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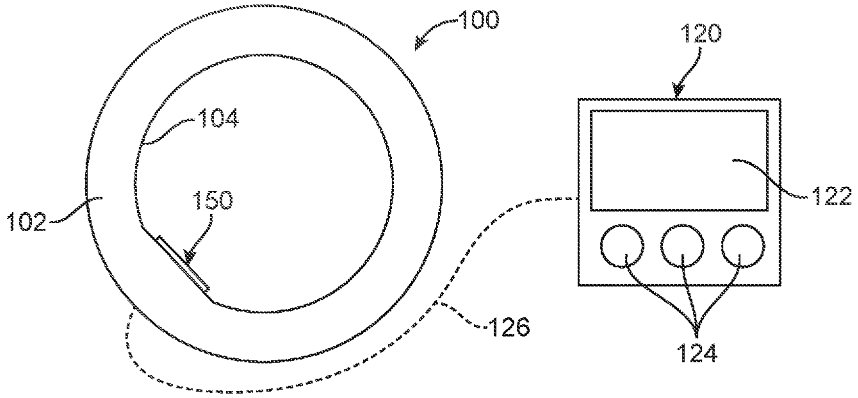

FIG. 1A

(57) **Abstract:** The present invention provides a wearable device for monitoring blood-pressure.

[Continued on next page]

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OPTICAL BLOOD PRESSURE MEASUREMENT DEVICES AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a non-provisional of U.S. provisional application 62/679,435 filed on June 1, 2018, the content of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Cardiovascular disease (CVD) accounts for approximately a significant number of deaths on a world-wide basis. CVD includes coronary heart disease (CHD), which accounts for the majority of CVD deaths, as well as stroke and heart failure. Many more individuals carry a diagnosis of CVD and live with the diagnosis. Those living with CVD are at risk of acute heart attack, strokes and other chronic conditions that can adversely affect the individual’s quality of live over a long term long-term. Ultimately, CVD increases the risks of mortality in the patient. Therefore, there is a keen interest by governments, healthcare providers, as well as the general population to prevent CVD.

[0003] The rise of portable smart-devices, such as smart phones, smart watches, fitness monitors, etc. has given individuals a useful tool to monitor health parameters to address CVD symptoms, where such health parameters include blood pressure and heart rate. Such devices are also of interest to healthy individuals so that who can monitor such data to avoid the onset or progression of CVD. In addition, a number of drugs or therapeutic strategies treat or manipulate the cardiovascular diseases. As a result, predicting short-term and long-term risk of cardiovascular diseases for people plays an important role in treatment. To this end, although pathogenesis of different cardiovascular diseases might be distinct from each other, most of them can be monitored and precautionary assessed through specific physical signs. Since most cardiovascular diseases including hypertension diseases and hypotension diseases are significantly related to blood pressures and such monitoring techniques thereof are not well-developed and implemented universal, there is a need to establish or develop a monitoring device or a monitoring method for monitoring blood pressures in households or hospitals in a simpler manner.

[0004] Non-invasive blood pressure measuring devices including sphygmomanometers and photoplethysmography are used in monitoring patient' s blood pressures to prevent various cardiovascular diseases or provide doctors with early diagnosis. However, most of them are bulky and heavy which are inconvenient for outdoor applications and long-time monitoring.

[0005] Furthermore, a need remains for a device to monitor blood pressure but avoids discomfort for patients.

[0006] Previously, wearable blood-pressure monitoring devices that allowed for real-time monitoring and portable capability are described in US20180049655 and WO2018005298, the entirety of each of which is incorporated by reference. However, there remains a need to more accurately measure blood pressure using a portable, non-obtrusive device.

SUMMARY

[0007] The present disclosure includes a force detecting device that uses elastomeric polymers to determine application of a force applied to the device. In one variation, the present disclosure includes devices for detecting a force in a surface region of tissue. For example, the device can include a transparent backing material comprising a planar shape, the transparent backing material comprising a first surface and a second surface on an opposite side of the planar shape; a first elastomer on the first surface of the transparent backing material, where a light transmission property of the first elastomer changes upon application of force to the first elastomer; and wherein when positioned on the surface region of tissue the force in the surface region causes a deformation of the first elastomer resulting in a change in the light transmission property of the first elastomer. In additional variations of the device, the transparent backing material is optional and can be replaced with a device body.

