



US 20080242958A1

(19) **United States**
(12) **Patent Application Publication**
Al-Ali et al.

(10) **Pub. No.: US 2008/0242958 A1**
(43) **Pub. Date: Oct. 2, 2008**

(54) **MULTIPLE WAVELENGTH OPTICAL SENSOR**

filed on Apr. 14, 2007, provisional application No. 61/033,007, filed on Mar. 2, 2008.

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Publication Classification

(51) **Int. Cl.**
A61B 5/00 (2006.01)
(52) **U.S. Cl.** **600/323; 600/310**

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(57) **ABSTRACT**

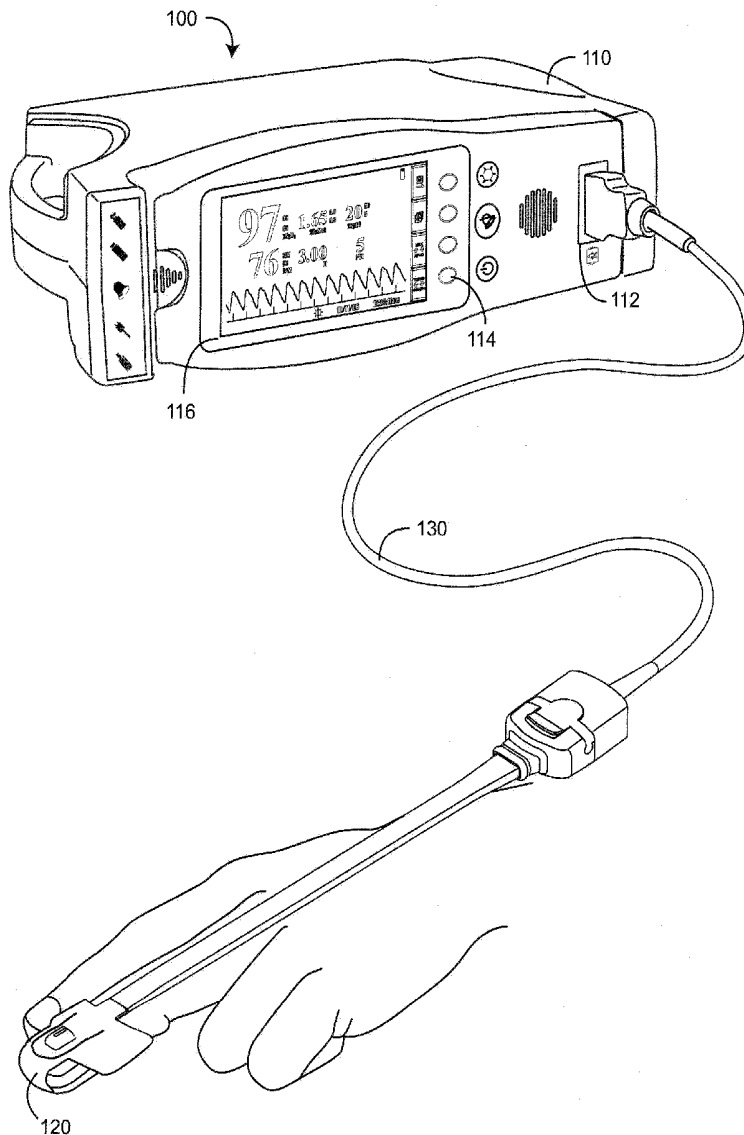
A multiple wavelength optical sensor has an emitter configured to radiate light having a plurality of wavelengths into a tissue site. The emitter comprises a plurality of LEDs configured in an array and connected within an electrical grid. A detector is configured to receive the light after absorption by pulsatile blood flow within the tissue site. The detector generates a sensor signal capable of being processed by a patient monitor so as to derive oxygen saturation, carboxyhemoglobin, methemoglobin and total hemoglobin.

(21) Appl. No.: **12/056,179**

(22) Filed: **Mar. 26, 2008**

Related U.S. Application Data

(60) Provisional application No. 60/920,474, filed on Mar. 27, 2007, provisional application No. 60/923,630,



