the signal is dynamic and cyclic being responsive to the pulsatile arterial blood flow—peak to peak measurements determine pulse. For a modulated light source, the light source should be modulated at a frequency of at least twice that of the highest frequency to be measured, e.g., at 300 Hz or more to measure a pulse rate of 150 beats per minute or less. In accordance with this embodiment, light of only one wavelength is needed and, thus, only one light source (e.g., a single LED) that is sensitive to blood oxygen saturation levels is needed. In an exemplary embodiment, the oximetry circuitry **244** calculates the blood oxygen saturation level and/or pulse rate in a region other than the third region **25**, e.g., within another region of the auditory canal **100** or external to the auditory canal.

Although the invention is illustrated and described herein with reference to specific embodiments, the invention is not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

What is claimed is:

**1.** An apparatus for detecting oxygen saturation levels in blood from within an auditory canal of a living being proximal to a tympanic membrane, the auditory canal being lined with tissue and including a proximal bend and a distal bend located between the proximal bend and the tympanic membrane, the apparatus comprising:

a first portion configured for placement in the auditory canal between the proximal bend and the distal bend, the first portion having a distal end extending toward

the tympanic membrane when the apparatus is positioned within the auditory canal;

a second portion movably coupled to the distal end of the first portion, the second portion comprising an outer surface configured to abut at least a portion of the tissue of the auditory canal between the distal bend and the tympanic membrane when the apparatus is positioned within the auditory canal,

an emitter that emits light of one or more wavelengths from a first position on the outer surface of the second portion into the tissue of the auditory canal between the distal bend and the tympanic membrane; and

a detector that detects the light of one or more wavelengths from the tissue of the auditory canal between the distal bend and the tympanic membrane impinging upon a second position on the outer surface of the second portion.

**2.** The apparatus of claim **1**, wherein the first portion is substantially rigid and the second portion extends from the first portion and is relatively flexible such that the second portion is movable relative to the first portion to at least partially isolate the second portion from movement of the first portion.

**3.** The apparatus of claim **1**, further comprising a joint coupled between the distal end of the first portion and the second portion.

**4.** The apparatus of claim **1**, the second portion having a proximal end coupled to the distal end of the first portion and a tympanic end extending toward the tympanic membrane when the apparatus is positioned within the auditory canal, the second portion further comprising a first hollow body portion defining an elongated passage extending between the proximal end and the tympanic end of the second portion for communication of acoustic signals through the second portion between the first portion and the tympanic membrane.

**5.** The apparatus of claim **4**, wherein the first portion has an outer end portion substantially opposite the distal end, the first portion further comprising a second hollow body portion defining an elongated passage extending between the outer end and distal end of the first portion for communication of acoustic signals through the first portion to the first hollow body portion of the second portion.

**6.** The apparatus of claim **1**, wherein the emitter comprises:

a light source positioned within the first portion; an optical channel extending from the light source through the second portion to the first position.

**7.** The apparatus of claim **1**, wherein the detector comprises:

a photo-detector positioned within the first portion; an optical channel extending from the second position on the second portion to the photo-detector.

**8.** The apparatus of claim **1**, further comprising: oximetry circuitry coupled to the detector, the oximetry circuitry positioned within the first portion and configured to determine an oxygen saturation level responsive to the light detected by the detector at the second position of the second portion.

**9.** The apparatus of claim **1**, wherein the first portion has an outer surface characterized by one or more protrusions forming one or more channels that enable the flow of air to and block light from the tissue of the auditory canal between the distal bend and the tympanic membrane when the apparatus is positioned within the auditory canal.

**10.** The apparatus of claim **1**, wherein the first position on the outer surface of the second portion is substantially opposite the second position.

11. The apparatus of claim 1, wherein the first and second positions on the outer surface of the second portion are radial spaced relative to one another by between about 5 degrees and about 180 degrees.

12. An apparatus for detecting oxygen saturation levels in blood from within an auditory canal of a living being proximal to a tympanic membrane, the auditory canal being lined with tissue and including a proximal bend and a distal bend located between the proximal bend and the tympanic membrane, the apparatus comprising:

a body having an outer surface configured to abut at least a portion of the tissue of the auditory canal between the distal bend and the tympanic membrane when the apparatus is positioned within the auditory canal;

an emitter that emits light of one or more wavelengths from a first position on the outer surface into the tissue of the auditory canal between the distal bend and the tympanic membrane; and

a detector that detects the light of one or more wavelengths from the tissue of the auditory canal between the distal bend and the tympanic membrane impinging upon a second position on the outer surface.

13. The apparatus of claim 12, wherein:

the body includes a hollow body portion surrounded by the outer surface, the hollow body portion defining an elongated passage extending through the apparatus for communication of acoustic signals to the tympanic membrane.

14. The apparatus of claim 12, wherein the first position on the outer surface is substantially opposite the second position.

15. The apparatus of claim 12, wherein the first and second positions on the outer surface are radial spaced relative to one another by between about 5 degrees and about 180 degrees.

16. A method for detecting oxygen saturation levels in blood from within an auditory canal of a living being

proximal to a tympanic membrane, the auditory canal being lined with tissue and including a proximal bend and a distal bend located between the proximal bend and the tympanic membrane, said method comprising the steps of:

emitting one or more wavelengths of light into a first position on the tissue of the auditory canal in a first region located between the distal bend and the tympanic membrane;

detecting the one or more wavelengths of light at a second position on the tissue of the auditory canal in the first region, the second position being spaced from the first position; and

calculating at least one of (i) a blood oxygen saturation level and (ii) a pulse rate responsive to intensity information corresponding to the one or more wavelengths of light detected at the second position.

17. The method of claim 16, further comprising the step of:

passing, from the first region to a second region distinct from the first region through a flexible coupling, the intensity information corresponding to the one or more wavelengths of light detected in the first region;

wherein the step of calculating at least one of (i) the blood oxygen saturation level and (ii) the pulse rate is performed in a region other than the first region.

18. The method of claim 16, further comprising the steps of:

blocking ambient light from external to the auditory canal from reaching the tissue surrounding the auditory canal in a region defined by the distal bend and the tympanic membrane; and

communicating acoustic signals from external to the auditory canal to the tympanic membrane.

\* \* \* \* \*

专利名称(译)	用于耳道内的脉搏血氧测定方法和装置		
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摘要(译)

公开了用于检测来自鼓膜近端的生物的耳道内的血液中的氧饱和度水平的方法和装置。耳道衬有组织，并包括近端弯曲和位于近端弯曲和鼓膜之间的远端弯曲。通过将一或多个波长的光发射到由远端弯曲和鼓膜限定的第一区域中的耳道组织上的第一位置来检测氧水平。然后，在第一区域中的耳道组织上的第二位置处感测光的波长。然后，响应于对应于在第二位置检测到的光的波长的强度信息，计算血氧饱和度和/或脉搏率。