[0008] The configuration described herein using polymers and optical devices allows for the optical devices to be monolithically integrated into a chip, allowing further miniaturization of the device. The configuration of the device allows for the optical devices to be a camera module of a smart phone, allowing the user to measure their own blood pressure on demand. The configuration also allows this measurement method to be applied on other portions of a body rather than just on a digit.

[0009] Variations of the device can further include a second elastomer on the first surface of the transparent backing material, where a light transmission property of the second elastomer changes upon application of force to the first elastomer; an opaque divider between the first elastomer and the second elastomer to block propagation of light therebetween; a stiffening layer on the second elastomer on a side opposite to the transparent backing material; and wherein when positioned on the surface region the stiffening layer prevents the force from changing the light transmission property of the second elastomer such that the second elastomer provides a reference to determine a deformation of the first elastomer.

[0010] In a first aspect, disclosed herein is a device for detecting a force in a surface region of tissue to measure and monitor a blood pressure of a wearer, the device comprising: a transparent backing material comprising a planar shape, the transparent backing material comprising a first surface and a second surface on an opposite side of the planar shape; a first elastomer on the first surface of the transparent backing material, where a light transmission property of the first elastomer changes upon application of force to the first elastomer; and a second elastomer on the first surface of the transparent backing material, where a light transmission property of the second elastomer changes upon application of force to the first elastomer; and a stiffening layer on the second elastomer on a side opposite to the transparent backing material, wherein when positioned on the surface region of tissue, the force in the surface region causes a deformation of the first elastomer resulting in a change in the light transmission property of the first elastomer, and wherein when positioned on the surface region, the stiffening layer prevents at least a portion of the force from changing the light transmission property of the second elastomer such that the second elastomer provides a reference to determine a deformation of the first elastomer.

[0011] A variation of the device further includes an opaque cover on the first elastomer and the second elastomer located on the side opposite to the transparent backing material, where the stiffening layer is located on the opaque cover and adjacent to the second elastomer.

[0012] Another variation of the invention includes an opaque cover on the first elastomer and the second elastomer located on the side opposite to the transparent backing material, where the stiffening layer is located on the second elastomer and the opaque layer and adjacent to the opaque cover. Variations of the device can include a stiffening layer, additive, or reinforcement on any portion of the elastomers.

[0013] The device further include a light emitting source and a light detecting element both located adjacent to the first elastomer and to the second elastomer, where the light emitting source is configured to illuminate the first elastomer and the second elastomer and where the light detecting element is configured to determine an absorption of light in the first elastomer and in the second elastomer.

[0014] Another variation of the device includes the light detecting element being configured to transmit a signal to a controller, where the signal comprises data of the absorption of light in the first elastomer and in the second elastomer to determine the force in the surface region.

[0015] The present disclosure also includes a method of measuring a blood pressure in an artery within a region of tissue. The measurements can be continuous over a period of time or on demand. In one example, the method includes positioning an assembly adjacent to the region of tissue, where the assembly comprises a first polymer configured to alter a light transmission property upon application of force to the first polymer, where deformation of the region of tissue causes deformation of the first polymer; illuminating the first polymer; observing an emission of light from the first polymer during application of a force on the first polymer where the force is produced by the artery; and determining a change in the emission of light caused by application of the force to calculate a blood pressure in the artery.