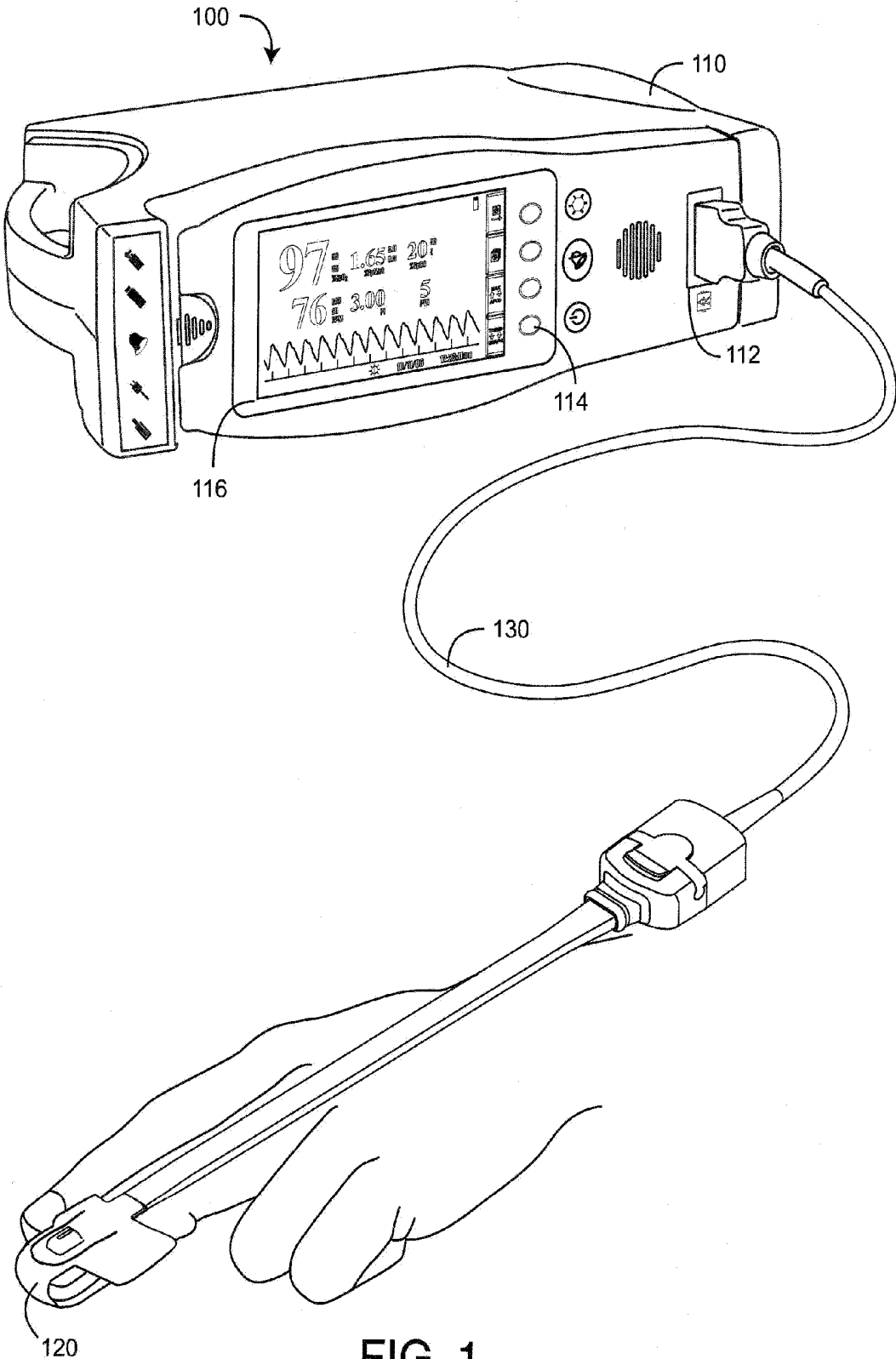


FIG. 1

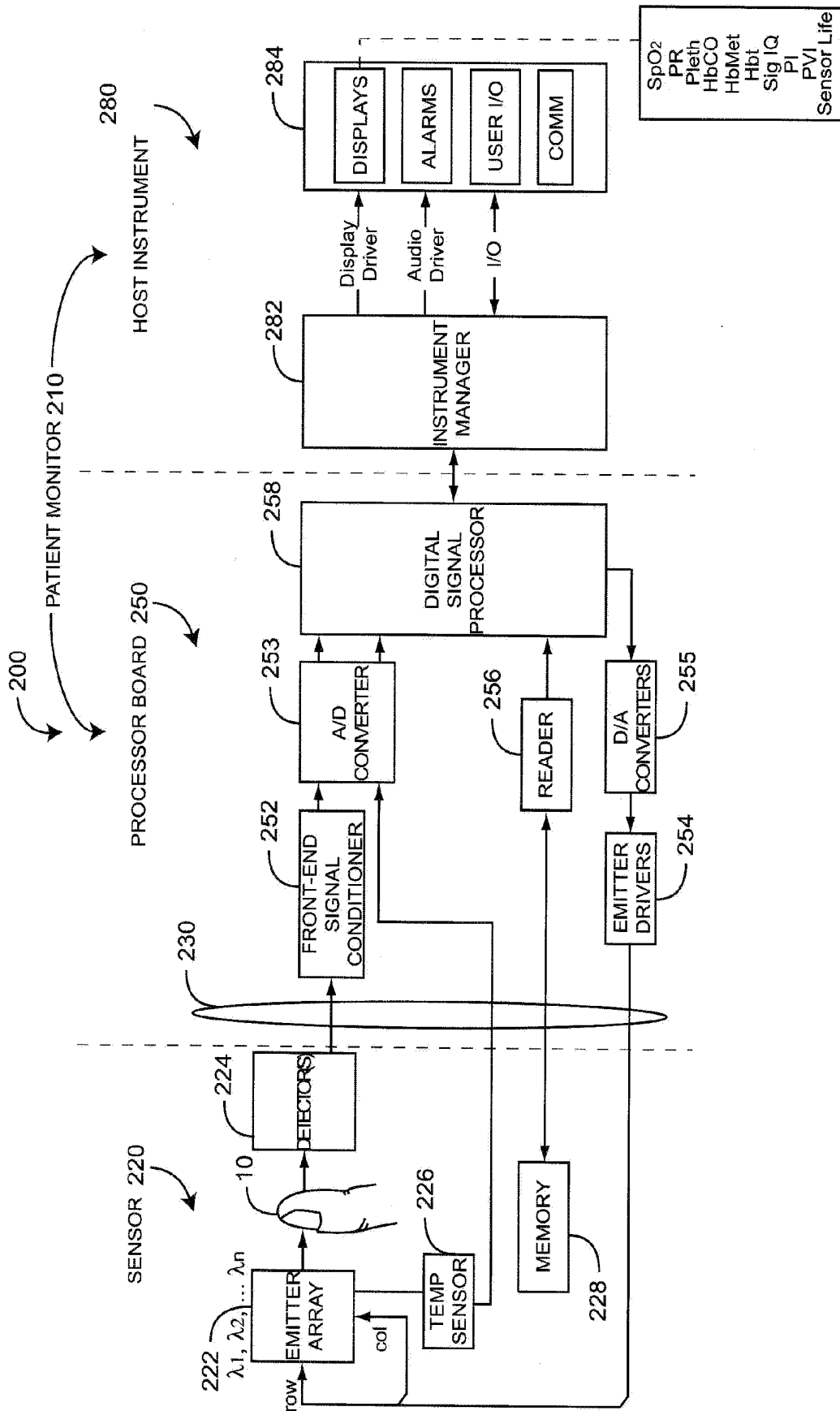


FIG. 2

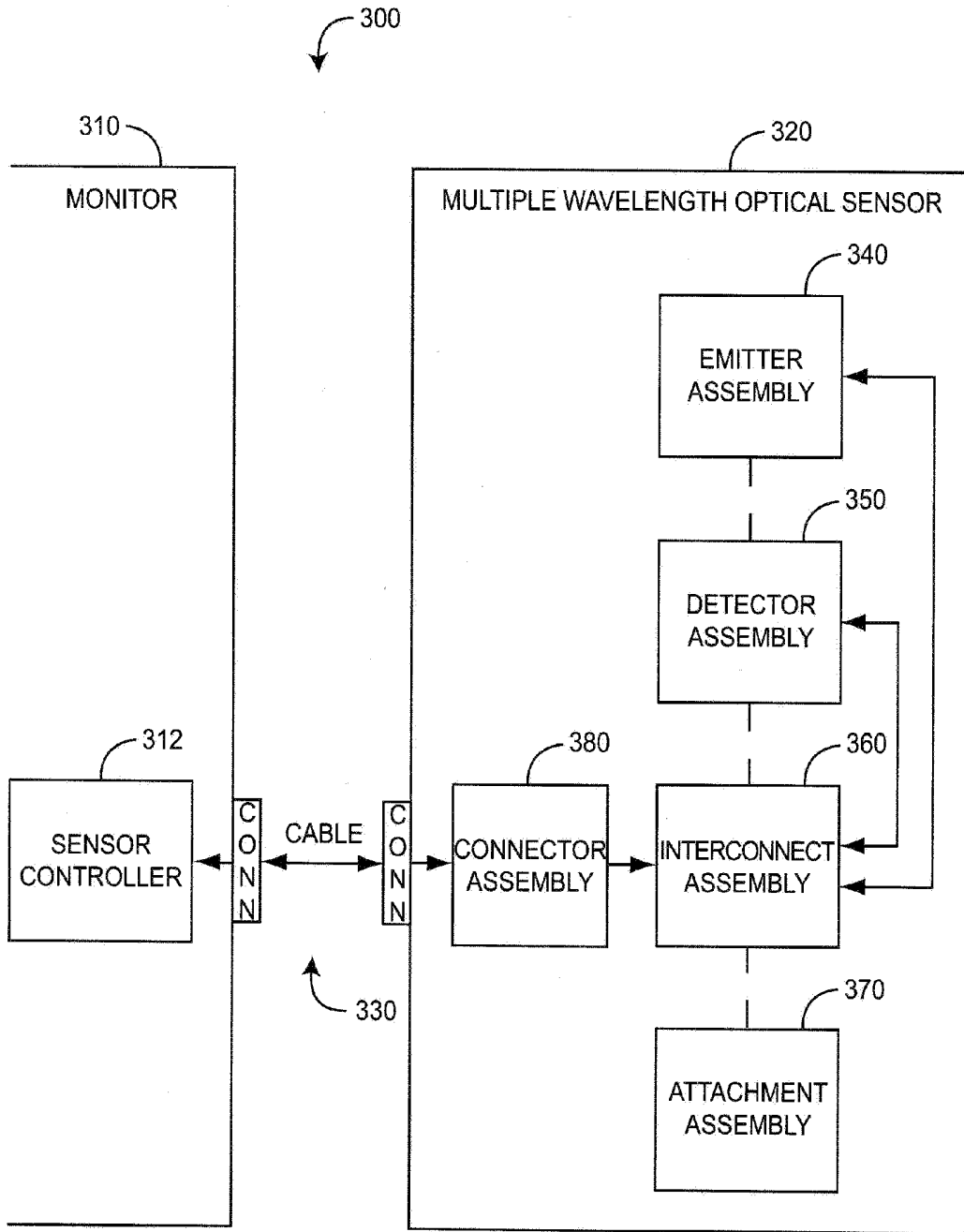


FIG. 3

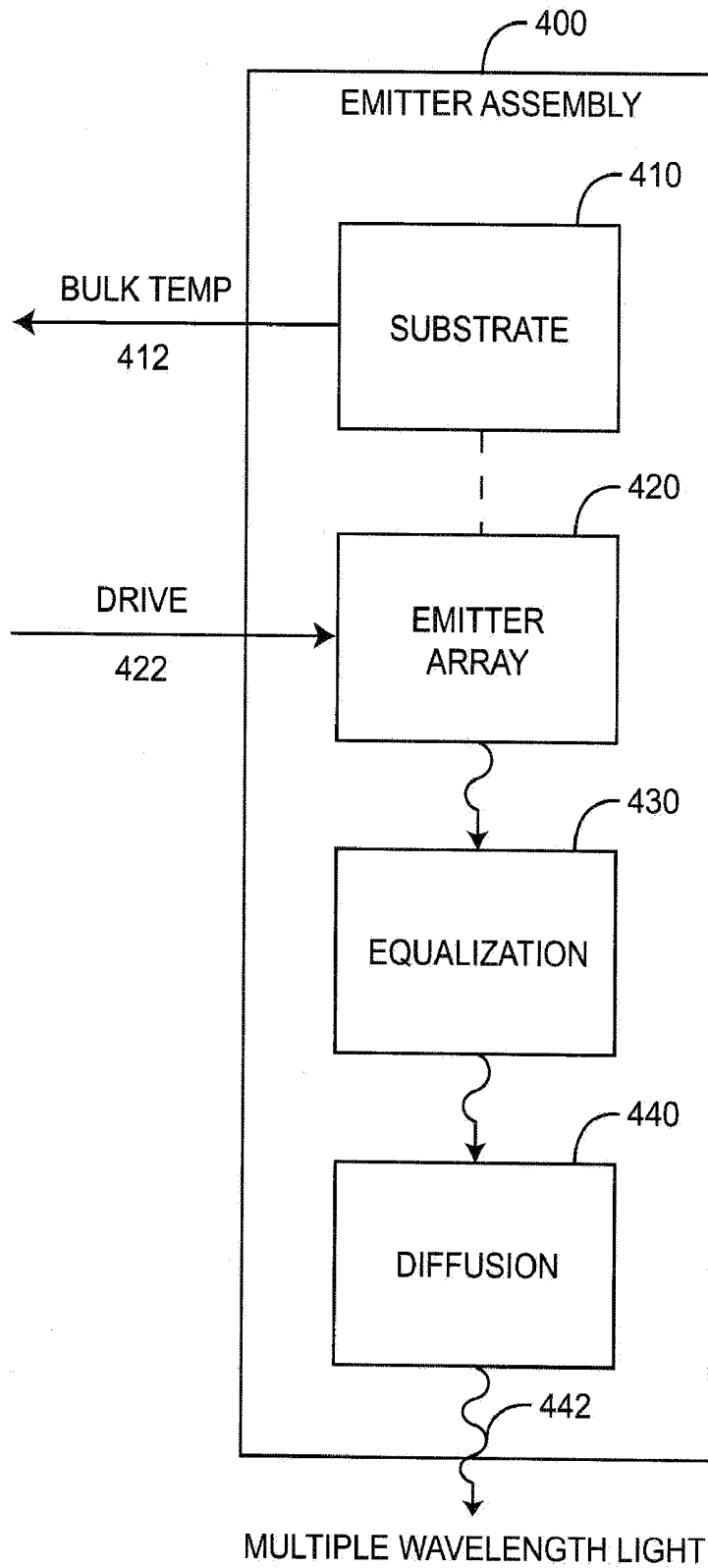


FIG. 4

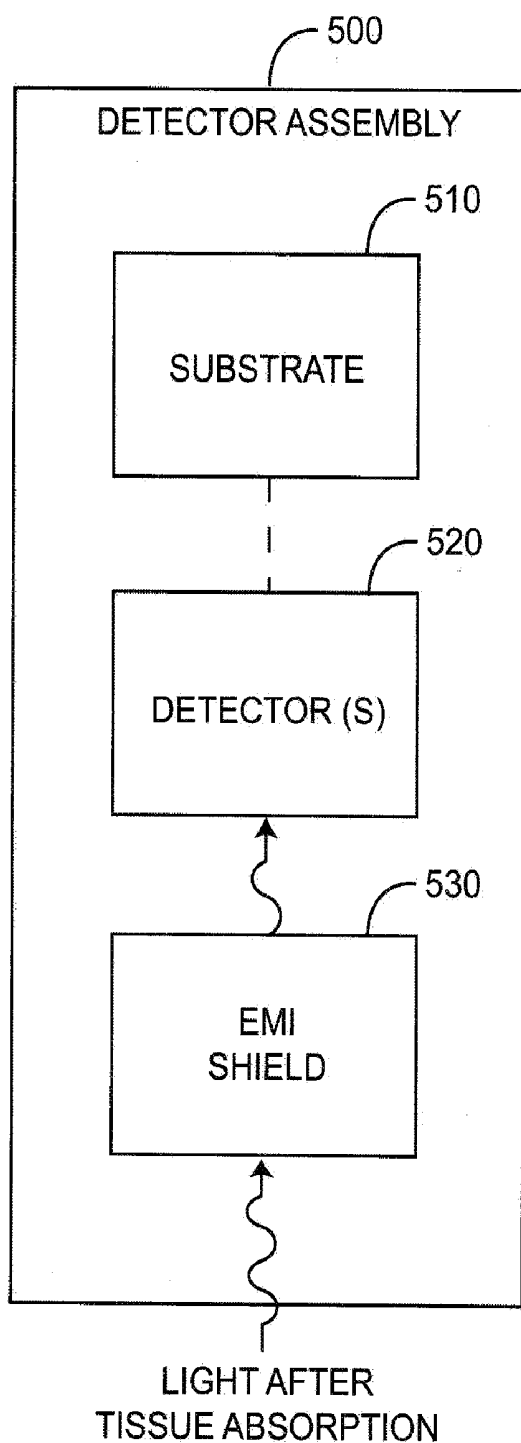


FIG. 5

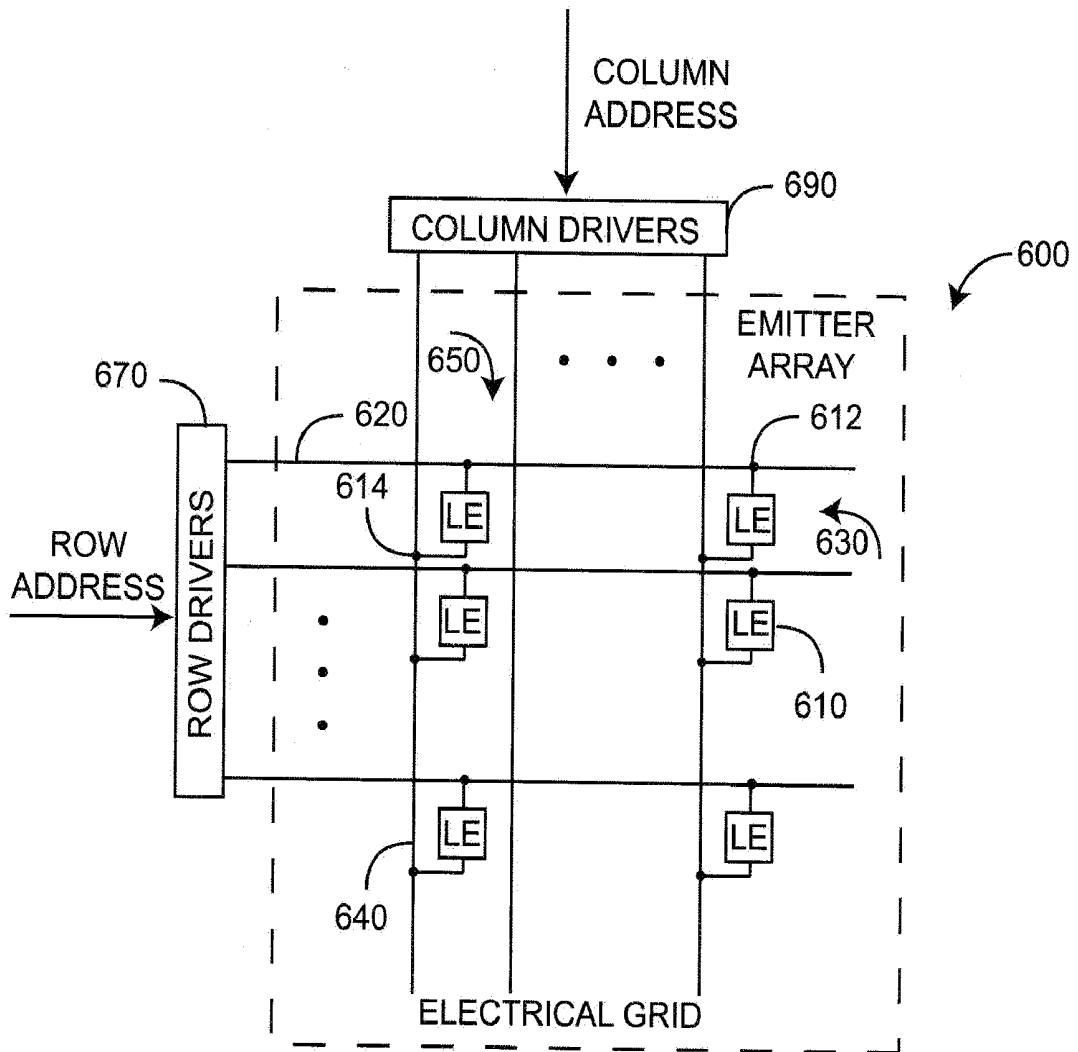


FIG. 6

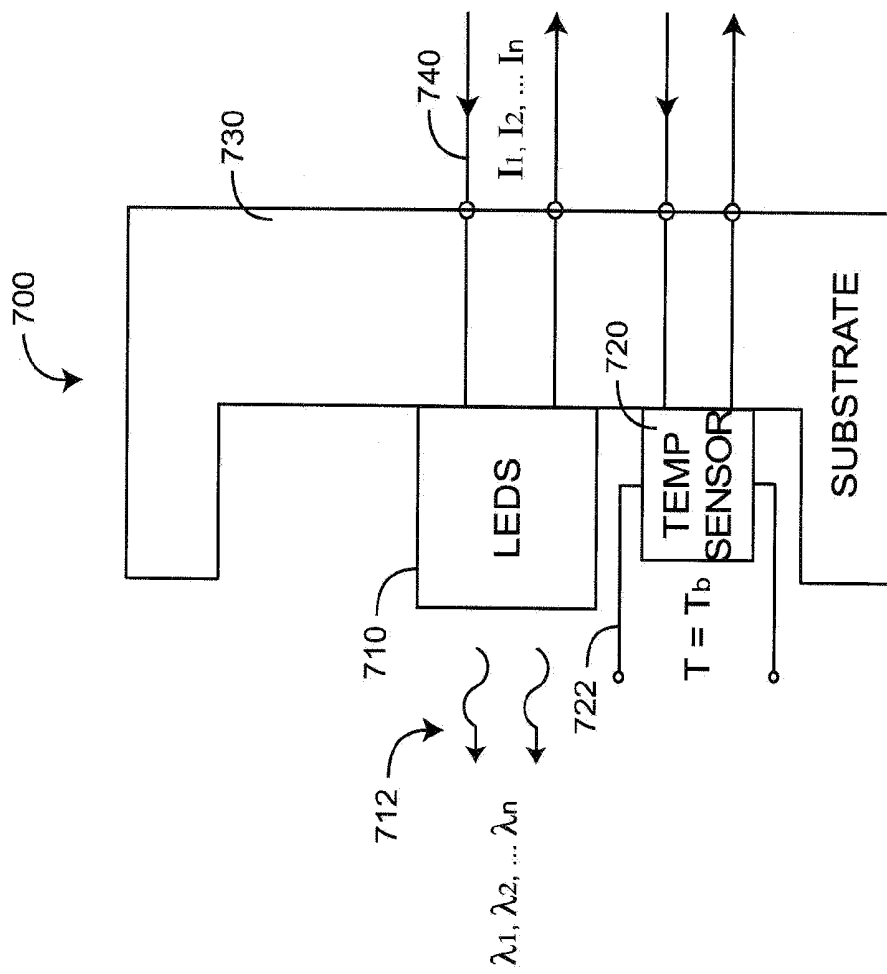


FIG. 7

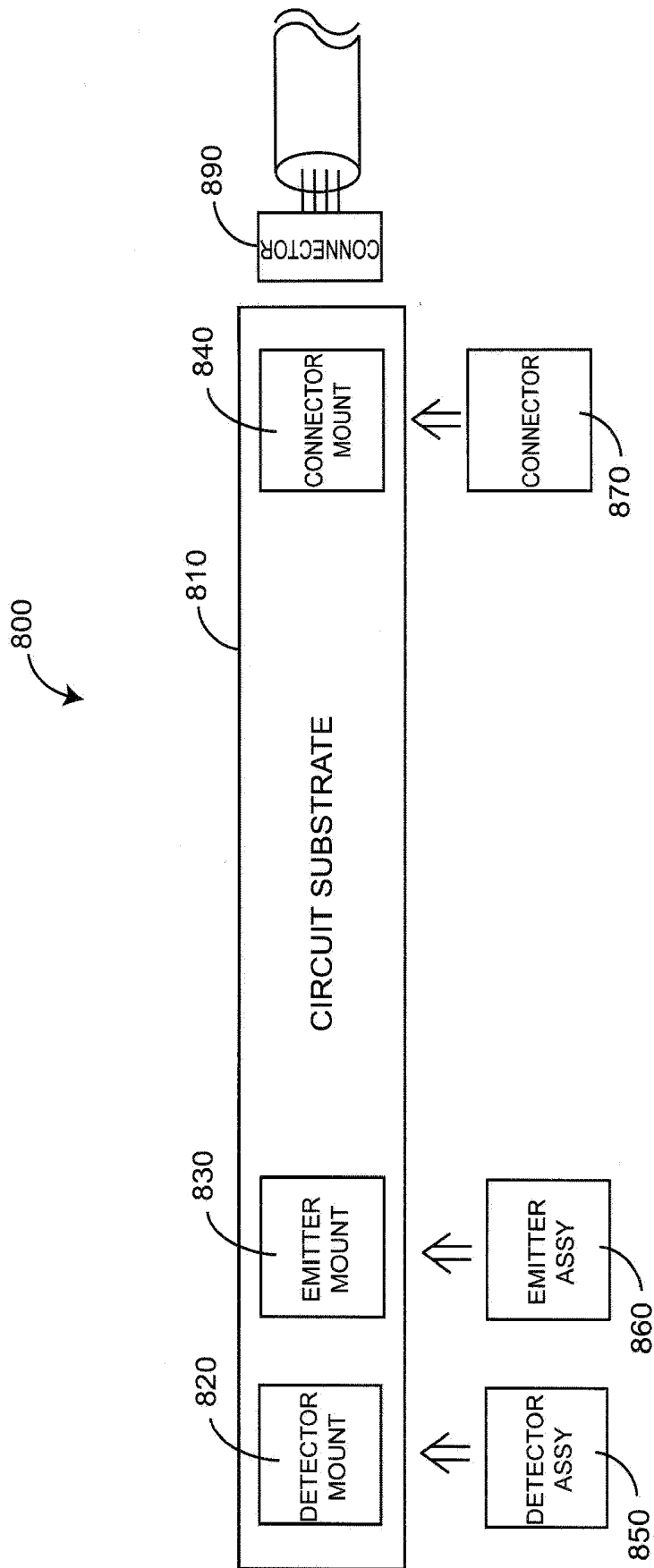
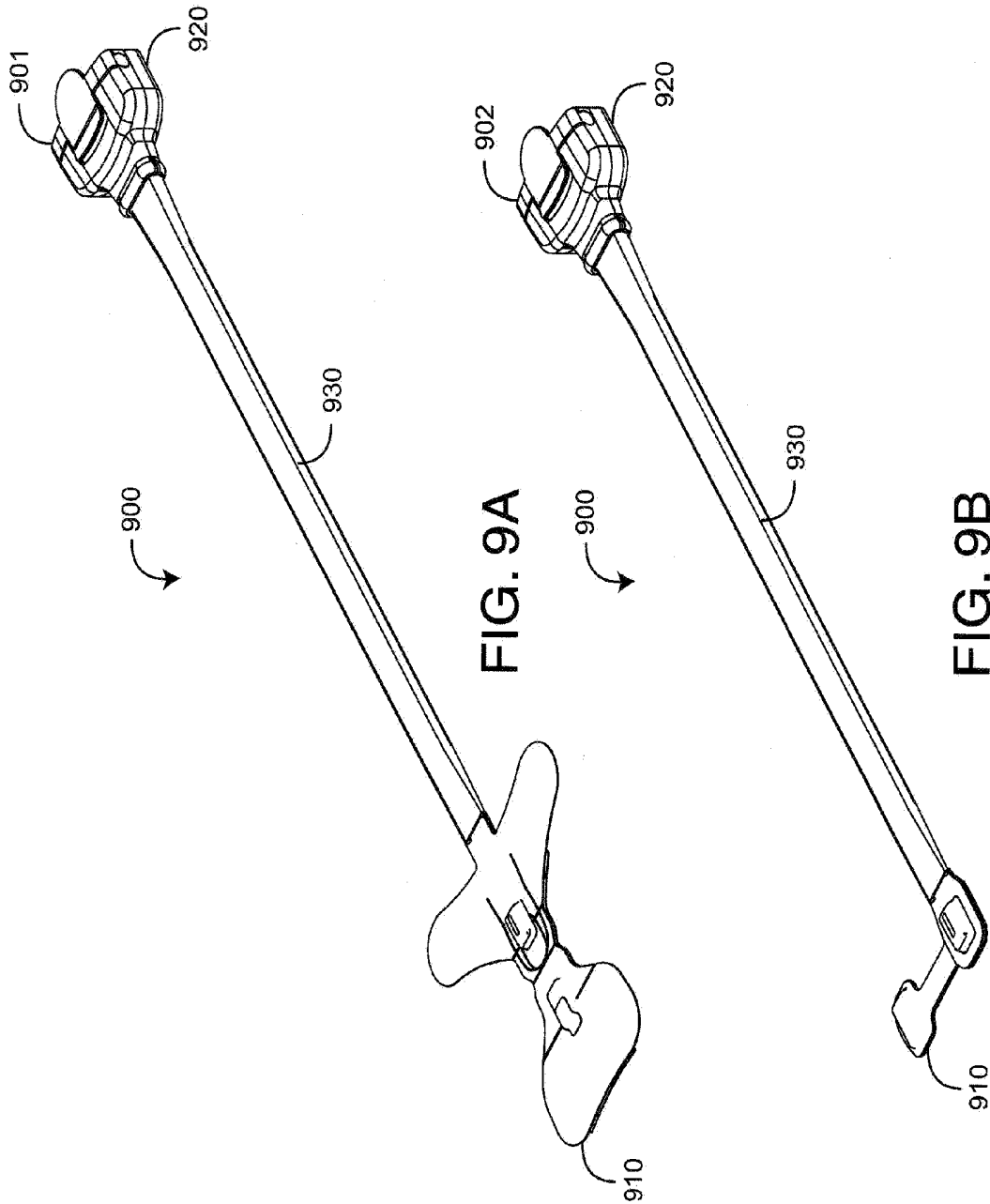