[0016] In a second aspect, disclosed herein is a method of measuring a blood pressure in an artery within a region of tissue, the method comprising: positioning a wearable assembly adjacent to a surface of the region of tissue, wherein the wearable assembly comprises a transparent backing material, a first polymer, a light emitter, and a light detector, wherein the transparent backing material is conformable to a surface of the region of tissue, wherein the surface of the region of tissue comprises an external surface of the region of tissue, wherein the transparent backing material has a transparent backing material first surface and a transparent backing material second surface opposite the transparent backing material first surface, wherein when the wearable assembly is worn, the transparent backing material first surface faces a body part having the region of tissue and the transparent backing material second surface faces away from the body part having the region of tissue, wherein the first polymer has a first polymer first surface and a first polymer second surface opposite the first polymer first surface, wherein when the wearable assembly is worn, the first polymer extends from the transparent backing material first surface toward the surface of the region of tissue, wherein when the wearable assembly is worn, the first polymer first surface faces the body part having the region of tissue and the first polymer second surface faces away from the body part having the region of tissue, wherein the first polymer has an undeformed state and a deformed state, wherein an application of a force to the first polymer is configured to change a light absorption of the first polymer such that the light absorption of the first polymer is different when the first polymer is in the undeformed state than when the first polymer is in the deformed state, wherein deformation of the region of tissue causes the application of the force to the first polymer, and wherein the force is produced by the artery; illuminating the first polymer via the light emitter; observing an emission of light from the first polymer via the light detector during the application of the force to the first polymer; and determining a change, via a controller, in the emission of light from the first polymer caused by application of the force to calculate a blood pressure in the artery based on signals received from the light detector.

[0017] A variation of the method can include an assembly having a second polymer, where the second polymer is configured such that deformation of the region of tissue does not cause deformation of the second polymer. The method can include illuminating the second polymer during illuminating of the first polymer.

[0018] A variation of the method further includes observing an emission of light from the second polymer during application of the force on the first polymer.

[0019] The methods can include comparing the emission of light of the first polymer to the emission of light from the second polymer.

[0020] The methods described herein can be performed on a region of tissue such as a digit, an arm, a leg, or any body part where measurement of tissue displaced by blood flow in an artery occurs.

[0021] The methods and device discussed herein can transmit the blood pressure information via a wired or wireless connection to any personal electronic device including but not limited to a smart phone, a smart watch, a fitness tracker, a tablet, a computer, and/or a network.

[0022] The methods and devices can also continuously illuminate the first polymer for a period of time to continuously calculate the blood pressure in the artery over the period of time.

[0023] Another variation of the devices described herein include a patch that converts external forces into change of light absorption, comprising: a transparent backing; a light-absorptive sensing elastomer on a surface of the transparent backing, wherein: the light absorption of the light-absorptive sensing elastomer is indicative of the light-absorptive sensing elastomer deformation subjected to static and fluctuating external forces.

[0024] The patch can further include an opaque cover on the surface, opposite to an interface between the transparent backing and the light-absorptive sensing elastomer, of the light-absorptive sensing elastomer.

[0025] A variation of the patch further includes a light-absorptive reference elastomer on the surface of the transparent backing and by one side of the light-absorptive sensing elastomer, wherein: the light absorption of the light-absorptive reference elastomer is indicative of the light-absorbing sensing elastomer deformation subjected to static external forces.

[0026] The patch can also include an opaque divider that prohibits light propagation between the light-absorptive reference elastomer and the light-absorptive sensing elastomer.

[0027] Additional variations of the patch include an opaque cover on the surface, opposite to an interface between the transparent backing and the light-absorptive sensing elastomer, of the light-absorptive sensing elastomer and the light-absorptive reference elastomer.

[0028] In a third aspect, disclosed herein is a system that converts external forces into change of light absorption to measure and monitor a blood pressure of a wearer, the system comprising: a wearable patch having a transparent backing and a light-absorptive sensing elastomer, wherein the light absorption of the light-absorptive sensing elastomer is indicative of deformation of the light-absorptive sensing elastomer subjected to static and fluctuating external forces, wherein the light-absorptive sensing elastomer has an undeformed state and a deformed state, wherein the light absorption of the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in the deformed state than when the light-absorptive sensing elastomer is in the undeformed state, wherein when the wearable patch is worn, the transparent backing is in contact with a tissue surface outside of a body and has a shape of the tissue surface outside of the body, wherein the transparent backing has a transparent backing first surface and a transparent backing second surface opposite the transparent backing first surface, wherein when the wearable patch is worn, the transparent backing first surface faces a body part having the tissue surface and the transparent backing second surface faces away from the body part having the tissue surface, wherein the light-absorptive sensing elastomer has a light-absorptive sensing elastomer first surface and a light-absorptive sensing elastomer second surface opposite the light-absorptive sensing elastomer first surface, wherein when the wearable patch is worn, the light-absorptive sensing elastomer first surface faces the body part having the tissue surface and the light-absorptive sensing elastomer second surface faces away from the body part having the tissue surface, wherein the light-absorptive sensing elastomer second surface is on the transparent backing first surface, and wherein when the wearable patch is worn, the light-absorptive sensing elastomer extends from the transparent backing first surface toward the tissue surface.

[0029] The present disclosure also includes methods to measure blood pressure. For example, such a method can include attaching a patch, that converts external forces into change of light absorption, on a skin under which an artery passes through; emitting at least a light into the patch; measuring the light propagating out from the patch; and converting the measurement of the light, propagating out from the patch, into blood pressure. In a fourth aspect, disclosed herein is a method of measuring blood pressure in an artery within a tissue, the method comprising: attaching a device on a skin under which an artery passes through, wherein the device comprises an elastomer, a transparent backing material, a light emitter, and a light detector, wherein the light emitter and the light detector are the same distance from the transparent backing material, wherein the transparent backing material is conformable to a surface of the tissue, wherein the surface of the tissue comprises an external surface of the tissue, wherein the transparent backing material has a transparent backing material first surface and a transparent backing material second surface opposite the transparent backing material first surface, wherein when the device is worn, the transparent backing material first surface faces a body part having the tissue and the transparent backing material second surface faces away from the body part having the tissue, wherein the elastomer has an elastomer first surface and an elastomer second surface opposite the elastomer first surface, wherein when the device is worn, the elastomer extends from the transparent backing material first surface toward the surface of the tissue, wherein when the device is worn, the elastomer first surface faces the body part having the tissue and the elastomer second surface faces away from the body part having the tissue, wherein when the device is worn, the elastomer is outside of the artery; emitting, via the light emitter, at least a light into the elastomer; measuring, via the light detector, a light propagating out from the elastomer, wherein an absorption of the light by the elastomer is different when the elastomer is in the deformed state than when the elastomer is in the undeformed state; and determining, via a controller, a force applied to the device based on signals produced by the light detector for calculation of blood pressure within the artery, wherein when a force is produced by the artery, the force produced by the artery results in the force applied to the device, wherein the force applied to the device results in a deformation of the elastomer that results in a change of the absorption of the light by the elastomer such that the absorption of the light by the elastomer is indicative of the blood pressure within the artery.

[0030] The disclosure also includes variations of continuous blood pressure monitoring systems. For example, such systems include a patch that converts external forces into change of light absorption; a light emitter that emits at least a light into the patch; a light detector that measures the light propagating out from the patch; and an algorithm that converts the measurement of the light, propagating out from the patch, into blood pressure.

[0031] A variation of the continuous blood pressure monitoring system includes a transparent backing; and a light-absorptive sensing elastomer on one surface of the transparent backing, wherein: the light absorption of the light-absorptive sensing elastomer is indicative of the elastomer deformation subjected to static and fluctuating external forces. In a fifth aspect, disclosed herein is a device for continuous blood pressure monitoring, the device comprising: a light-absorptive sensing elastomer; a light emitter that emits at least a light into the light-absorptive sensing elastomer; a light detector that measures a light propagating out from the light-absorptive sensing elastomer, wherein an absorption of the light by the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in a deformed state than when the light-absorptive sensing elastomer is in an undeformed state, wherein when a force is produced by an artery, the force results in a force applied to the device, wherein the force applied to the device results in a deformation of the light-absorptive sensing elastomer that results in a change of the absorption of the light by the light-absorptive sensing elastomer such that the absorption of the light by the light-absorptive sensing elastomer is indicative of the blood pressure of a wearer; and a controller that processes signals from the light detector to determine a force applied to the device for calculation of blood pressure, wherein the signals comprise data of the absorption of the light in the light-absorptive sensing elastomer.