FIG. 8



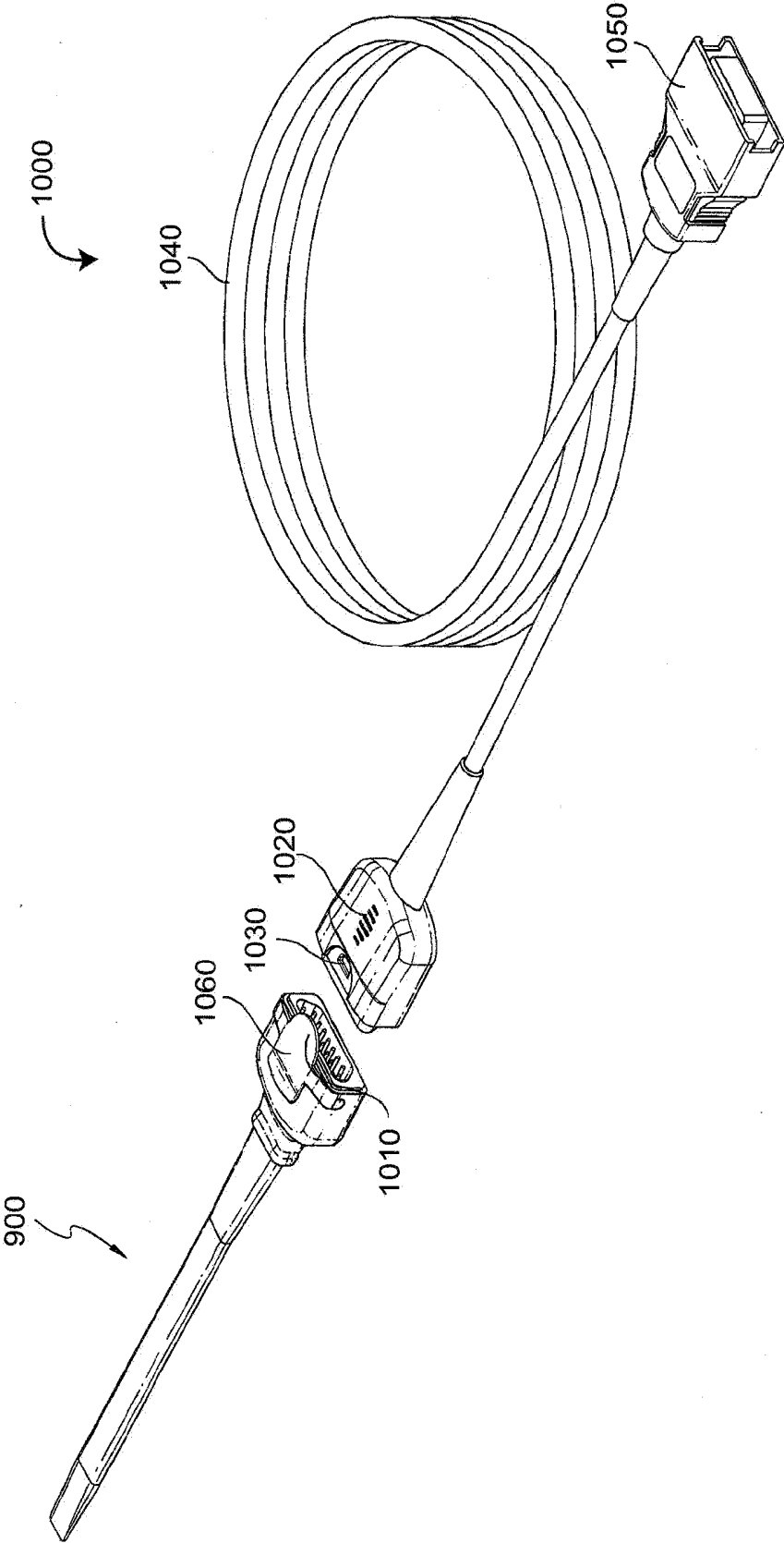


FIG. 10

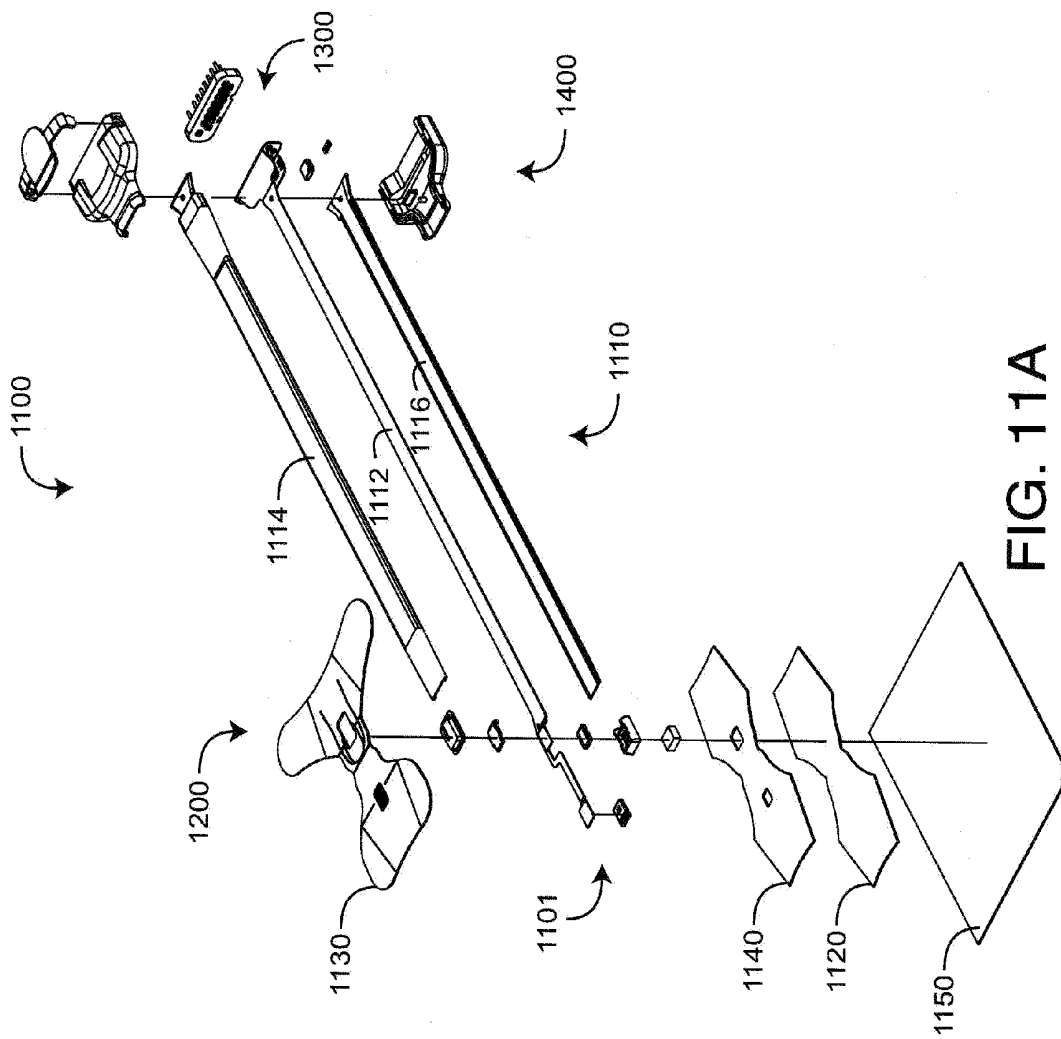


FIG. 11A

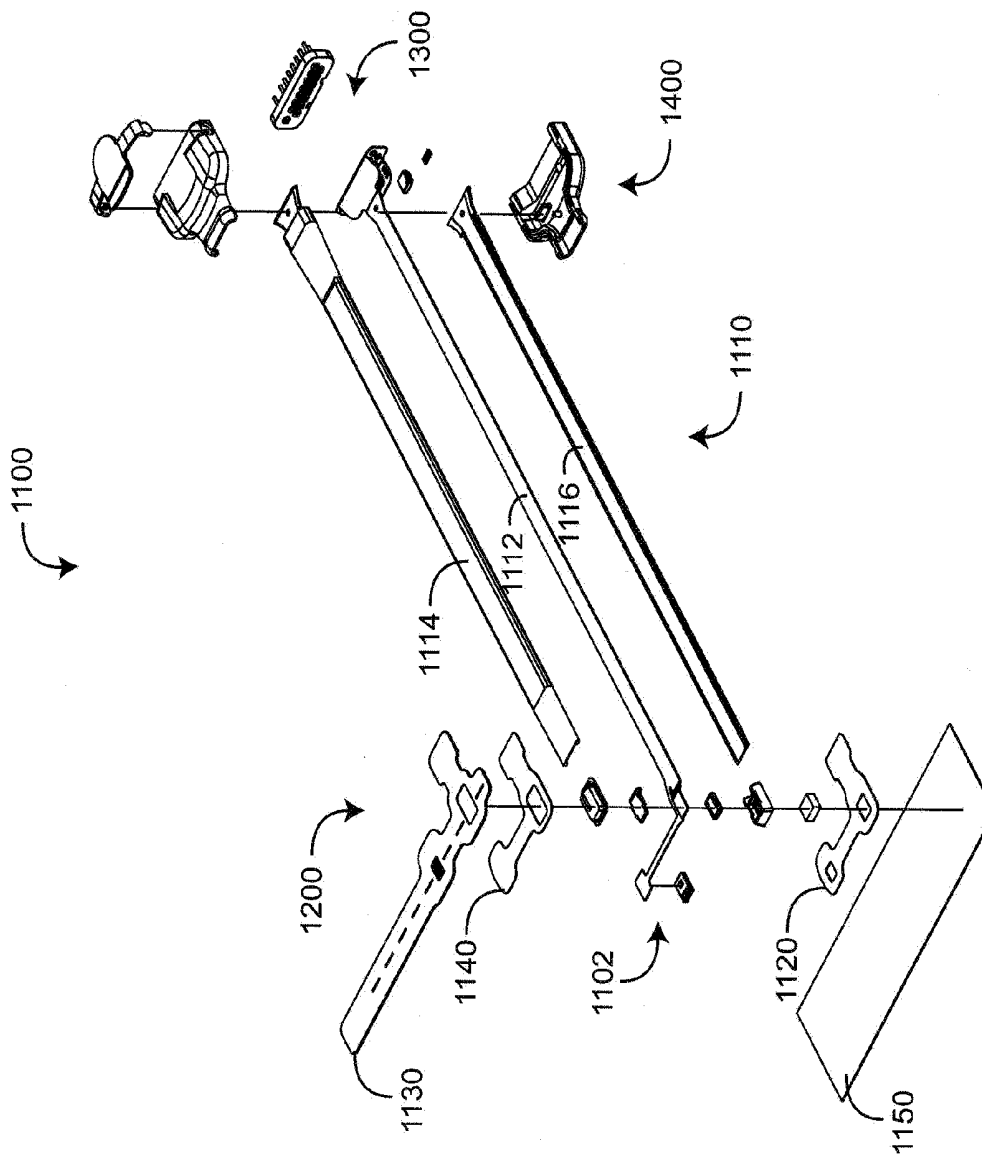


FIG. 11B

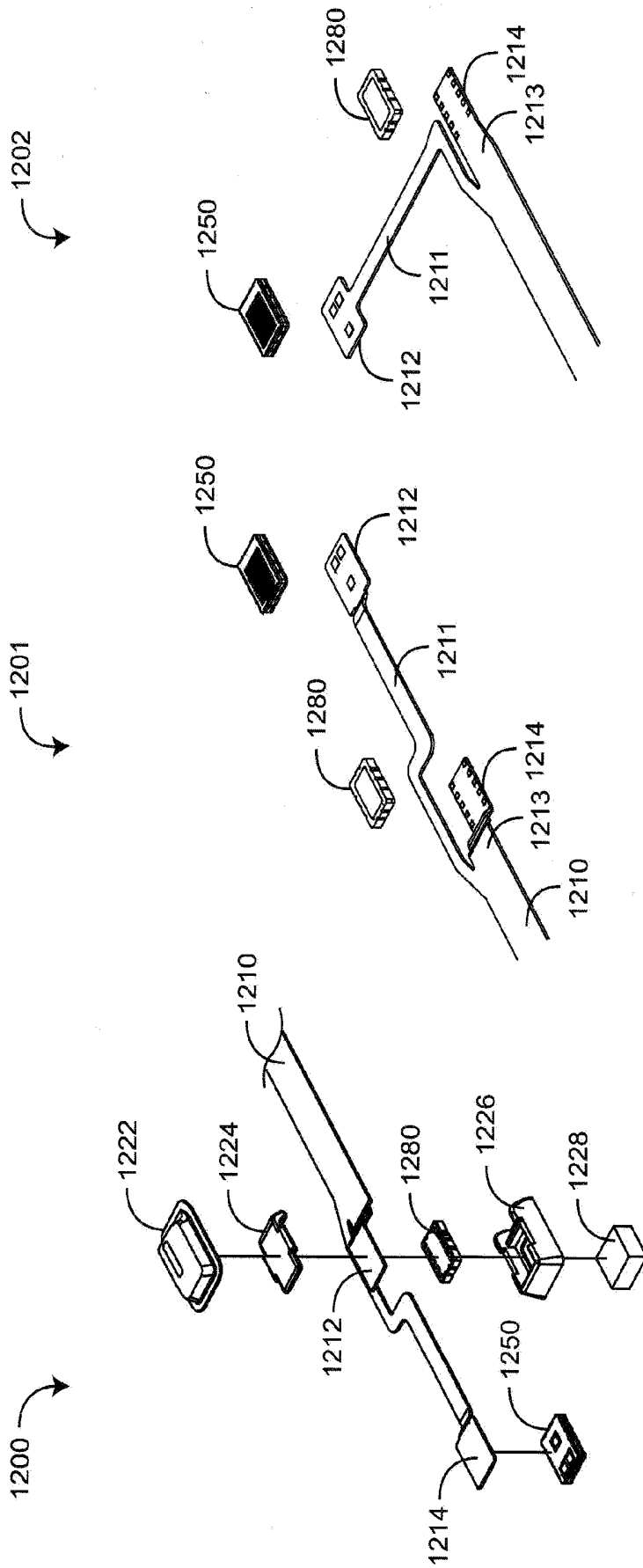


FIG. 12C

FIG. 12B

FIG. 12A

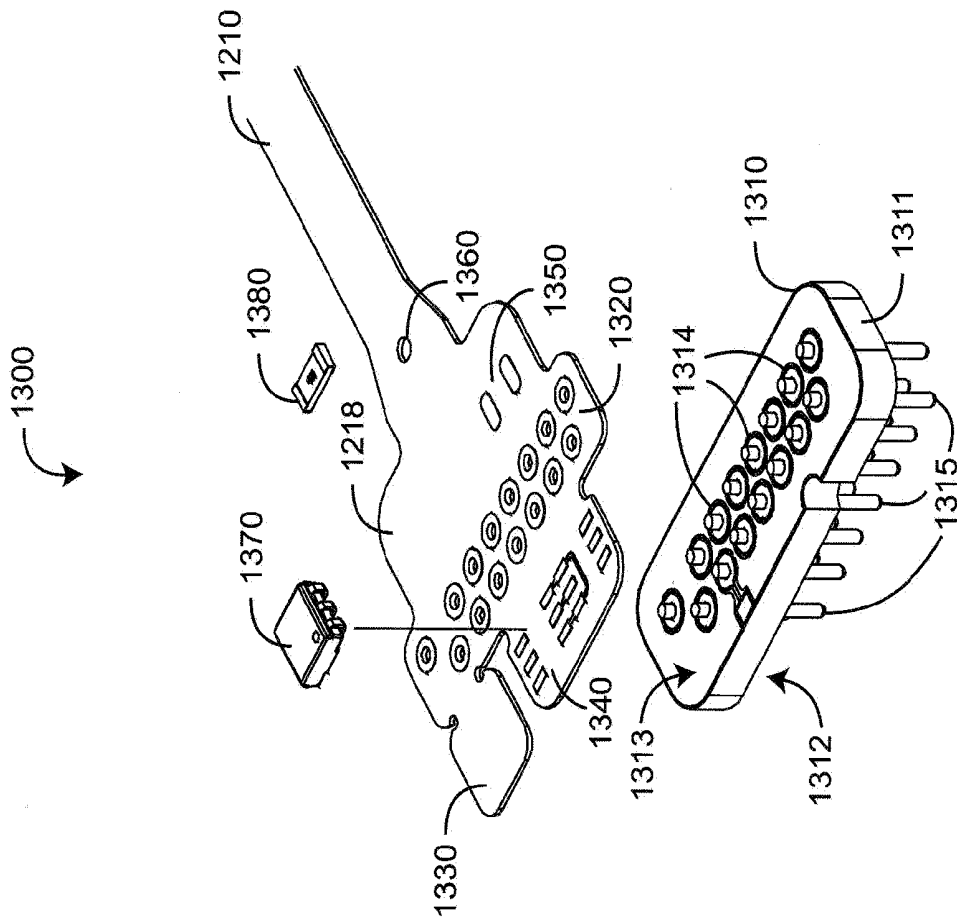


FIG. 13

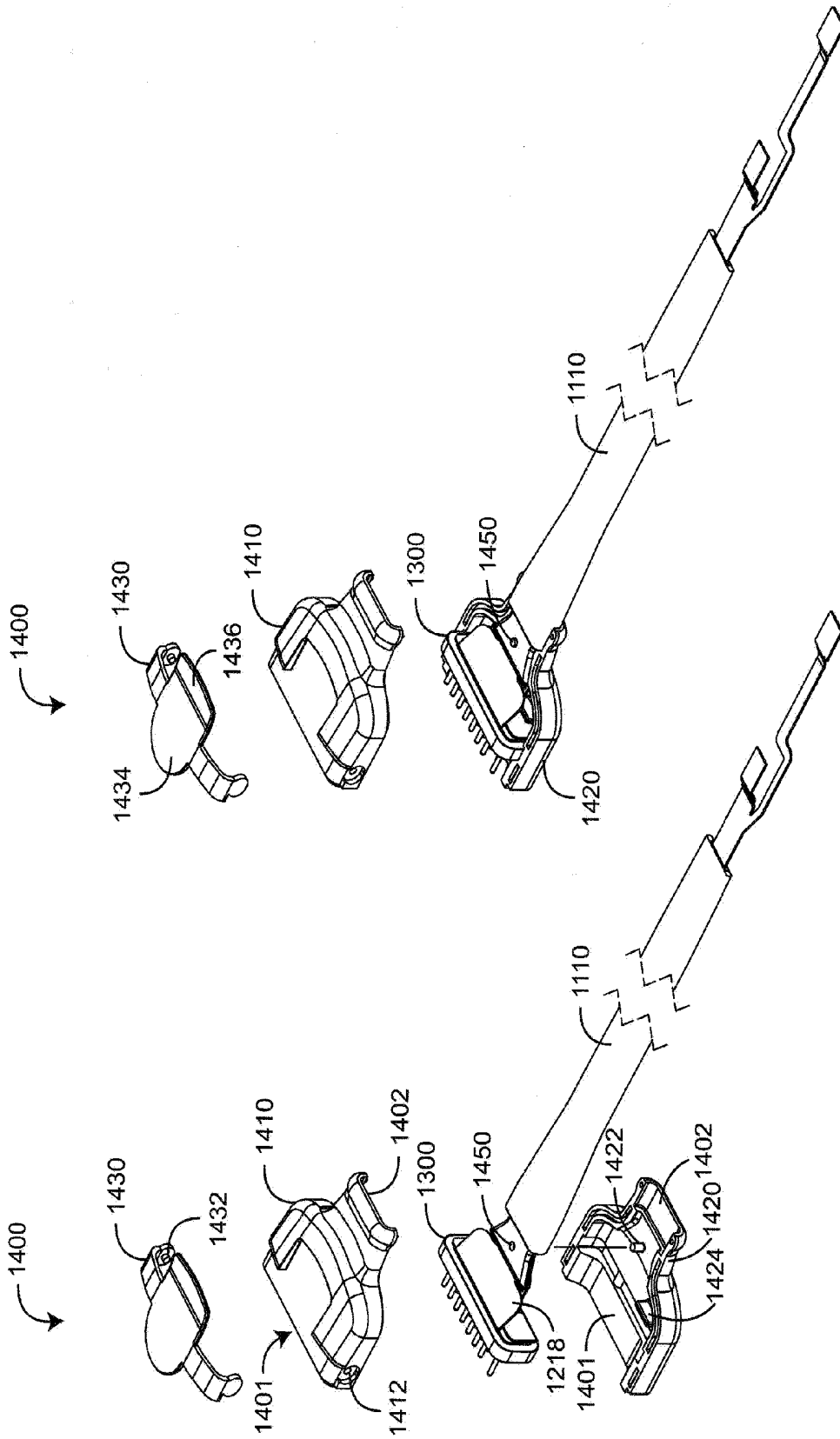


FIG. 14A

FIG. 14B

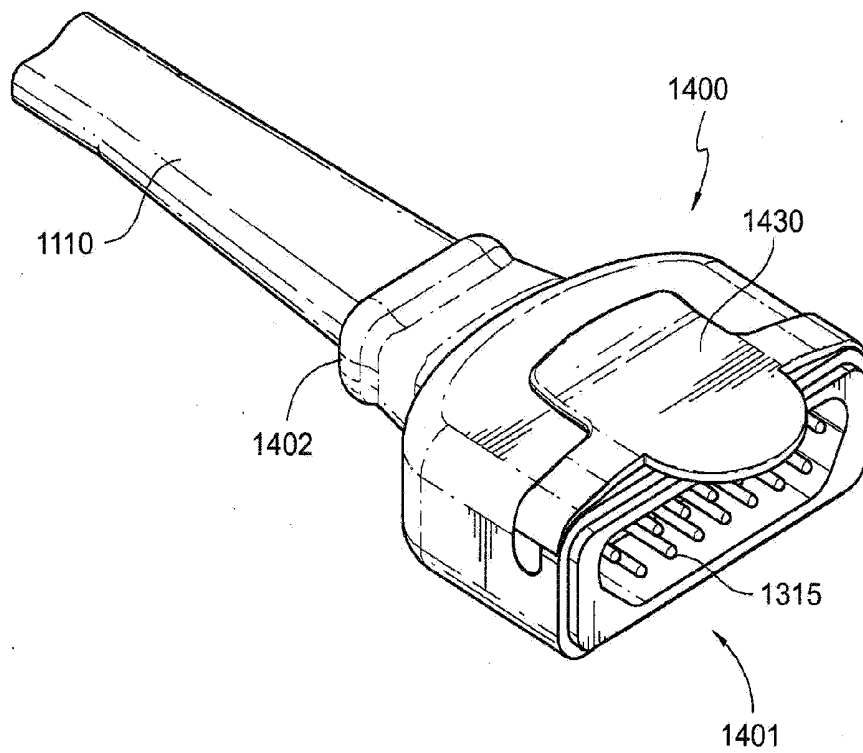


FIG. 14C

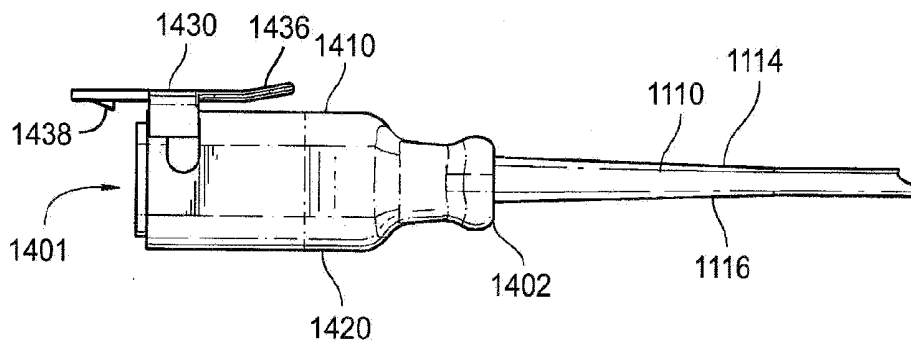


FIG. 14D

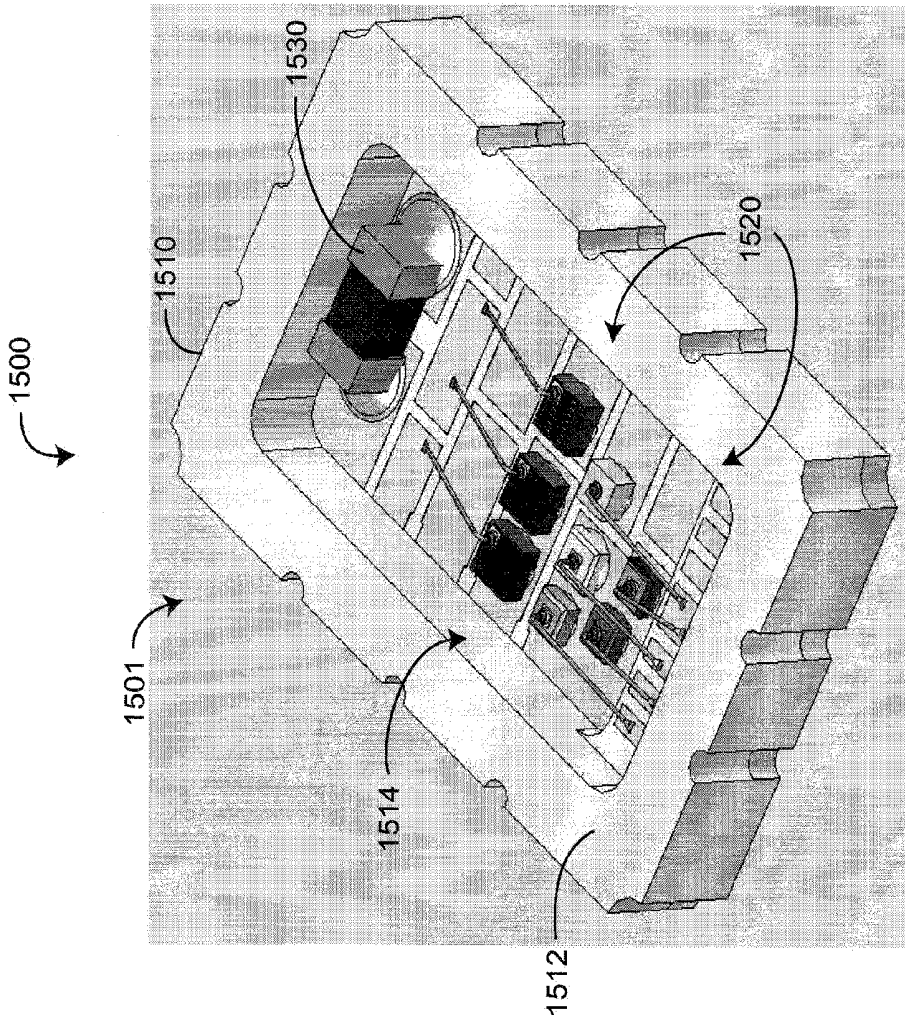


FIG. 15A

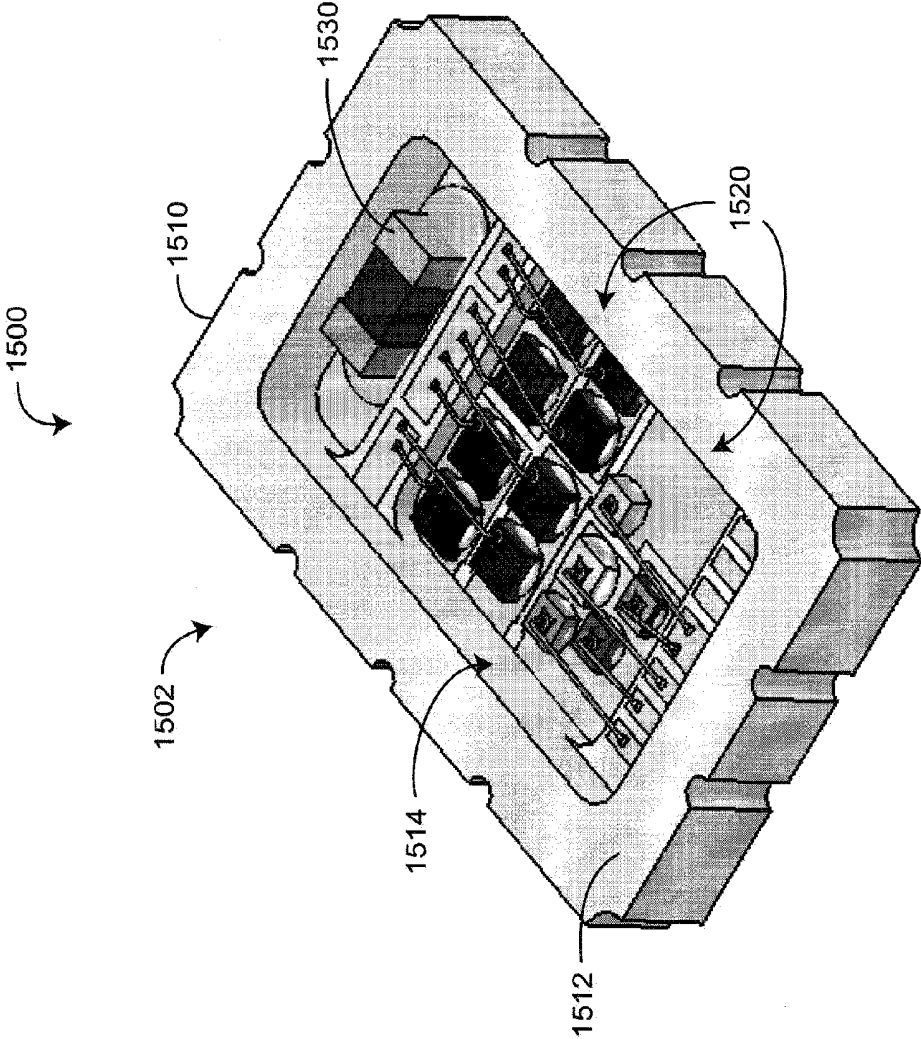


FIG. 15B

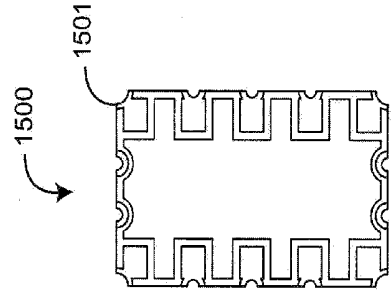


FIG. 16D

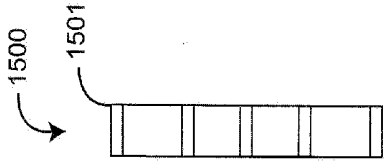
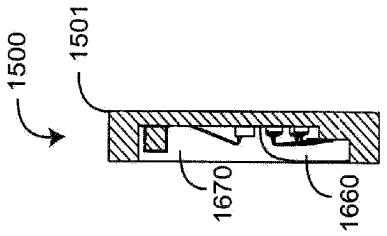


FIG. 16C



SECTION A-A

FIG. 16B

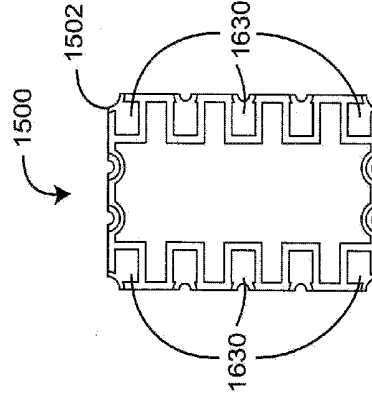


FIG. 16H

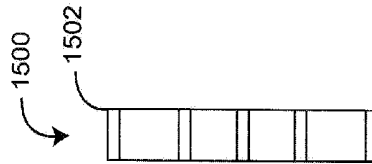
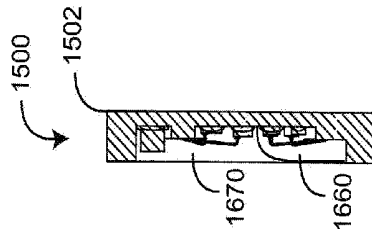


FIG. 16G



SECTION B-B

FIG. 16F

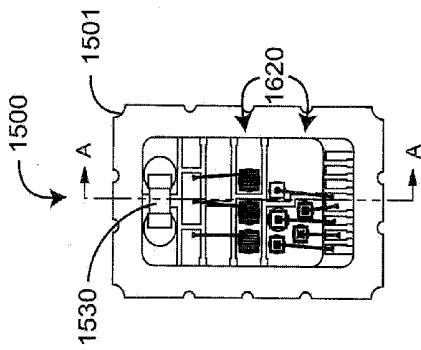


FIG. 16A

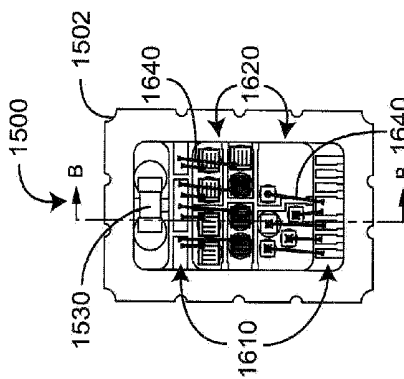


FIG. 16E

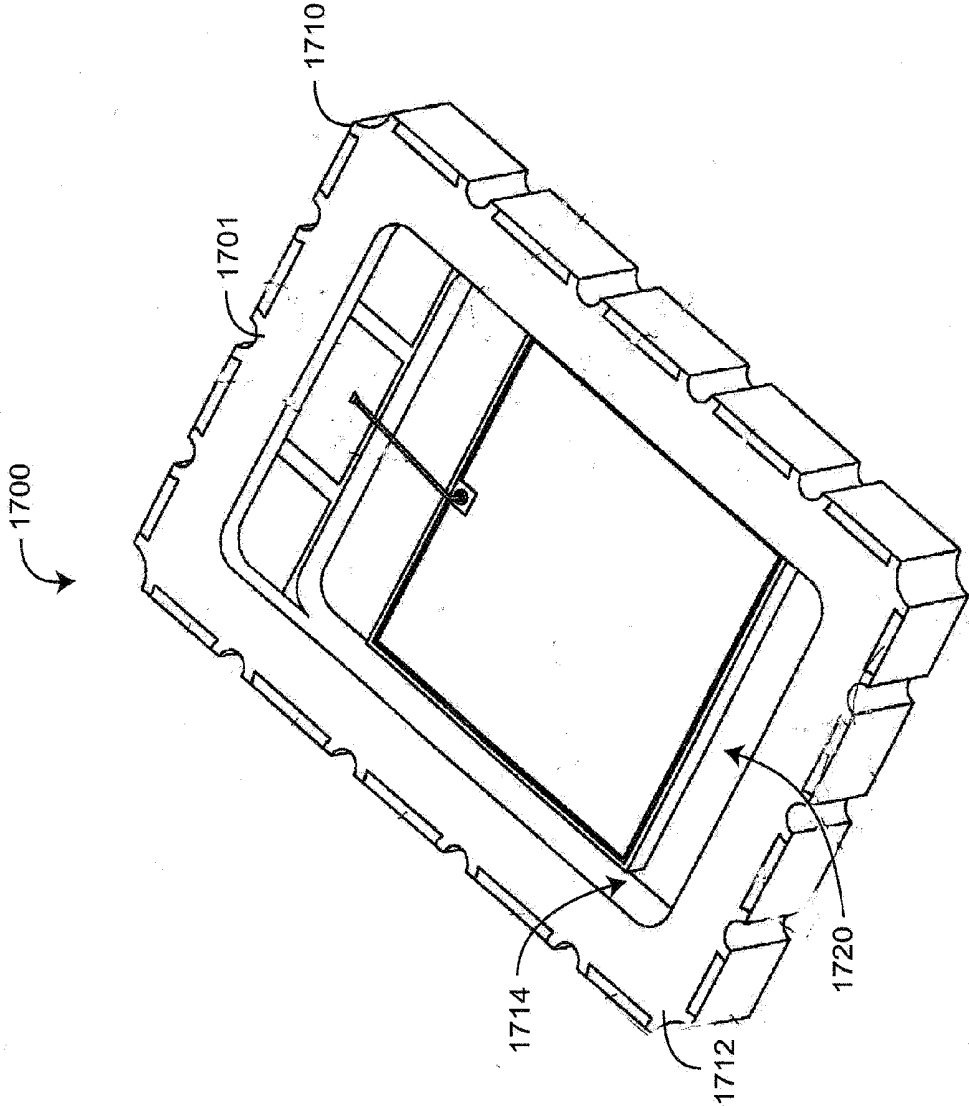


FIG. 17A

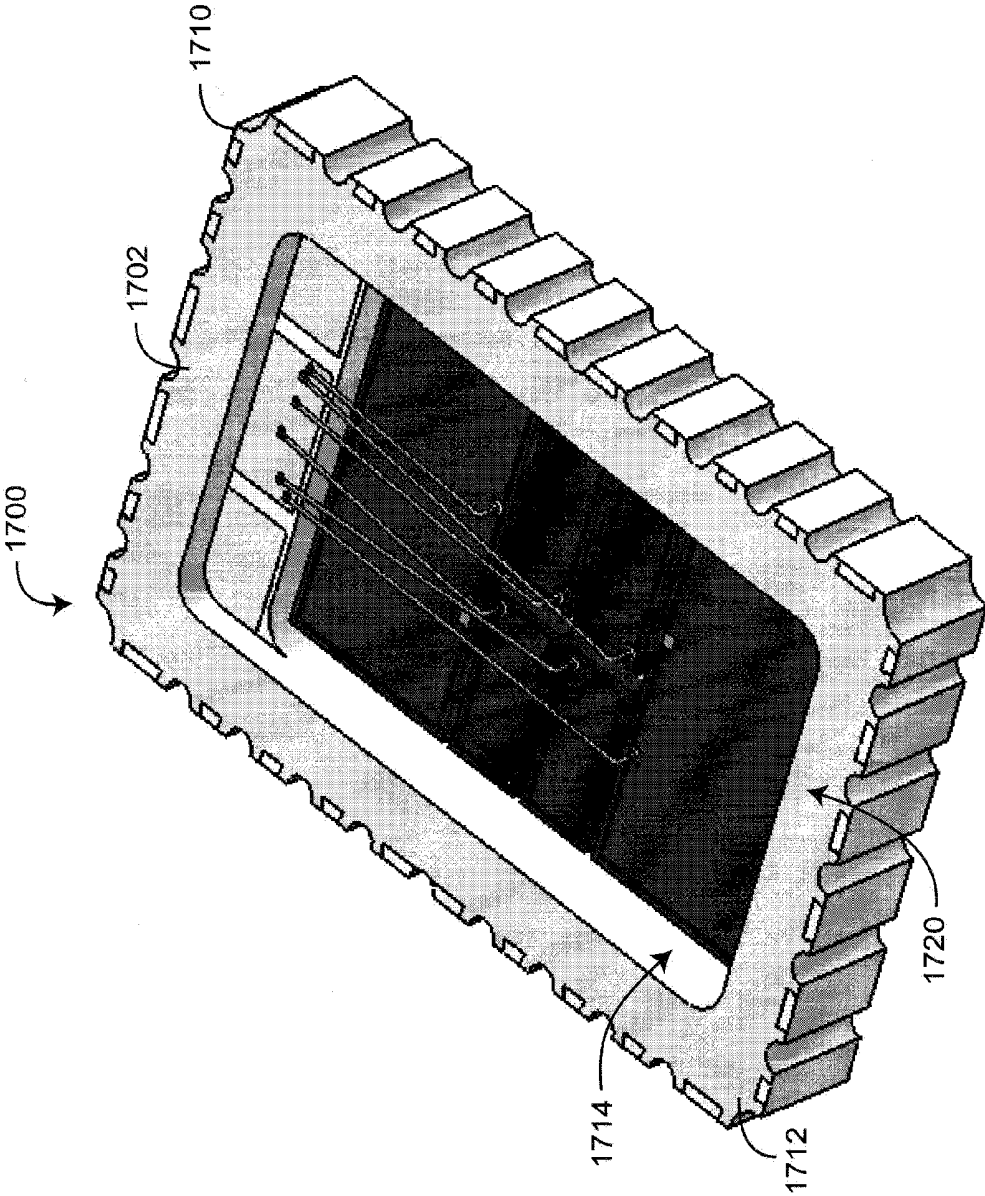


FIG. 17B

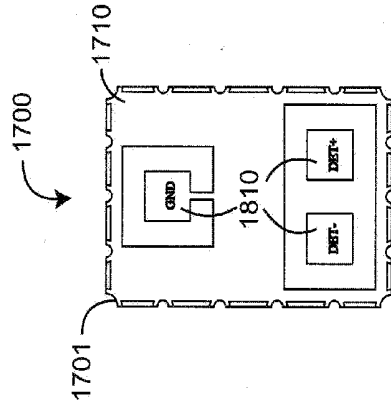


FIG. 18D

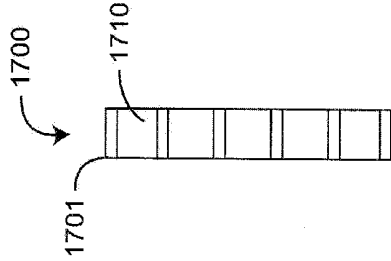


FIG. 18C

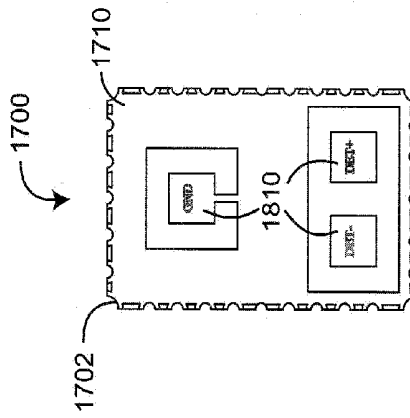


FIG. 18H

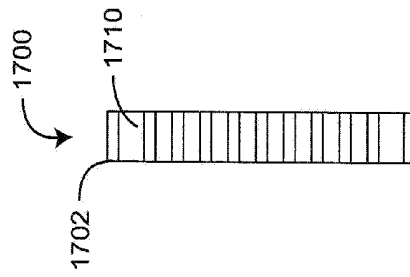


FIG. 18G

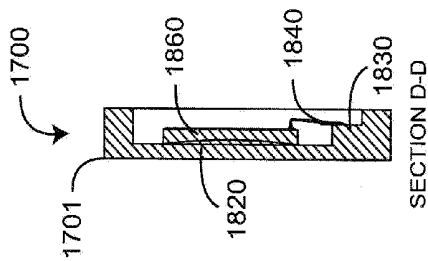


FIG. 18B

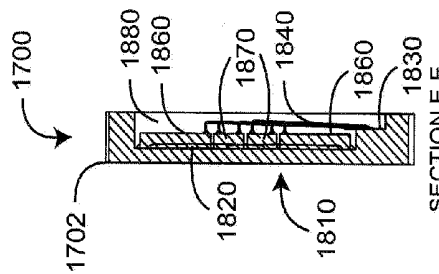


FIG. 18F

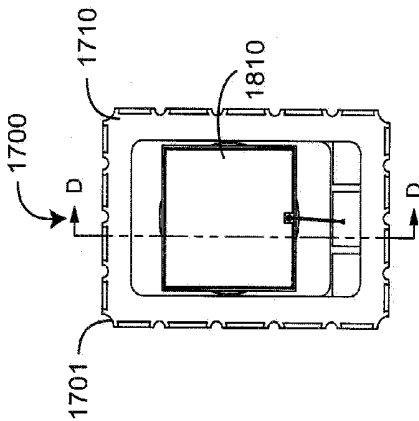


FIG. 18A

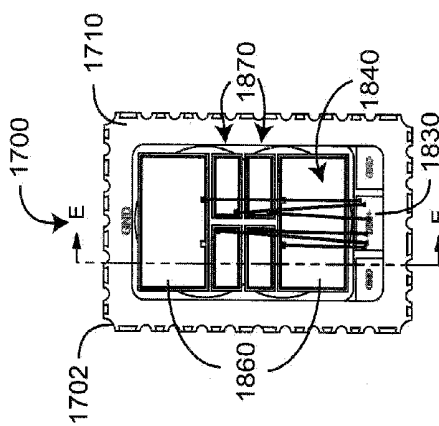


FIG. 18E

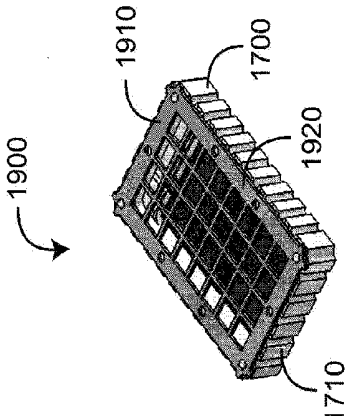


FIG. 19A

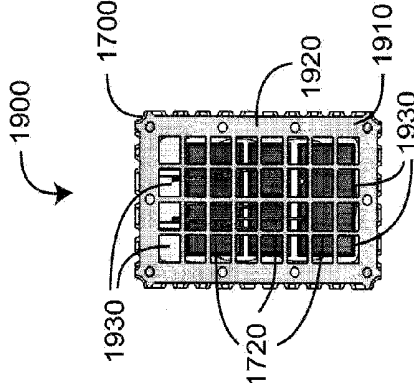


FIG. 19B

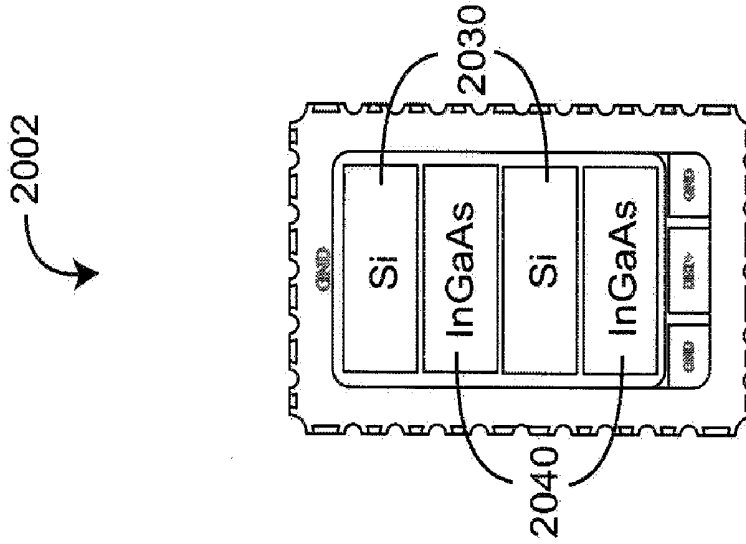


FIG. 20B

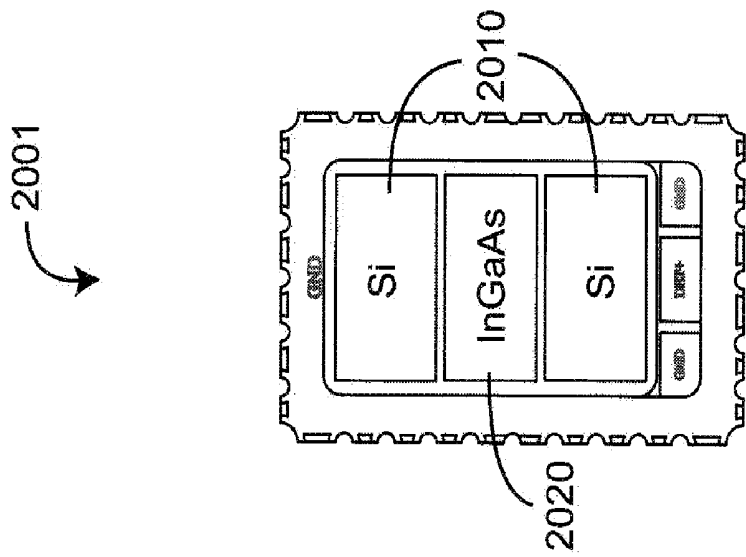


FIG. 20A

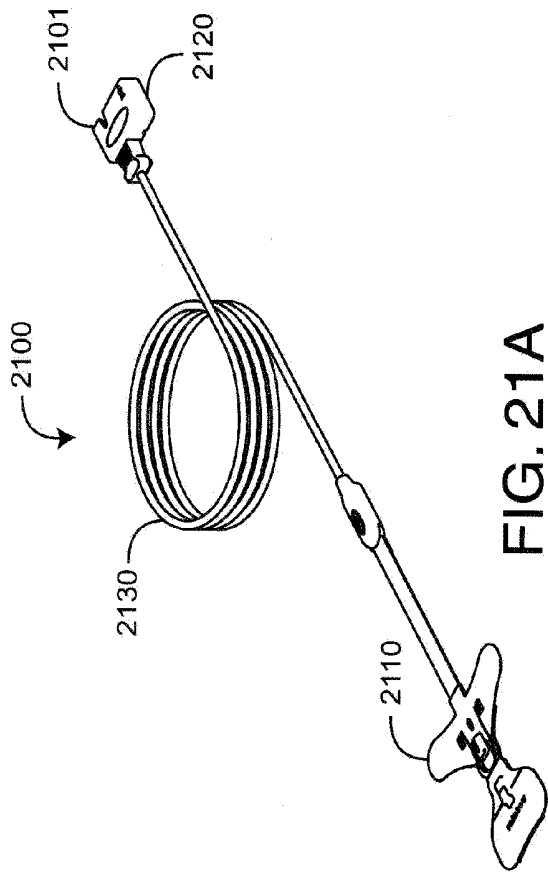


FIG. 21A

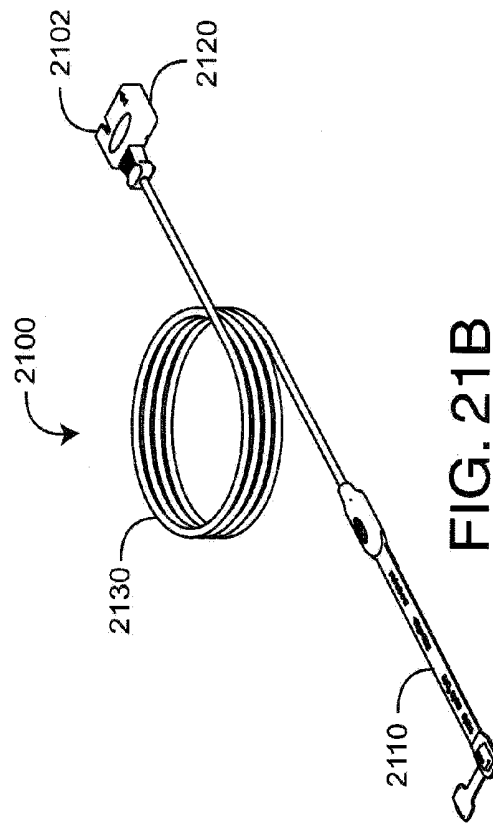


FIG. 21B

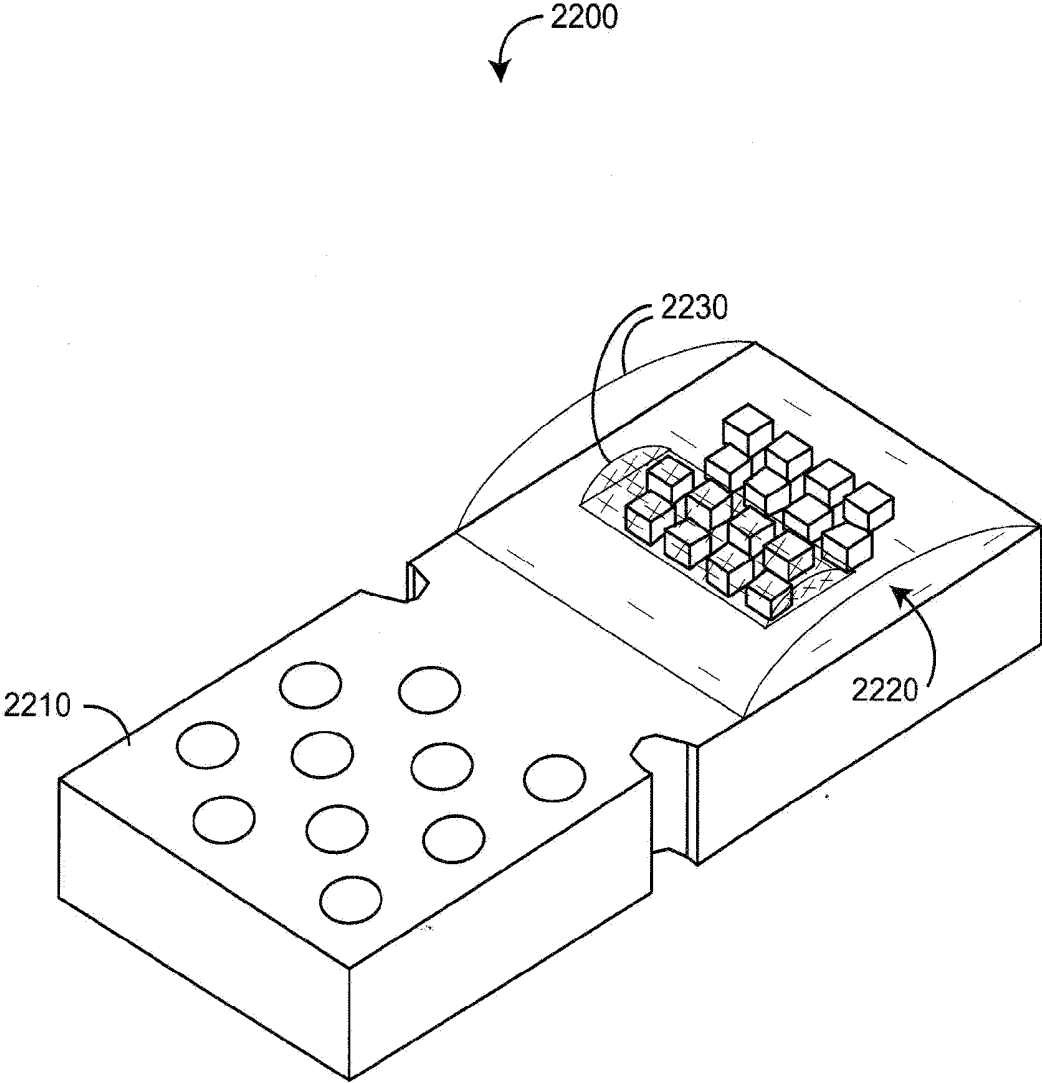


FIG. 22

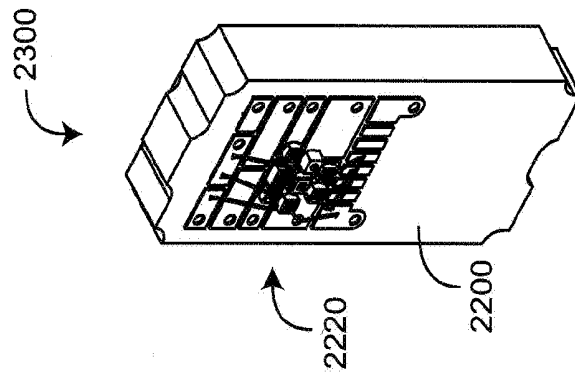


FIG. 23A

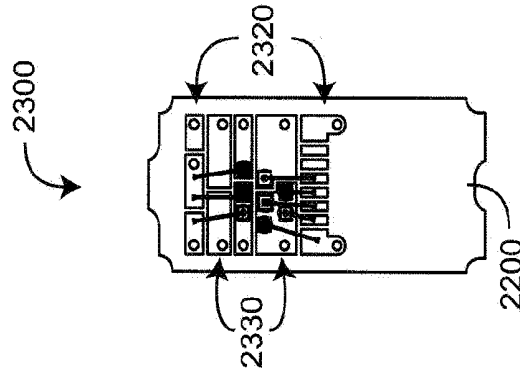


FIG. 23B

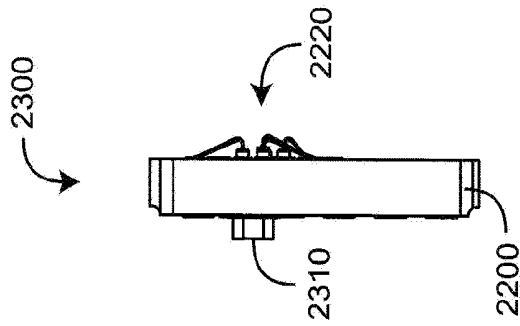


FIG. 23C

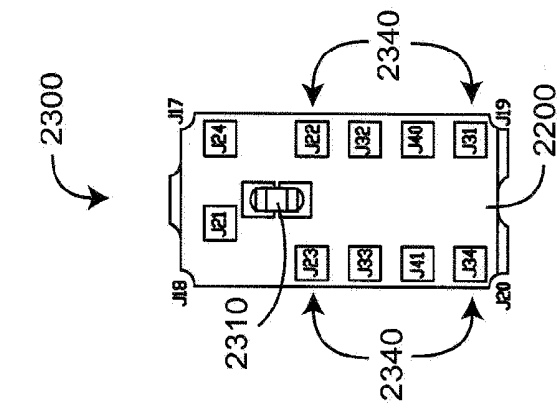


FIG. 23D

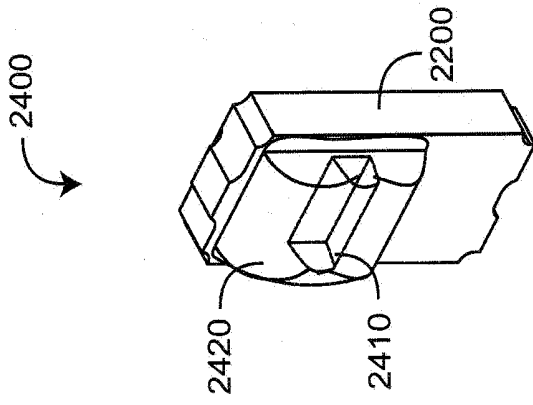


FIG. 24A

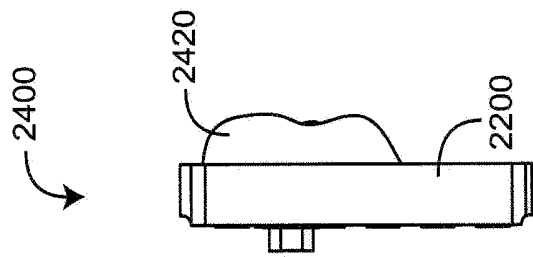


FIG. 24B

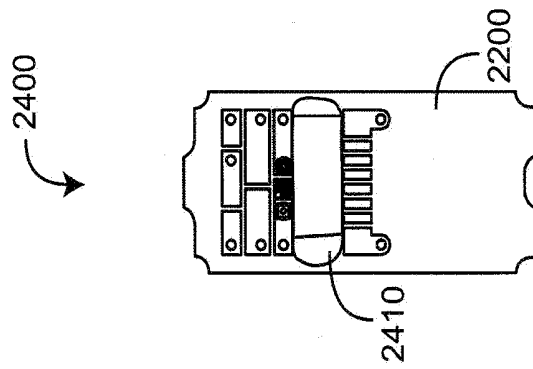


FIG. 24C

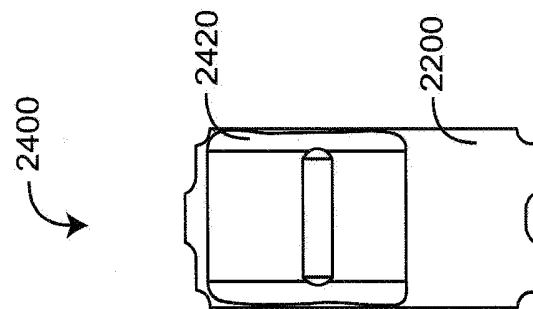


FIG. 24D

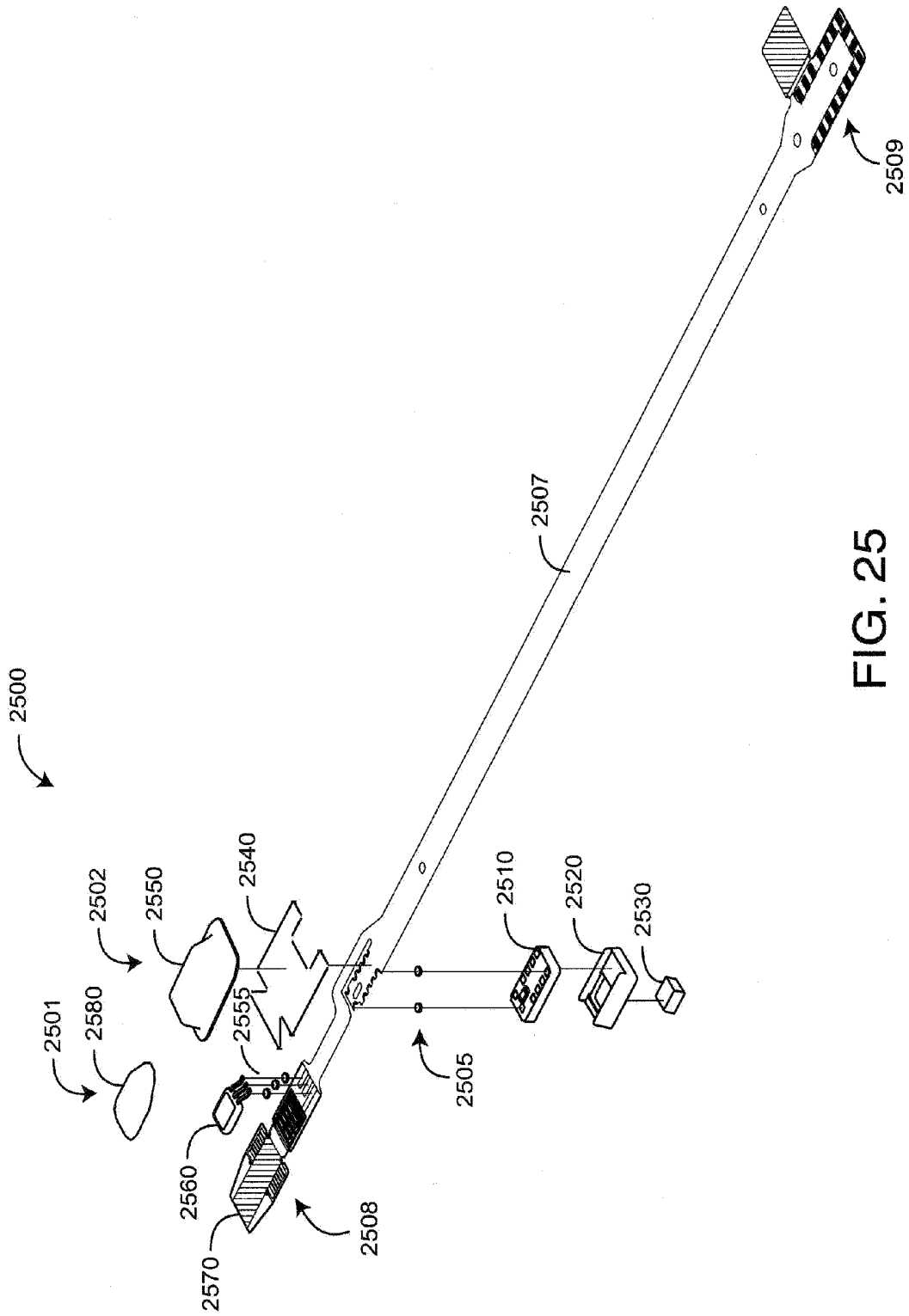


FIG. 25

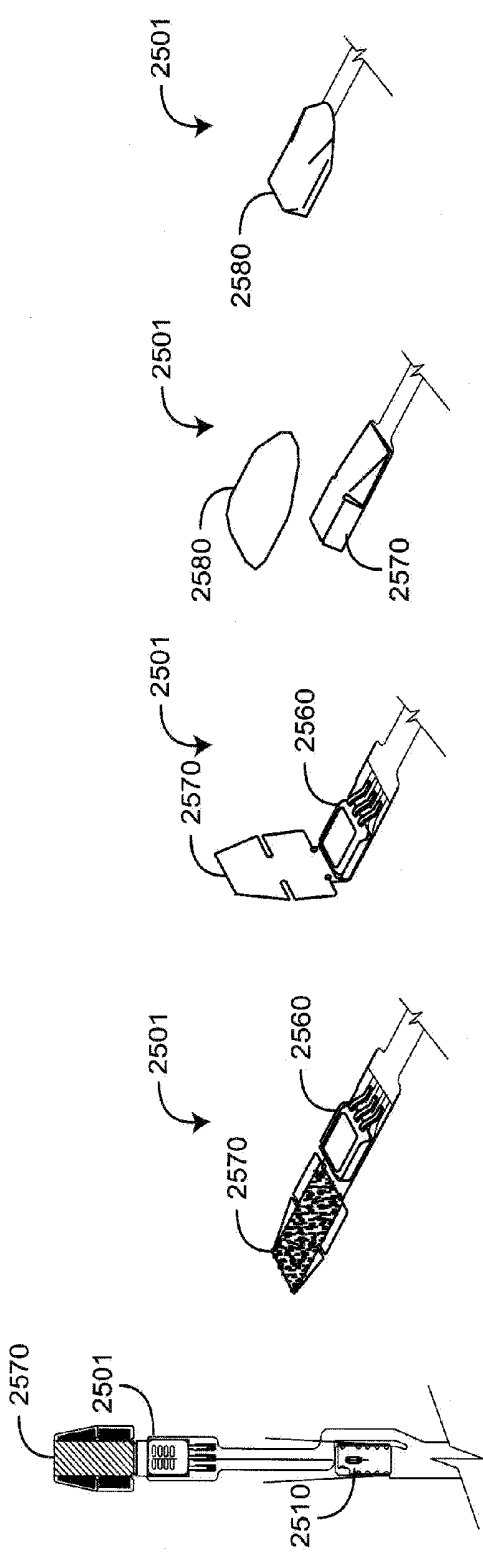


FIG. 26A FIG. 26B FIG. 26C FIG. 26D FIG. 26E

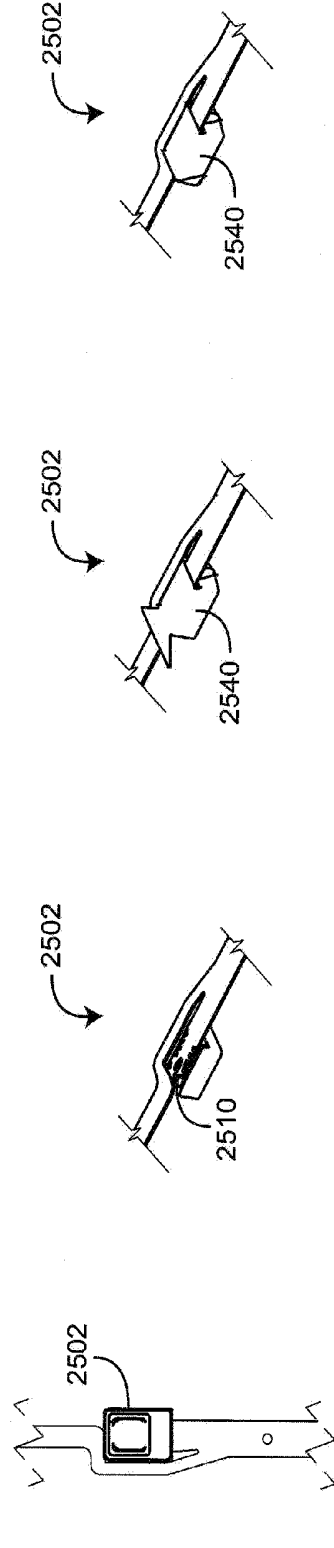


FIG. 26F FIG. 26G FIG. 26H FIG. 26I FIG. 26J

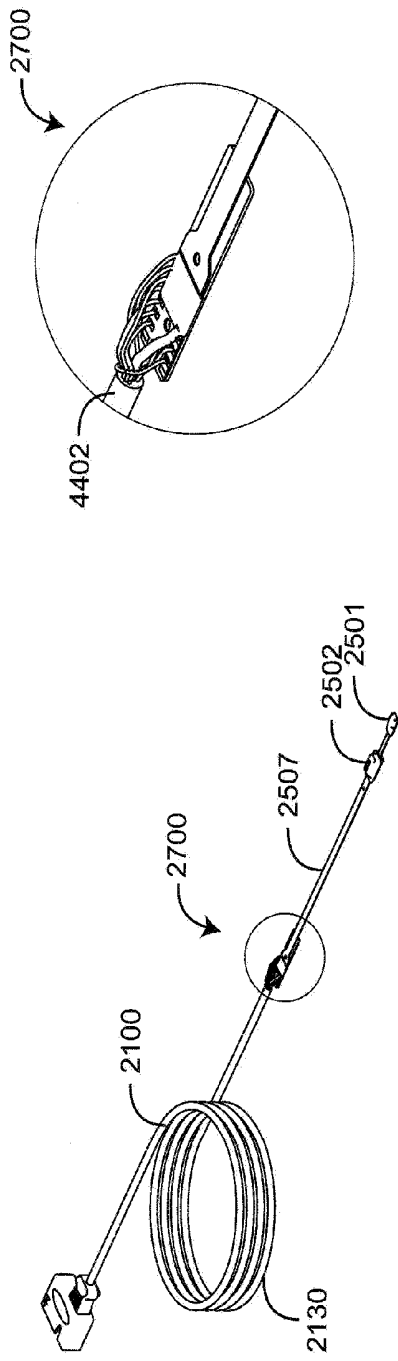


FIG. 27A

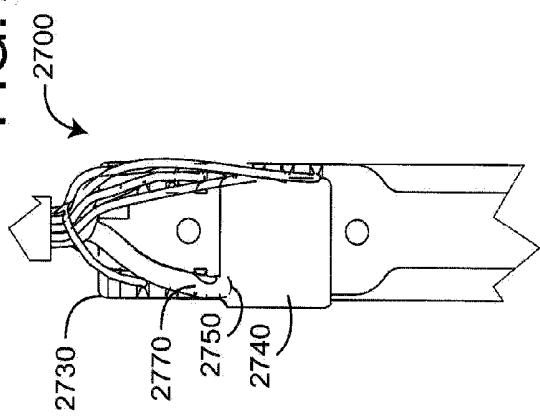


FIG. 27C

FIG. 27B

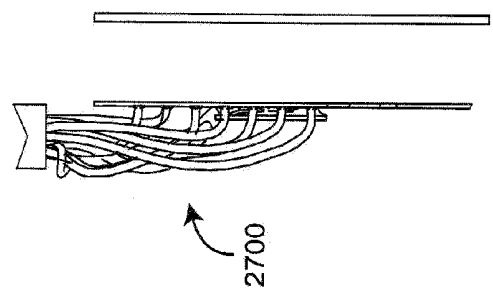
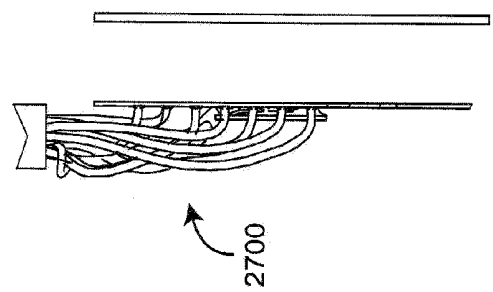


FIG. 27D

FIG. 27E



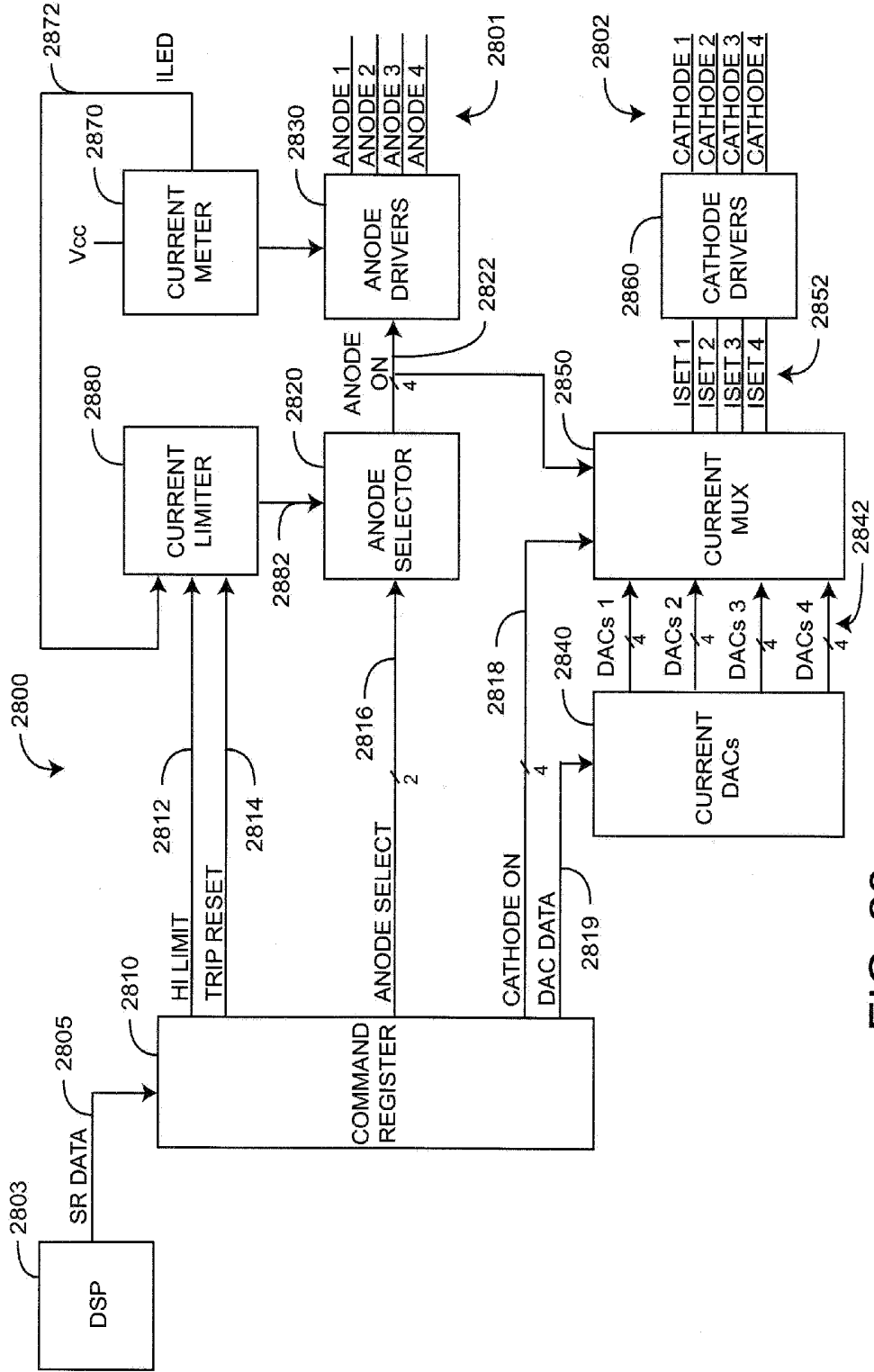


FIG. 28

MULTIPLE WAVELENGTH OPTICAL SENSOR

PRIORITY CLAIM TO RELATED PROVISIONAL APPLICATIONS

[0001] The present application claims priority benefit under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 60/920,474, filed Mar. 27, 2007, titled Disposable Multiple Wavelength Optical Sensor, No. 60/923,630, filed Apr. 14, 2007, titled Disposable Multiple Wavelength Optical Sensor, and No. 61/033,007, filed Mar. 2, 2008, titled Multiple Wavelength Optical Sensor. All of the above-referenced applications are hereby incorporated by reference herein.

INCORPORATION BY REFERENCE OF COPENDING RELATED CASES

[0002] The present disclosure is generally related to U.S. Provisional Application Ser. No. 60/998,659, filed Oct. 12, 2007, titled Ceramic Emitter Substrate; U.S. Provisional Application Ser. No. 60/979,658, filed Oct. 12, 2007, titled Ceramic Detectors; U.S. Provisional Application Ser. No. 60/979,674, filed Oct. 12, 2007, titled Connector Assembly; U.S. Design Patent Application Ser. No. 29/296,064, filed Oct. 12, 2007, titled Connector Assembly; U.S. Design Patent Application Ser. No. 29/296,067, filed Oct. 12, 2007, titled Connector Assembly; U.S. Provisional Application Ser. No. 61/_____, filed Feb. 29, 2008, titled Connector Assembly; and U.S. Design Patent Application Ser. No. 29/_____, filed Feb. 29, 2008, titled Connector. All of the above-referenced applications are hereby incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0003] Pulse oximetry systems for measuring constituents of circulating blood have gained rapid acceptance in a wide variety of medical applications including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios. A pulse oximetry system generally includes an optical sensor applied to a patient, a monitor for processing sensor signals and displaying results and a patient cable electrically interconnecting the sensor and the monitor. A pulse oximetry sensor has light emitting diodes (LEDs), typically one emitting a red wavelength and one emitting an infrared (IR) wavelength, and a photodiode detector. The emitters and detector are attached to a patient tissue site, such as a finger. The patient cable transmits drive signals to these emitters from the monitor, and the emitters respond to the drive signals to transmit light into the tissue site. The detector generates a signal responsive to the emitted light after attenuation by pulsatile blood flow within the tissue site. The patient cable transmits the detector signal to the monitor, which processes the signal to provide a numerical readout of physiological parameters such as oxygen saturation (SpO_2) and pulse rate. Advanced physiological monitoring systems utilize multiple wavelength sensors and multiple parameter monitors to provide enhanced measurement capabilities including, for example, the measurement of carboxyhemoglobin (HbCO), methemoglobin (HbMet) and total hemoglobin (Hbt).

[0004] Pulse oximeters capable of reading through motion induced noise are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,650,917, 6,157,850, 6,002,952, 5,769,785, and 5,758,644; low noise pulse oximetry sensors are dis-

closed in at least U.S. Pat. Nos. 6,088,607 and 5,782,757; all of which are assigned to Masimo Corporation, Irvine, Calif. ("Masimo") and are incorporated by reference herein.