[0032] The present disclosure also includes wearable devices that continuously monitor blood pressure. Such devices include a ring body; a light emitter disposed on a monitoring surface at the inner side of the ring body; a light detector disposed on a monitoring surface at the inner side of the ring body and by a side of the light emitter; and a light-absorptive sensing elastomer covering the light emitter and the detector, wherein: the light absorption, which is measured by the light detector, of the light-absorptive sensing elastomer is indicative of the blood pressure of a wearer. In a sixth aspect, disclosed herein is a A wearable device that continuously monitors blood pressure, the wearable device comprising: a ring body; a light emitter disposed on a monitoring surface at an inner side of the ring body; a light detector disposed on a monitoring surface at the inner side of the ring body and by a side of the light emitter; a light-absorptive sensing elastomer covering the light emitter and the light detector; and a controller, wherein the light emitter is configured to emit a light into the light-absorptive sensing elastomer, wherein the light detector is configured to measure a light propagating out from the light-absorptive sensing elastomer, wherein an absorption of the light by the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in a deformed state than when the light-absorptive sensing elastomer is in an undeformed state, wherein when a force is produced by an artery, the force results in a force applied to the device, wherein the force applied to the device results in a deformation of the light-absorptive sensing elastomer that results in a change of the absorption of the light by the light-absorptive sensing elastomer is indicative of the blood pressure of a wearer, wherein the controller is configured to process signals from the light detector to determine the force applied to the device for calculation of the blood pressure, and wherein the signals comprise data of the absorption of the light in the light-absorptive sensing elastomer.

[0033] Another example of a wearable device that continuously monitors blood pressure, includes a ring body; a light emitter disposed on a monitoring surface at the inner side of the ring body; a light detector disposed on a monitoring surface at the inner side of the ring body and by a side of the light emitter; a light-absorptive sensing elastomer covering a portion of the light emitter and a portion of the detector; and a light absorptive reference elastomer covering the remaining portion of the light emitter and the remaining portion of the detector; wherein: the comparative light absorption, which is measured by the light detector, of the light-absorptive sensing elastomer and the light-absorptive reference elastomer is indicative of the blood pressure of a wearer. In a seventh aspect, disclosed herein is a wearable device that continuously monitors blood pressure, the wearable device comprising: a ring body; a light emitter disposed on a monitoring surface at an inner side of the ring body; a light detector disposed on a monitoring surface at the inner side of the ring body and by a side of the light emitter; a light-absorptive sensing elastomer covering a portion of the light emitter and a portion of the light detector; a light-absorptive reference elastomer covering the remaining portion of the light emitter and the remaining portion of the light detector; and a controller, wherein the light emitter is configured to emit a light into the light-absorptive sensing elastomer, wherein the light detector is configured to measure a light propagating out from the light-absorptive sensing elastomer, wherein an absorption of the light by the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in a deformed state than when the light-absorptive sensing elastomer is in an undeformed state, wherein the light-absorptive reference elastomer is configured to resist deformation such that the light-absorptive reference elastomer provides a reference to determine a deformation of the light-absorptive sensing elastomer, wherein when a force is produced by an artery, the force results in a force applied to the device, wherein the force applied to the device results in a deformation of the light-absorptive sensing elastomer that results in a change of a comparative light absorption between the light-absorptive sensing elastomer and the light-absorptive reference elastomer such that the comparative light absorption between the light-absorptive sensing elastomer and the light-absorptive reference elastomer is indicative of the blood pressure of a wearer, wherein the controller is configured to process signals from the light detector to determine the comparative light absorption between the light-absorptive sensing elastomer and the light-absorptive reference elastomer for calculation of the blood pressure, and wherein the signals comprise data of the light absorption of the light-absorptive sensing elastomer and data of a light absorption of the light-absorptive reference elastomer.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0034] FIGS. 1A and 1B illustrate respective front and oblique views of an example of a device configured to monitor blood pressure using movement in tissue that is driven by the blood flow within a vessel located in that tissue.

[0035] FIGS. 2A and 2B illustrate additional variations of tissue displacement assemblies for use with additional variations of blood pressure measuring devices.

[0036] FIG. 3A illustrates components of a force detecting device used to detect movement.

[0037] FIG. 3B shows components of another variation of a force detecting device where a second or reference elastomer is positioned adjacent to a first elastomer.