[0005] Physiological monitors and corresponding multiple wavelength optical sensors are described in at least U.S. patent application Ser. No. 11/367,013, filed Mar. 1, 2006 and titled Multiple Wavelength Sensor Emitters and U.S. patent application Ser. No. 11/366,208, filed Mar. 1, 2006 and titled Noninvasive Multi-Parameter Patient Monitor, both assigned to Masimo Laboratories, Irvine, Calif. (Masimo Labs) and both incorporated by reference herein.

[0006] Further, physiological monitoring systems that include low noise optical sensors and pulse oximetry monitors, such as any of LNOP® adhesive or reusable sensors, SofTouch™ sensors, Hi-Fi Trauma™ or Blue™ sensors; and any of Radical®, SatShare™, Rad-9™, Rad-5™, Rad-5v™ or PPO+™ Masimo SET® pulse oximeters, are all available from Masimo. Physiological monitoring systems including multiple wavelength sensors and corresponding noninvasive blood parameter monitors, such as Rainbow™ adhesive and reusable sensors and RAD-57™ and Radical-7™ monitors for measuring SpO_2 , pulse rate, perfusion index, signal quality, HbCO and HbMet among other parameters are also available from Masimo.

SUMMARY OF THE INVENTION

[0007] There is a need to noninvasively measure multiple physiological parameters, other than, or in addition to, oxygen saturation and pulse rate. For example, hemoglobin parameters that are also significant are total hemoglobin (Hbt) and the percentage of carboxyhemoglobin and methemoglobin. Other blood parameters that may be amenable to noninvasive optical sensor measurement are fractional oxygen saturation, bilirubin and blood glucose, to name a few.

[0008] One aspect of a physiological sensor is an emitter that emits light having a plurality of wavelengths. A detector generates an output signal responsive to the emitted light after absorption by tissue. An attachment assembly removably attaches the emitter and the detector to tissue. A spacer provides a predetermined gap between the emitter and tissue when the emitter is attached to tissue. A light scattering medium is disposed in an optical path between the emitter and tissue. The spacer and the light scattering medium provide at least a substantially uniform illumination of tissue by the emitted light for each of the wavelengths. In various embodiments, the light scattering medium comprises glass beads mixed with an encapsulant disposed proximate the spacer. The light scattering medium comprises microspheres mixed with an epoxy disposed proximate the emitter. The emitter comprises an array of at least eight light emitting diodes emitting light generally centered around eight unique wavelengths. The emitter comprises an array of at least thirteen light emitting diodes emitting light generally centered around at least twelve unique wavelengths. The detector comprises at least one Si photodiode and at least one InGaAs photodiode connected in parallel. The detector comprises two Si photodiodes and four InGaAs photodiodes all connected in parallel. The light emitting diodes emit light within a first range of about 620-905 nm and within a second range of about 1040-1270 nm.

[0009] Another aspect of a physiological sensor comprising an emitter configured to radiate light having a plurality of wavelengths into a tissue site. The emitter comprises a plurality of LEDs disposed within an emitter ceramic substrate.

A detector is configured to receive the light after absorption by pulsatile blood flow within the tissue site. The detector generates a sensor signal capable of being processed by a patient monitor so as to derive total hemoglobin (Hbt). The detector comprises a plurality of photodiodes disposed within a detector ceramic substrate. A first set of the photodiodes is responsive to a first set of the wavelengths and a second set of the photodiodes is responsive to a second set of the wavelengths. In various embodiments a diffuser scatters the radiated light so that a tissue site is uniformly illuminated across all of the wavelengths. A first encapsulate containing glass beads is mounted in a spacer proximate the emitter ceramic substrate. A second encapsulate mixed with microspheres is disposed on the LEDs within the emitter ceramic substrate. The photodiodes comprise at least one Si photodiode and at least one InGaAs photodiode connected in parallel. The LEDs radiate light generally centered around at least twelve unique wavelengths. The LEDs are mounted in an array of at least thirteen LEDs connected within an electrical grid. The twelve unique wavelengths comprise eight wavelengths within a first range of about 620-905 nm. and four wavelengths within a second range of about 1040-1270 nm.

[0010] A further aspect of a physiological sensor comprises a light source that radiates light having a plurality of wavelengths, a diffuser that scatters the radiated light so that a tissue site is uniformly illuminated across all of the wavelengths, and at least one detector that generates a sensor signal responsive to the radiated light after tissue attenuation. In an embodiment, the light source comprises a ceramic substrate having conductors arranged as an electrical grid and a plurality of LEDs mounted within the ceramic substrate in an array. In other embodiments, the diffuser comprises a first encapsulant having microspheres disposed over the LEDs; and a second encapsulant having glass beads disposed proximate the ceramic substrate. A spacer is disposed proximate the ceramic substrate so as to form a gap between the LEDs and the tissue site. A connector connects to a patient cable so as to communicate the sensor signal to a monitor. A flexible coupling has an optical end proximate the light source and the detector and a connector end proximate the connector. The flexible coupling has conductors that communicate the sensor signal from the optical end to the connector end.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a perspective view of a physiological measurement system;

[0012] FIG. 2 is a general block diagram of a physiological measurement system;

[0013] FIG. 3 are block diagrams of a multiple wavelength optical sensor and a monitor;

[0014] FIG. 4 is a general block diagram of an emitter assembly;

[0015] FIG. 5 is a general block diagram of a detector assembly;

[0016] FIG. 6 is a general block diagram of an emitter array;

[0017] FIG. 7 is a block diagram of an emitter component;

[0018] FIG. 8 is a block diagram of a circuit substrate;

[0019] FIGS. 9A-B are perspective views of multiple wavelength optical sensor embodiments;

[0020] FIG. 10 is a perspective view of a patient cable and corresponding sensor connector;

[0021] FIGS. 11A-B are exploded perspective views of multiple wavelength optical sensor embodiments;

[0022] FIGS. 12A-C are exploded perspective views of an optical assembly;

[0023] FIG. 13 is an exploded perspective view of a contact assembly;

[0024] FIGS. 14A-D are exploded perspective views, and perspective and side views, respectively, of a connector assembly;

[0025] FIGS. 15A-B are perspective views of emitters;

[0026] FIGS. 16A-H are top, cross-sectional, side and bottom views, respectively, of emitter embodiments;

[0027] FIGS. 17A-B are perspective views of a detector components;

[0028] FIGS. 18A-H are top, cross-sectional, side and bottom views, respectively, of detector components;

[0029] FIGS. 19A-B are perspective and top views, respectively, of a detector;

[0030] FIGS. 20A-B are top views of detector component embodiments;

[0031] FIGS. 21A-B are perspective views of multiple wavelength optical sensor embodiments;

[0032] FIG. 22 is a perspective view of an emitter assembly;

[0033] FIGS. 23A-D are bottom, side, top and perspective views of an emitter assembly;

[0034] FIGS. 24A-D are views of an encapsulated emitter assembly;

[0035] FIG. 25 is an exploded, perspective view of an optical assembly;

[0036] FIGS. 26A-I are assembly views for an optical assembly;

[0037] FIGS. 27A-E are views of a cable connection assembly; and

[0038] FIG. 28 is a general block diagram of an emitter driver.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0039] FIG. 1 illustrates a physiological measurement system having a monitor 110 and a multiple wavelength optical sensor 120 with enhanced measurement capabilities as compared with conventional pulse oximetry. In particular, the multiple wavelength optical sensor 120 allows the measurement of various blood constituents and related parameters in addition to oxygen saturation and pulse rate. Alternatively, the multiple wavelength optical sensor 120 allows the measurement of oxygen saturation and pulse rate with increased accuracy or robustness as compared with conventional pulse oximetry.

[0040] In one embodiment, the optical sensor 120 is configured to plug into a monitor sensor port 112 via a patient cable 130. Monitor keys 114 provide control over operating modes and alarms, to name a few. A display 116 provides readouts of measured parameters, such as oxygen saturation, pulse rate, HbCO, HbMet and Hbt to name a few. Other blood parameters that may be measured to provide important clinical information are fractional oxygen saturation, bilirubin and blood glucose, to name a few.

[0041] In this application, reference is made to many blood parameters. Some references that have common shorthand designations are referenced through such shorthand designations. For example, as used herein, HbCO designates carboxyhemoglobin, HbMet designates methemoglobin, and Hbt designates total hemoglobin. Other shorthand designations such as COHb, MetHb, and tHb are also common in the

art for these same constituents. These constituents are generally reported in terms of a percentage, often referred to as saturation, relative concentration or fractional saturation. Total hemoglobin is generally reported as a concentration in g/dL. The use of the particular shorthand designators presented in this application does not restrict the term to any particular manner in which the designated constituent is reported.

[0042] FIG. 2 illustrates a block diagram a physiological measurement system 200. This measurement system includes a monitor 210 and an optical sensor 220 communicating via a patient cable 230. The monitor 210 has one or more processor boards 250 communicating with a host instrument 280. Generally, the processor board 250 communicates with the sensor 220 so as to control the emission of light into a tissue site 10. Also the processor board 250 receives and processes a corresponding sensor signal responsive to the emitted light after scattering and absorption by tissue site constituents. Accordingly, the processor board 250 derives physiological parameters relating to pulsatile blood flow within the tissue site and communicates values for those parameters to the host instrument 280. Generally, the host instrument 280 provides user I/O and communications with external devices so as to define operating conditions and communicate those conditions to the processor board 250. The host instrument 280 also transfers parameter values from the processor board for display and for triggering alarms.