[0038] FIG. 4A illustrates another variation of components of a variation of a force detecting device showing a first elastomer and a second elastomer on a transparent backing material where the elastomers are separated by an opaque divider.

[0039] FIG. 4B illustrates a cross sectional view of the components shown in FIG. 4A taken along the line 4B-4B to demonstrate an operation of a variation of a force detecting device.

[0040] FIG. 5A illustrates a variation of a force detecting device positioned on a finger to detect a blood pressure of a vessel within the finger using displacement of tissue adjacent to the blood vessel.

[0041] FIG. 5B shows a cross sectional view of the device of FIG. 5A taken along line 5B-5B.

[0042] FIG. 5C is a cross sectional illustration taken along lines 5C-5C from FIG. 5A.

[0043] FIGS. 6A to 6D illustrate another variation of a device having a force detecting apparatus positioned on a ring body.

DETAILED DESCRIPTION

[0044] In the following detailed description, reference is made to accompanying drawings which form a part of the detailed description. The illustrative embodiments described in the detailed description, depicted in the drawings and defined in the claims, are not intended to be limiting. Other embodiments may be utilised and other changes may be made without departing from the spirit or scope of the subject matter presented. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the drawings can be arranged, substituted, combined, separated and designed in a wide variety of different configurations, all of which are contemplated in this disclosure.

[0045] Methods and devices are described herein that relate to monitoring blood pressure in a vessel of a region of tissue. The methods and devices described herein can monitor blood pressure in a digit of a hand or in other areas of the body where the pulsatile flow of blood in a vessel displaces adjacent tissue that can be detected from a surface of the tissue. In addition, the methods and devices disclosed herein include improvements for detecting movement in a tissue of a region of the body, where the movement in the tissue arises from blood pressure changes within a vessel in that tissue. Optionally, the devices and methods described herein can be used wearable devices and non-invasive monitoring blood-pressure in real-time.

[0046] FIGS. 1A and 1B illustrate respective front and oblique views of an example of a monitoring device 100 configured to monitor blood pressure using movement in tissue that is driven by the blood flow within a vessel located in that tissue. In the examples illustrated in FIGS. 1A and 1B, the variation of the monitoring device 100 is configured with a ring-shaped body 102 that houses a device for detecting a force in a region of tissue 150 where a portion of the force detecting device 150 protrudes from an inner surface 104 of the ring shaped body 100. This variation is suited for placement about a digit of an individual’s hand such that it can detect movement of tissue in the digit that is caused by pulsatile flow of a vessel within the digit/tissue. However, additional variations of a blood pressure monitoring apparatus under the present disclosure are not limited to ring-type devices. The movement detecting apparatus 150 monitors movement of tissue in the digit, where the tissue movement can be caused by the oscillation of the blood vessel due to pressure changes therein. As shown, the device 100 can communicate 126 (either via a wire, wireless connection, cloud-based transmission, etc.) to a user interface 120. The user interface 120 can comprise a body wearable apparatus or can comprise a computer, smart-phone, smart-watch, tablet, or other electronic apparatus. Variations of the user interface 120 can include a feedback portion 122 (either visual, audible, etc.) and/or controls 124.

[0047] FIGS. 2A and 2B illustrate additional variations of tissue displacement assemblies 150 for use with additional variations of blood pressure measuring devices 100. The variation shown in FIG. 2A illustrates a finger cuff or cradle 110 that houses one or more force detecting devices 150. As shown, a finger 22 of a hand 20 is positioned within or on the device 110 such that one or more force detecting assemblies 150 can detect movement of tissue and transmit information (via a wired or wireless connection 126) to a user interface device 120 (as described above) such that blood pressure can be monitored. FIG. 2B illustrates a traditional blood pressure cuff 122 having a pump or bladder 114 that is used to secure the cuff 112 about a leg or arm of a patient. The cuff 112 includes any number of force detecting devices 150 that can measure displacement of tissue due to pulsatile flow of blood in a vessel within the tissue that is adjacent to the cuff 112.