[0043] In an embodiment, the optical sensor 220 includes an emitter array 222, at least one detector 224, a temperature sensor 226 and a memory 228. The emitter array 222 irradiates a tissue site 10 with multiple wavelength light. One or more detectors 224 detect the light after attenuation by the tissue site 10. The temperature sensor 226 is located so as to detect the bulk temperature of the emitters within the emitter array, so as to accurately determine emitter wavelengths, as described below. The memory 228 can include any of a wide variety of memory devices known to an artisan from the disclosure herein, including an EPROM, an EEPROM, a flash memory, a ROM, a non-volatile RAM and a two-terminal serial memory device, to name a few, and combinations of the same. The memory 228 can advantageously store a wide variety of sensor-related information, including sensor type, manufacturer information, sensor characteristics including wavelengths emitted, wavelength correction data, emitter drive requirements, demodulation data, calculation mode data, calibration data and sensor life data to name a few. The memory can also store software such as scripts and executable code, encryption information, monitor and algorithm upgrade instructions and enabled parameters.

[0044] Although described herein with respect to various disposable sensor embodiments, a sensor may be reusable, resposable (partially reusable/partially disposable), adhesive or non-adhesive, or a transmittance, reflectance or transreflectance sensor. Further, a sensor may be configured for a variety of tissue sites such as a finger, hand, foot, forehead or ear or for attachment to multiple tissue sites, including multiple-head sensors capable of simultaneous multi-site measurements.

[0045] As shown in FIG. 2, the processor board 250 includes a front end signal conditioner 252, an analog-to-digital (A/D) converter 253, a digital signal processor (DSP) 258, a memory reader 256, emitter drivers 254 and digital-to-analog (D/A) converters 255. In general, the drivers 254 convert digital control signals into analog drive signals capable of

activating the emitter array 222. The front-end 252 and A/D converter 253 transform composite analog intensity signal(s) from light sensitive detector(s) 224 into digital data input to the DSP 258. In an embodiment, the DSP 258 is adapted to communicate via a reader 256 with one or more information elements such as the memory 228.

[0046] According to an embodiment, the DSP 258 comprises a processing device based on the Super Harvard ARCHitecture ("SHARC"), such as those commercially available from Analog Devices. However, the DSP 258 can comprise a wide variety of data and/or signal processors capable of executing programs for determining physiological parameters from input data. According to an embodiment, the processor board 250 may comprise one or more microcontrollers (not shown) for board management, including, for example, communications of calculated parameter data and the like to the host instrument 280.

[0047] Also shown in FIG. 2, the host instrument 280 communicates with the processor board 250 to receive signals indicative of the physiological parameter information calculated by the DSP 258. The host instrument 280 preferably includes one or more display devices, alarms, user I/O and communication ports 284. The alarms may be audible or visual indicators or both. The user I/O may be, as examples, keypads, touch screens, pointing devices or voice recognition devices. The displays may be indicators, numerics or graphics for displaying one or more of a pulse rate, plethysmograph data, signal quality, perfusion index and blood constituents values, such as SpO₂, carboxyhemoglobin (HbCO), methemoglobin (HbMet) and total hemoglobin (Hbt), or the like. The host instrument 280 may also be capable of storing or displaying historical or trending data related to one or more of the measured values or combinations of the measured values. A patient monitor is disclosed in U.S. App. No. 11,367,033, filed on Mar. 1, 2006, titled Noninvasive Multi-Parameter Patient Monitor, which is assigned to Masimo and incorporated by reference herein.

[0048] FIG. 3 illustrates a physiological measurement system 300 having a monitor 310 and a multiple wavelength sensor 320. The sensor 320 has an emitter assembly 340, a detector assembly 350, an interconnect assembly 360, an attachment assembly 370 and a connector assembly 380. The monitor 310 has a sensor controller 312 that communicates with the sensor 320 via a cable 330. As but one example, the sensor controller 312 may include emitter drivers, detector signal conditioning circuitry, A/D and D/A connectors, and a DSP incorporated onto a processor board, such as described with respect to FIG. 2, above.

[0049] As shown in FIG. 3, the emitter assembly 340 responds to drive signals received from the sensor controller 312 so as to emit light having a plurality of wavelengths. The detector assembly 350 provides a sensor signal to the sensor controller 312 in response to the emitted light after absorption by a tissue site. The interconnect assembly 360 mechanically mounts the emitter assembly 340 and the detector assembly 350 and provides electrical communication between the cable 330 and these assemblies 340, 350. The attachment assembly 370 attaches the emitter assembly 340 and detector assembly 350 to a tissue site. The connector assembly 380 provides a mechanical and electrical interface to the connector at one end of the cable 330. A tape assembly example of an attachment assembly is described with respect to FIGS. 11A-B, below. A contact assembly example of a connector assembly is described with respect to FIGS. 13-14, below.

[0050] FIG. 4 illustrates an emitter assembly 400 having a substrate 410, an emitter array 420, an equalization 430 and a diffusion 440. The emitter array 420 has multiple light emitting sources, each activated by drive signals 422. The light emitting sources are capable of generating light 442 having multiple wavelengths. The equalization 430 accounts for differences in emitter intensity and tissue absorption of the light across the multiple wavelengths so as to at least partially equalize wavelength-dependent variations in intensity at the detector. The substrate 410 provides a physical mount for the emitter array and emitter-related equalization and an electrical connection between the emitter array and an interconnect assembly, such as described above. Advantageously, the substrate 410 also maintains a uniform bulk temperature measurement so as to calculate the operating wavelengths for the light emitting sources. One example of an emitter array embodiment 420 is described with respect to FIG. 6, below. One example of equalization 430 is described with respect to encapsulants, below. Examples of substrates 410 are described with respect to ceramic and board substrates, below.

[0051] FIG. 5 illustrates a detector assembly 500 including a substrate 510, detector(s) 520 and an EMI shield 530. The substrate 510 acts as a mechanical support for, and provides electrical contacts to, the detector(s) 520. In an embodiment, the substrate 510 acts as an electrical insulator allowing the detector(s) 520 to be electrically isolated from EMI shielding 530 applied to a detector component. In an embodiment, the substrate 510 is a ceramic material.

[0052] FIG. 6 illustrates an emitter array 600 having multiple light emitters (LE) 610 capable of emitting light having multiple wavelengths. Row drivers 670 and column drivers 690 are electrically connected to the light emitters 610 and activate one or more light emitters 610 by addressing at least one row 620 and at least one column 640 of an electrical grid. In one embodiment, the light emitters 610 each include a first contact 612 and a second contact 614. The first contact 612 of a first subset 630 of light emitters is in communication with a first conductor 620 of the electrical grid. The second contact 614 of a second subset 650 of light emitters is in communication with a second conductor 640.

[0053] FIG. 7 illustrates an example of an emitter assembly 700 having light emitting diodes 710, a temperature sensor 720 and a substrate 730. The substrate 730 provides a thermal mass so as to stabilize a bulk temperature for the LEDs 710. A temperature sensor 720 is thermally coupled to the substrate 730 so as to output, say, a current responsive to the bulk temperature T_b . The LED wavelengths 712 are determinable as a function of the drive currents 740 and the temperature sensor output 722. In an embodiment, the substrate 730 is a ceramic material or, alternatively, a circuit board material having multiple materialization layers for thermal mass.

[0054] In one embodiment, an operating wavelength λ_a of each LED 710 is determined according to EQ. 1:

$$\lambda_a = f(T_b, I_{drive}, \Sigma I_{drive}) \quad (1)$$

where T_b is the bulk temperature, I_{drive} is the drive current for a particular LED, as determined by a sensor controller, and ΣI_{drive} is the total drive current for all LEDs. In another embodiment, temperature sensors are configured to measure the temperature of each LED 710 and an operating wavelength λ_a of each light emitter is determined according to EQ. 2:

$$\lambda_a = f(T_a, I_{drive}, \Sigma I_{drive}) \quad (2)$$

where T_a is the temperature of a particular light emitter, I_{drive} is the drive current for that light emitter and ΣI_{drive} is the total drive current for all light emitters.

[0055] In yet another embodiment, an operating wavelength for each LED is determined by measuring the junction voltage for each LED 710. In a further embodiment, the temperature of each LED 710 is controlled, such as by one or more Peltier cells coupled to each LED 710, and an operating wavelength for each LED 710 is determined as a function of the resulting controlled temperature or temperatures. In other embodiments, the operating wavelength for each LED 710 is determined directly, for example by attaching a charge coupled device (CCD) to each light emitter or by attaching a fiberoptic to each light emitter and coupling the fiberoptics to a wavelength measuring device, to name a few.

[0056] FIG. 8 illustrates an interconnect assembly 800 having a circuit substrate 810, an emitter mount 830, a detector mount 820 and a connector mount 840. The emitter mount 830 mounts and electrically connects to an emitter assembly 860 having multiple light emitters. The detector mount 820 mounts and electrically connects to a detector assembly 850 having a detector. The connector mount 840 attaches a connector 870 having conductors that mate with a patient cable connector 890. A first plurality of conductors disposed on the circuit substrate 810 electrically interconnect the emitter mount 830 and the connector 870. A second plurality of conductors disposed on the circuit substrate 810 electrically interconnect the detector mount 820 and the connector 870.

[0057] FIGS. 9A-B illustrate embodiments of a multiple wavelength optical sensor. In particular, illustrated are a disposable sensor 900 including an adult/pediatric sensor 901 configured for finger placement and an infant/neonate sensor 902 configured for toe, foot or hand placement. Each sensor 900 has a tape end 910 and an opposite connector end 920 electrically and mechanically interconnected via a flexible coupling 930. The tape end 910 attaches an emitter and detector to a tissue site, as described below. The emitter illuminates the tissue site and the detector generates a sensor signal responsive to the light after tissue absorption, such as absorption by pulsatile arterial blood flow within the tissue site. The sensor signal is communicated via the flexible coupling 930 to the connector end 920. The connector mates with a cable (not shown) that communicates the sensor signal to a monitor (not shown). The monitor calculates a variety of physiological parameters from the detector signal, such as pulse rate (PR), oxygen saturation (SpO_2), carboxyhemoglobin (HbCO), methemoglobin (HbMet) and total hemoglobin (Hbt), to name a few. A sensor configured for measurement of at least some of the above-mentioned physiological parameters is described in U.S. Provisional Application Ser. No. 60/920,474, filed Mar. 27, 2007, titled Disposable Multiple Wavelength Optical Sensor; and U.S. Provisional Application Ser. No. 60/923,630, filed Apr. 14, 2007, titled Disposable Multiple Wavelength Optical Sensor, both applications incorporated by reference herein.

[0058] FIG. 10 illustrates an optical sensor 900 connecting with a patient cable 1000. In the illustrated embodiment, the sensor 900 connects to the patient cable 1000 via a 15-pin sensor connector 1010 that mates with a 15-socket patient cable connector 1020. In various embodiments, the sensor connector 1010 may have all of the pins electrically active, and, in other embodiments, only a subset of the pins may be active and used to communicate sensor signals. For example, in one embodiment only 9 pins are active. In other embodi-

ments, the sensor connector may be a standard SpO₂ sensor, having, for example, a 9-pin mini-D connector, which is well known in the art. A latch 1060 disposed on the sensor connector 1010 is configured to engage a catch 1030 disposed on the patient cable connector 1020 so as to releasably hold the sensor connector 1010 and patient cable connector 1020 together. The sensor connector 1010 and patient cable connector 1020 are connected by pressing them together until the latch 1060 clicks into the catch 1030 and separated by pulling them apart while pressing downward on the latch 1060, thereby disengaging the latch 1060 from the catch 1030. In one embodiment, the monitor connector 1050 is a 20-pin DB connector. An example of a sensor connector is described with respect to FIGS. 13-14.

[0059] FIGS. 11A-B illustrate sensor assemblies 1100, including an “I” configuration 1101 for adult/pediatric sensors and an “L” configuration 1102 for infant/neonate sensors. A sensor assembly 1100 has a flexible coupling 1110 interconnecting optical components 1200 at an optical end and connector components 1300 at a connector end. The coupling 1110 includes a flex circuit 1112, a top sleeve 1114 and a bottom sleeve 1116. The top sleeve 1114 and bottom sleeve 1116 interlock to create a channel which encloses a flex circuit 1112. In one embodiment, the sleeve 1114, 1116 is comprised of silicone rubber. The flex circuit 1112 mounts the optical components 1200 and a contact assembly 1300 and provides electrical communications between the optical components 1200 and the connector components 1400, including the contact assembly 1300. In an embodiment, base-tape, center-tape, face-tape and release liner layers 1150 are attached to “two-up” untaped assemblies and then cut to shape so as to provide an attachment assembly at tape end 910 (FIGS. 9A-B) for tissue attachment, described above.

[0060] FIGS. 12A-C further illustrate optical components 1200 having emitter components 1220 and a detector 1250 mounted to a flex circuit 1210. The emitter components 1220 include a cover 1222, a light block 1224, an emitter 1280, a spacer 1226 and an encapsulant 1228. Advantageously, the spacer 1226 and encapsulant 1228 provide a relatively uniform illumination of a tissue site across all emitted wavelengths. In particular, the spacer 1226 provides a gap between the emitter 1280 and a tissue site, allowing emitted light from, say, individual LEDs of the emitter 1280 to spread as the multiple wavelength light propagates to a tissue site. Further, the encapsulant 1228 can be configured to diffuse or scatter emitted light as the light propagates to a tissue site. In an embodiment, the spacer 1226 gap is 70 mm. In an embodiment, the encapsulant 1228 contains 0.1 mm glass beads, 25% by weight, in a clear silicon RTV. In an embodiment, the emitter has an epoxy fill over LEDs incorporated within the emitter that contain microspheres so as to diffuse or scatter LED transmitted light, as described below. In an embodiment, an attenuation epoxy is dispersed over selected emitter LEDs so as to equalize intensities of the various LEDs, also as described, below. LED intensity equalization is disclosed in U.S. patent application Ser. No. 11/366,995, filed Mar. 1, 2006, titled Multiple Wavelength Sensor Equalization, incorporated by reference herein. In an embodiment, the encapsulant or LED fill or both provide notch filter characteristics according to emitted wavelengths so as to substantially attenuate secondary emissions from one or more LEDs.

[0061] As shown in FIGS. 12B-C, the flex circuit 1210 terminates a first solder plate 1212 which is generally rectangular and connected to and is slightly wider than a first con-

nection arm 1211. In an “I” configuration 1201, the first connection arm 1211 bends along its length in order to accommodate a second solder plate 1214. In an “L” configuration 1202, the first connection arm 1211 has a generally right-angle bend away from the second solder plate 1214. The second solder plate 1214 terminates a second connection arm 1213. In an embodiment, the first solder plate 1212 has three solder pads arranged in a triangular fashion for connecting to corresponding detector solder pads. The second solder plate 1214 has ten smaller solder pads arranged in rows for connecting to corresponding emitter solder pads. It is well known in the art to include conductors and conductor paths on one or more sides of the flex circuit 1210. In various embodiments, the shape of the flex circuit 1210 may vary. For instance, in some embodiments, the flex circuit 1210 may vary in length and the bends, if any, may vary in characteristics.

[0062] FIG. 13 illustrates a contact assembly 1300 having a connector plug 1310 that mates with a flex circuit connector plate 1218. The connector plate 1218 forms one end of the flex circuit 1210 in communication with solder plates 1212, 1214 (FIGS. 12B-C) at an opposite end of the flex circuit 1210. The connector plug 1310 has a generally rectangular base 1311 and pins 1315. The base 1311 has a front 1312, a back 1313 and pin apertures 1314 extending through the base 1311. The pin apertures 1314 are arranged in two rows, and the pins 1315 extend through the apertures 1314 so that a relatively long plug portion of the pins 1315 extends from base front 1312 and a relatively short solder portion of the pins 1315 extends from the base back 1313. The solder portion of the pins 1315 extend through and are fixedly soldered within corresponding connector plate apertures 1320. In one embodiment, the base 1311 is comprised of a PC-ABS blend and the pins 1315 are comprised of a brass, bronze or copper base with gold plating.

[0063] As shown in FIG. 13, the connector plate 1218 has plug apertures 1320, a flap 1330, memory pads 1340, resistor pads 1350 and a peg aperture 1360. The flap 430 folds over a detector pin portion of the plug apertures 1320 so as to provide shielding for detector pins, which communicate a sensor signal from the detector 1250 (FIGS. 12A-C) to a patient monitor. The peg aperture 1360 is configured to accommodate a shell peg 1422 (FIG. 14A), securing the flex circuit 1210 to the sleeve 1114, 1116 (FIGS. 11A-B) and connector shell 1410, 1420 (FIGS. 14A-B). At least one memory 1370 is soldered to the memory pads 1340. In one embodiment, the memory 1370 is a 20K EEPROM advantageously providing various sensor identification, diagnostic and control functions. In an embodiment, two 20K EEPROMs are utilized.

[0064] FIGS. 14A-D illustrate a connector 1400 having a top shell 1410, a bottom shell 1420, a clip 1430 and a contact assembly 1300. The connector front has a passageway 1401 that accommodates a mating patient cable connector. A positioning tab 1424 abuts the flex circuit connector plate 1218 (FIG. 13). Apertures 1412 secure the clip 1430 by accommodating clip pegs 1432. The connector back has a passageway 1402 that accommodates the flexible coupling 1110. A shell peg 1422 engages a sleeve aperture 1450, which secures the flex circuit 1112 and sleeve 1110 to the connector shell 1410, 1420. In one embodiment, the connector shell 1410, 1420 is a PC-ABS blend.

[0065] The clip 1430 has a sloping latch 1438 located underneath the clip front 1434 and a lever 1030 (FIG. 10) extending from the clip back. The latch 1438 snaps into a corresponding catch of a mating patient cable connector.

Advantageously, the lever **1436** is rigidly connected to the clip front **1434** and corresponding latch **1438** so that pressing downward with a finger or thumb on the lever **1436** raises the latch so as to disengage it from the corresponding catch **1030** (FIG. **10**). As such, the clip **1430** advantageously releasably holds the connector **1400** to a mating patient cable connector **1020** (FIG. **10**) so as to reduce accidental disconnects and provide for relatively straightforward and efficient connection and release. In certain embodiments, the clip **1430** releases without depressing the lever **1436** when a threshold of tension is placed on the connection. This avoids equipment damage and injuries if a sensor is accidentally jerked by a patient. In one embodiment, the clip **1430** is comprised of a PC-ABS blend.

[**0066**] FIGS. **15A-B** illustrate emitters **1500**, including an eight-LED emitter **1501** particularly advantageously for SpO₂, HbCO and HbMet measurements and a thirteen-LED emitter **1502** particularly advantageously for total hemoglobin (Hbt) measurements in addition to SpO₂, HbCO and HbMet. Each emitter **1500** has a ceramic substrate **1510**, light-emitting diodes (LEDs) **1520** and a thermistor **1530**. The ceramic substrate **1510** has a body **1512** defining a cavity **1514**. The cavity **1514** contains bonding pads that mount an array of LEDs **1520**. The ceramic substrate **1510** also has multiple layers of traces, feed-thrus and solder pads so as to interconnect the LEDs **1520** in an electrical grid. The solder pads allow a monitor to electrically activate the LEDs **1520** via the flex circuit **1112** (FIGS. **11A-B**), the connector **1010** (FIG. **10**) and an attached patient cable **1000** (FIG. **10**). The cavity **1514** also contains a thermistor **1530**, the resistance of which can be measured in order to determine the bulk temperature of the LEDs **1520**. The thermal characteristics of ceramic stabilize and normalize the bulk temperature of the substrate **1510** so that the thermistor measurement of bulk temperature allows an accurate determination of LED temperature and, hence, LED wavelengths.

[**0067**] As shown in FIGS. **15A-B**, an LED array **1520** is connected within an electrical grid of n rows and m columns totaling n+m LED drive lines where n and m are integers greater than one. The electrical grid advantageously minimizes the number of drive lines required to activate the LEDs **1520** while preserving flexibility to selectively activate individual LEDs **1520** in any sequence and multiple LEDs **1520** simultaneously. The electrical grid also facilitates setting LED currents so as to control intensity at each LED wavelength, determining operating wavelengths and monitoring total grid current so as to limit power dissipation. The LED array **1520** is physically configured in rows, which facilitates clustering LEDs according to wavelength so as to minimize pathlength variations and which facilitates equalization of LED intensities. In an embodiment the LED array **1520** comprises up to sixteen LEDs configured in an electrical grid of four rows and four columns. Each of four row drive lines provide a common anode connection to four LEDs, and each of four column drive lines provide a common cathode connection to four LEDs. Thus, sixteen LEDs are advantageously driven with only eight wires, including four anode drive lines and four cathode drive lines. In an embodiment, an LED array is partially populated with eight LEDs having nominal wavelengths as shown in TABLE 1. In an embodiment, the LED array is partially populated with thirteen LEDs having nominal wavelengths as shown in TABLE 2. Advantageously, LED array and the corresponding LED wavelengths are adapted to measure total hemoglobin (Hbt) in addition to SpO₂, pulse

rate, HbCO and HbMet, among other physiological parameters. In an embodiment, LEDs **D1-D5** are encapsulated with an attenuating epoxy **1660** (FIGS. **16B, F**) so as to equalize LED intensities. In an embodiment, a clear fill epoxy **1670** (FIGS. **16B, F**) mixed with 1-20 μm microspheres is dispersed and cured over the LEDs. An LED array and corresponding drivers for an electrical grid are disclosed in U.S. patent application Ser. No. 11/367,013, filed Mar. 1, 2006, titled Multiple Wavelength Sensor Emitters, incorporated by reference herein.

TABLE 1

Nominal LED Wavelengths (in nm)			
LED	λ	Row	Col
D1	630	1	1
D2	620	1	2
D3		1	3
D4		1	4
D5	700	2	1
D6	720	2	2
D7	660	2	3
D8	805	2	4
D9	905	3	1
D10		3	2
D11		3	3
D12		3	4
D13	645	4	1
D14		4	2
D15		4	3
D16		4	4

TABLE 2

Nominal LED Wavelengths (in nm)			
LED	λ	Row	Col
D1	700	1	1
D2	660	1	2
D3	730	1	3
D4	805	1	4
D5	905	2	1
D6		2	2
D7		2	3
D8		2	4
D9	630	3	1
D10	620	3	2
D11	1170	3	3
D12	1240	3	4
D13	645	4	1
D14	1270	4	2
D15	1040	4	3
D16	1270	4	4

[**0068**] FIGS. **16A-H** further illustrate emitters **1500** having bonding pads **1610**, mounting pads **1620**, solder pads **1630**, bonding wires **1640**, an optical filter **1660** and an encapsulant **1670**. The mounting pads **1620** mount and electrically connect a first side (anode or cathode) of the array of LEDs **1520** (FIGS. **15A-B**) into an electrical grid. The bonding pads **1610** electrically connect a second side (cathode or anode) of the LEDs **1520** (FIGS. **15A-B**) into the electrical grid, via bonding wires **1640**. The thermistor **1530** is also attached to a pair of mounting pads **1620**. Plated "feed-thru" holes electrically connect the mounting pads **1620** and the bonding pads **1610** on the ceramic substrate top side (FIGS. **16A, E**) with solder pads **1630** on the bottom side (FIGS. **16D, H**).

[0069] FIGS. 17A-B illustrate detectors 1700 including a detector 1701 utilizing a single Si photodiode 1720 particularly advantageous for SpO₂, HbCO and HbMet measurements and a detector 1702 utilizing multiple photodiodes 1720 particularly advantageous for total hemoglobin (Hbt) measurements in addition to SpO₂, HbCO and HbMet. Each detector 1700 has a ceramic substrate 1710 and one or more photodiodes 1720. The ceramic substrate 1710 has a body 1712 defining a cavity 1714. The cavity 1714 contains bonding pads that mount the photodiode(s) 1720 and electrically connect the photodiode(s) 1720, if more than one, in parallel. The solder pads (not visible) output detector current to a monitor via the flex circuit 1112 (FIGS. 11A-B), the connector 1010 (FIG. 10) and an attached patient cable 1000 (FIG. 10). In an embodiment, a single Si photodiode 1720 is utilized. In an embodiment, multiple photodiodes advantageously utilize parallel connected combinations of one or more Si photodiodes and one or more InGaAs photodiodes. The Si photodiodes are generally responsive to red and shorter near-IR wavelengths. The InGaAs photodiodes are generally responsive to longer near-IR wavelengths. Thus, the parallel combination of Si and InGaAs photodiodes extends the bandwidth of the detector component 1700 over the entire range of nominal LED emitter wavelengths, described above, so as to allow a corresponding monitor to non-invasively measure a patient's total hemoglobin (Hbt) among other blood parameters.

[0070] FIGS. 18A-H further illustrate a detector component 1700 having a ceramic substrate 1710, solder pads 1810, a mounting pad 1820, bonding pads 1830, wire bonds 1840, Si photodiodes 1860 and InGaAs photodiodes 1870. The photodiodes 1860, 1870 are mounted on a mounting pad 1820 electrically connected to a first solder pad 1810. The photodiodes 1860, 1870 are wire bonded 1840 to a bonding pad 1830 electrically connected to a second solder pad 1810. The solder pads 1810 include DET-, DET+ and GND pads that mount the detector component 1700/detector 1900 to a flex circuit 1210, as described with respect to FIGS. 12A-C, above. A clear epoxy 1880 fills the remainder of the detector cavity 1714 (FIGS. 17A-B).

[0071] FIGS. 19A-B illustrate a detector 1900 having a detector component 1700 and a shield 1910. The shield 1910 has a conductive surface 1920 defining windows 1930. The windows 1930 can be any shape appropriate to the passage of light and the blocking of electromagnetic noise. In an embodiment, the windows 1930 are large rectangles with minimal interconnect so as to allow for a substantial passage of emitted light to the photodiodes 1720. In an embodiment, the shield 1910 is soldered to the ceramic substrate 1710 on at least the four corners, electrically and mechanically coupling the shield 1910 to the ceramic substrate 1710 and allowing the shield to form one side of a Faraday cage. Mechanical coupling can be, for example, gluing, welding, soldering, screwing, snap fitting, or other suitable fastening. Electrical coupling can be, for example, soldering, wire bonding, die bonding, or other suitable forms of electrical connection. In an embodiment, the ceramic substrate 1710 is printed with shielding material to complete the Faraday cage. Additional shielding material can be attached to or plated on the ceramic substrate 1710.

[0072] FIGS. 20A-B illustrate other photodiode array configurations 2001, 2002. In an embodiment 2001, one or two relatively large surface area InGaAs photodiodes 2020 are mounted between two relatively large surface area Si photodiodes 2010. In an embodiment 2002, four relatively medium surface area photodiodes 2030, 2040 are arrayed so as to intersperse Si photodiodes 2030 and InGaAs photodiodes

2040. In other embodiments, various photodiodes of relatively small, medium and large surface areas and in various mixes of Si and InGaAs technologies are arranged in various topologies within the detector substrate cavity so as to advantageously measure total hemoglobin among other parameters. Other embodiments incorporate other photodiode technologies capable of measuring red and infrared wavelengths in addition to, or in lieu of, Si and InGaAs technologies.

[0073] FIGS. 21A-B illustrate additional embodiments of a multiple wavelength optical sensor 2100. In particular, disposable sensors include an adult/pediatric sensor 2101 and an infant/pediatric sensor 2102. Each sensor 2100 has a tape end 2110 and an opposite connector end 2120 electrically and mechanically interconnected via a cable 2130. The tape end 2110 attaches an emitter and detector to a tissue site. An emitter, described below, emits transmits light into the tissue site and a detector, also described below, generates a sensor signal responsive to the emitted light after tissue absorption. The sensor signal is communicated via the cable 2130 to the connector 2120. The connector 2120 mates with a patient cable (not shown) that communicates the sensor signal to a monitor (not shown). The relative spacing between the emitter and detector are selected to obtain a desired alignment of the emitter and detector when the sensor is attached to the body tissue of a patient.

[0074] FIG. 22 illustrates an emitter 2200 embodiment having a board substrate 2210, an LED array 2220 and one or more encapsulants 2230. The LED array 2220 emits optical radiation having multiple wavelengths of predetermined nominal values, advantageously allowing multiple parameter measurements. In particular, the LED array 2220 has multiple light emitting diodes (LEDs) that are physically arranged and electrically connected in an electrical grid to facilitate drive control, equalization, and minimization of optical pathlength differences at particular wavelengths. The LEDs are each activated by addressing at least one row and at least one column of the electrical grid, as described above. At least a portion of the encapsulants 2230 are advantageously configured to provide intensity equalization across a specific LED subset. In an embodiment, the LEDs emit light having wavelengths generally centered around the values shown in TABLE 3.

TABLE 3

LED	Nominal LED Wavelengths		
	λ	Row	Col
D1	630	1	1
D2	620	1	2
D3	610	1	3
D4		1	4
D5	700	2	1
D6	730	2	2
D7	660	2	3
D8	805	2	4
D9		3	1
D10		3	2
D11		3	3
D12	905	3	4
D13		4	1
D14		4	2
D15		4	3
D16		4	4

[0075] FIGS. 23A-D illustrate a component-populated board substrate 2300 having a board substrate 2200, a LED array 2220, a thermistor 2310, bonding pads 2320, component pads 2330 and solder pads 2340. The LED array 2220 is

soldered to the component pads **2330**, which are electrically connected to the solder pads **2340**. Accordingly, the solder pads **2340** provide an electrical connection via a flex circuit, described below, between the LED array **2220** and a sensor drive (FIG. **28**) located in a monitor (not shown). The thermistor **2310** provides a bulk temperature measurement of the LED array **2220** so as to better determine LED operating wavelengths. Either the N or P side of each LED die is electrically connected to the component pads **2330**. The opposite P or N side of each LED die is electrically connected to the wire-bond pads **2320**.

[0076] FIGS. **24A-D** illustrate an encapsulated board substrate **2400** having board substrate **2200**, a first encapsulant **2410** and a second encapsulant **2420**. The first encapsulant is colored so as to provide an optical filter to equalize the intensities of a specific LED subset. This equalization accounts for differences in LED intensity across the multiple wavelengths so as to at least reduce wavelength-dependent variations in detected intensity. In a particular embodiment, the first encapsulant **2410** encapsulates the shorter wavelength LEDs.

[0077] FIG. **25** illustrates a flex circuit assembly **2500** including a flex circuit **2507** having an optics end **2508** and a cable end **2509**. FIGS. **26A-I** describe a detector circuit assembly **2501** and an emitter circuit assembly **2502** at the optics end **2508**. FIG. **27** describes a cable assembly at the cable end **2509**. The emitter circuit assembly **2502** has an emitter **2510**, a spacer **2520**, an encapsulant **2530**, a light barrier **2540** and an emitter cover **2550**. The detector circuit assembly **2501** has a detector **2560**, an EMI shield **2570** and a detector cover **2580**. Solder **2505** attaches the emitter **2510** to flex circuit pads. Solder **2555** also attaches the detector **2560** to flex circuit pads. Advantageously, the spacer **2520** and encapsulant **2530** provide a relatively uniform illumination of patient tissue across all emitted wavelengths. In particular, the spacer **2520** provides a gap between the emitter LEDs and patient tissue, allowing the emitted light from each LED to spread as it propagates to a tissue site. In an embodiment, the gap is 70 mm. In an embodiment, the encapsulant is configured to diffuse or scatter emitter light from each LED as it propagates to a tissue site. In an embodiment, the encapsulant contains 0.1 mm glass beads, 25% by weight, in a clear silicon RTV. In an embodiment, the encapsulant contains filtering media that provides pass-band characteristics for the emitted wavelengths of the emitter assembly or notch filter characteristics away from the emitted wavelengths so as to substantially attenuate secondary emissions of the LEDs.

[0078] FIGS. **26A-I** illustrate the detector circuit assembly **2501** and the emitter circuit assembly **2502**. FIGS. **26A-E** illustrates the detector assembly **2501** with an unfolded and folded EMI shield **2570**. FIGS. **26F-I** illustrate folding of a light barrier **2540** around the emitter **2510**.

[0079] FIGS. **27A-E** illustrate a cable assembly **2700**. The sensor cable **2100** is mounted to a cable connector **2730** extending from the cable end **2509** of the flex circuit **2507**. Detector wires **2770** are shielded at the flex circuit junction by a fold-over conductive ink flap **2740**, which is connected to a cable inner shield **2750**.

[0080] FIG. **28** illustrates a sensor controller **2800** located in a monitor **100** (not shown) and configured to provide anode drive signals **2801** and cathode drive signals **2802** to an LED array. The DSP (digital signal processor) **2803**, which performs signal processing functions for the monitor, also provides commands **2842** to the sensor controller **2800**. These commands determine drive signal **2801**, **2802** levels and tim-

ing. The sensor controller **2800** has a command register **2810**, an anode selector **2820**, anode drivers **2830**, current DACs (digital-to-analog converters) **2840**, a current multiplexer **2850**, cathode drivers **2860**, a current meter **2870** and a current limiter **2880**. The command register **2810** provides control signals responsive to the DSP commands **2842**. In one embodiment, the command register **2810** is a shift register that loads serial command data **2805** from the DSP **2803** and synchronously sets output bits that select or enable various functions within the sensor controller **2800**, as described below.

[0081] As shown in FIG. **28**, the anode selector **2820** is responsive to anode select **2816** inputs from the command register **2810** that determine which LED array row is active. Accordingly, the anode selector **2820** sets one of the anode on **2822** outputs to the anode drivers **2830**, which pulls up to Vcc one of the anode outputs **2801** to the LED array.

[0082] Also shown in FIG. **28**, the current DACs **2840** are responsive to command register data **2819** that determines the currents through each LEDr array column. In one embodiment, there are four, 12-bit DACs associated with each emitter array column, sixteen DACs in total. That is, there are four DAC outputs **2842** associated with each emitter array column corresponding to the currents associated with each row along that column. In a particular embodiment, all sixteen DACs **2840** are organized as a single shift register, and the command register **2810** serially clocks DAC data **2819** into the DACs **2840**. A current multiplexer **2850** is responsive to cathode on **2818** inputs from the command register **2810** and anode on **2822** inputs from the anode selector **2820** so as to convert the appropriate DAC outputs **2842** to current set **2852** inputs to the cathode drivers **2860**. The cathode drivers **2860** are responsive to the current set **2852** inputs to pull down to ground one to four of the cathode outputs **2802** to the LED array.

[0083] The current meter **2870** outputs a current measure **2872** that indicates the total LED current driving the LED array. The current limiter **2880** is responsive to the current measure **2872** and limits specified by the command register **2810** so as to prevent excessive power dissipation by the LED array. The current limiter **2880** provides an enable **2882** output to the anode selector **2820**. A Hi Limit **2812** input specifies the higher of two preset current limits. The current limiter **2880** latches the enable **2882** output in an off condition when the current limit is exceeded, disabling the anode selector **2820**. A trip reset **2814** input resets the enable **2882** output to re-enable the anode selector **2820**.

[0084] A multiple wavelength sensor has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the claims that follow. Although a multiple wavelength sensor has been disclosed with respect to various disposable sensor embodiments, other embodiments incorporate other tissue site attachment technologies including reusable and resposable sensors configured to attach to various tissue sites including fingers, hands, feet, toes, ears to name a few. Further, although a multiple wavelength sensor has been disclosed with respect to light transmission with respect to emitters, tissue site and detectors, other embodiments incorporate reflectance and transreflectance configurations. A reusable sensor is disclosed in U.S. patent application Ser. No. 11/366,833, filed Mar. 1, 2006, titled Multiple Wave-

length Sensor Attachment, incorporated by reference herein. One of ordinary skill in art will appreciate many variations and modifications.

What is claimed is:

1. A physiological sensor comprising:
 - an emitter that emits light having a plurality of wavelengths;
 - a detector that generates an output signal responsive to the emitted light after absorption by tissue;
 - an attachment assembly that removably attaches the emitter and the detector to tissue;
 - a spacer that provides a predetermined gap between the emitter and tissue when the emitter is attached to tissue; and
 - a light scattering medium disposed in an optical path between the emitter and tissue;
- the spacer and the light scattering medium providing at least a substantially uniform illumination of tissue by the emitted light for each of the wavelengths.
2. The physiological sensor according to claim 1 wherein the light scattering medium comprises glass beads mixed with an encapsulant disposed proximate the spacer.
3. The physiological sensor according to claim 2 wherein the light scattering medium further comprises microspheres mixed with an epoxy disposed proximate the emitter.
4. The physiological sensor according to claim 3 wherein the emitter comprises an array of at least eight light emitting diodes emitting light generally centered around eight unique wavelengths.
5. The physiological sensor according to claim 4 wherein the emitter comprises an array of at least thirteen light emitting diodes emitting light generally centered around at least twelve unique wavelengths.
6. The physiological sensor according to claim 5 wherein the detector comprises at least one Si photodiode and at least one InGaAs photodiode connected in parallel.
7. The physiological sensor according to claim 6 wherein the detector comprises two Si photodiodes and four InGaAs photodiodes all connected in parallel.
8. The physiological sensor according to claim 7 wherein the light emitting diodes emit light within a first range of about 620-905 nm. and within a second range of about 1040-1270 nm.
9. A physiological sensor comprising:
 - an emitter configured to radiate light having a plurality of wavelengths into a tissue site;
 - the emitter comprises a plurality of LEDs disposed within an emitter ceramic substrate;
 - a detector configured to receive the light after absorption by pulsatile blood flow within the tissue site;
 - the detector generates a sensor signal capable of being processed by a patient monitor so as to derive total hemoglobin (Hbt);
 - the detector comprises a plurality of photodiodes disposed within a detector ceramic substrate; and
 - a first set of the photodiodes is responsive to a first set of the wavelengths and a second set of the photodiodes is responsive to a second set of the wavelengths.
10. The physiological sensor according to claim 9 further comprising:
 - a diffuser that scatters the radiated light so that a tissue site is uniformly illuminated across all of the wavelengths.
11. The physiological sensor according to claim 10 wherein the diffuser comprises at least one of:
 - a first encapsulate containing glass beads mounted in a spacer proximate the emitter ceramic substrate; and
 - a second encapsulate mixed with microspheres disposed on the LEDs within the emitter ceramic substrate.
12. The physiological sensor according to claim 11 wherein the photodiodes comprise at least one Si photodiode and at least one InGaAs photodiode connected in parallel.
13. The physiological sensor according to claim 12 wherein the LEDs radiate light generally centered around at least twelve unique wavelengths.
14. The physiological sensor according to claim 13 wherein the LEDs are mounted in an array of at least thirteen LEDs connected within an electrical grid.
15. The physiological sensor according to claim 14 wherein the twelve unique wavelengths comprise eight wavelengths within a first range of about 620-905 nm. and four wavelengths within a second range of about 1040-1270 nm.
16. A physiological sensor comprising:
 - a light source that radiates light having a plurality of wavelengths;
 - a diffuser that scatters the radiated light so that a tissue site is uniformly illuminated across all of the wavelengths; and
 - at least one detector that generates a sensor signal responsive to the radiated light after tissue attenuation.
17. The physiological sensor according to claim 16 wherein the light source comprises:
 - a ceramic substrate having conductors arranged as an electrical grid;
 - a plurality of LEDs mounted within the ceramic substrate in an array.
18. The physiological sensor according to claim 17 wherein the diffuser comprises:
 - a first encapsulant having microspheres disposed over the LEDs; and
 - a second encapsulant having glass beads disposed proximate the ceramic substrate.
19. The physiological sensor according to claim 18 further comprising a spacer disposed proximate the ceramic substrate so as to form a gap between the LEDs and the tissue site.
20. The physiological sensor according to claim 19 further comprising:
 - a connector that connects to a patient cable so as to communicate the sensor signal to a monitor;
 - a flexible coupling having an optical end proximate the light source and the detector and a connector end proximate the connector; and
 - the flexible coupling having conductors that communicate the sensor signal from the optical end to the connector end.

* * * * *

专利名称(译)	多波长光学传感器		
公开(公告)号	US20080242958A1	公开(公告)日	2008-10-02
申请号	US12/056179	申请日	2008-03-26
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IPC分类号	A61B5/00		
CPC分类号	A61B5/02427 A61B5/14532 A61B5/14546 A61B5/14552 A61B5/6826 A61B5/6838 A61B2562/0238 H01L2924/3025 H01L25/0753 H01L2224/48465 H01L2224/49113 H01L2924/19105 H01L2924/00		
优先权	60/920474 2007-03-27 US 61/033007 2008-03-02 US 60/923630 2007-04-14 US		
其他公开文献	US8781544		
外部链接	Espacenet USPTO		

摘要(译)

多波长光学传感器具有发射器，该发射器被配置为将具有多个波长的光辐射到组织部位中。发射器包括多个LED，这些LED配置成阵列并连接在电网内。检测器配置成在组织部位内的脉动血流吸收之后接收光。检测器产生能够由患者监测器处理的传感器信号，以便获得氧饱和度，碳氧血红蛋白，高铁血红蛋白和总血红蛋白。