[0048] FIG. 3A illustrates components of a force detecting device 150 used to detect movement. Variations of the device 150 can be used as described herein to monitor movement of tissue arising from flow of blood in an artery within the tissue. The force detecting device 150 includes a first elastomer 152 a first surface 156 of a transparent backing material 154, where a light transmission property of the first elastomer 152 changes upon application of force to the first elastomer 152. The first elastomer 152 and the second elastomer 160 can comprise the same or different materials. However, as noted below, the operation of the first and second elastomers 152 160 will vary in the device 150.

[0049] In this variation of the device 150, the first surface 156 of the transparent backing material 154 is positioned facing tissue while the second surface 158 is opposite to the first surface 156 and faces away from tissue. The transparent backing material 154 can also be malleable or shaped to conform to a surface for measuring deflection of that surface.

[0050] Variations of the transparent backing materials include, but are not limited to: silicone rubber, polycarbonate, PDMS, polyethylene terephthalate, polyethylene, PMMA, gelatin, hydrogel, polymer-dispersed liquid crystal, amorphous copolyester, polyvinyl chloride, cyclic olefin copolymers, ionomer resin, polypropylene, fluorinated ethylene propylene, styrene methyl methacrylate. The first/second polymer materials: same as above and their composites or nanocomposites by adding nanomaterials made of titanium oxides, silicon oxides, cavities, or others

[0051] FIG. 3B shows components of another variation of a force detecting device 150 where a second or reference elastomer 160 is positioned adjacent to a first elastomer 152. The second elastomer 160 can be spaced from the first elastomer 152 or positioned in contact with the first elastomer 152. Optionally, an opaque barrier (e.g., a film, coating, layer, etc.) 165 is positioned between the first elastomer 152 and second elastomer 160 to enable separate measurement of the light transmission properties of each elastomer.

[0052] FIG. 4A illustrates another variation of components of a variation of a force detecting device 150 showing a first elastomer 152 and a second elastomer 160 on a transparent backing material 154 where the elastomers are separated by an opaque divider 164. This variation also includes an opaque cover 166 that prevents undesirable illumination from the tissue surface of the device 150. As discussed above, the second elastomer 160 includes a stiffening reinforcement or layer 162 to prevent deformation of the second elastomer 160.

[0053] FIG. 4B illustrates a cross sectional view of the components shown in FIG. 4A taken along the line 4B-4B to demonstrate an operation of a variation of a force detecting device 150. As discussed herein, a surface of the device 150 opposite to the transparent backing material 154 is positioned adjacent to a surface to be monitored. In one example, the surface being monitored is a tissue region having an artery, where the tissue region experiences displacement arising from the pressure differential caused by flow of blood in the artery. The displacement creates a force 30 that acts on a surface of the device 150. The first elastomeric material 152 experiences deformation (along with any opaque layer 166) depicted by deformed lines 36. In contrast, the second elastomer 160 is configured to resist deformation typically by the use of a stiffening layer 162 (alternative means of stiffening the polymer without affecting the light transmission properties of the elastomer are within the scope of this disclosure.)

[0054] FIG. 4B depicts a force 30 acting on the second elastomer 160 but failing to cause displacement of the second elastomer 160. FIG. 4B also shows a representation of an emitting device 180 (e.g. laser, LED, or other illumination source) that directs electromagnetic radiation (e.g., visible light or other electromagnetic radiation) through the transparent backing material 154 to the first and second elastomers 150 160. Although the figure illustrates a single emitter 180 any number of emitters can be used. The device 150 also includes one or more detectors 182 (e.g., detectors configured to measure reflected light and/or radiation). The deformation of the first elastomer 152 changes the optical properties of the elastomer 152 such that an absorption of the light (or other radiation) changes. Therefore, the reflected illumination 42 from the first elastomer 152 will be different than a reflected illumination 44 from the second non-deformed elastomer 160. This change in reflected illumination is used to determine the force 30 applied to the device 150, which is then used to determine a blood pressure of the artery causing the displacement 30. As shown, the elastomers 152 160 can be optically separated by an opaque divider 164 or via any other structural configuration that optically separates the elastomers.

[0055] Although the above example illustrates a second elastomer or reference elastomer, variations of the device 150 can omit this reference elastomer and determine an applied force by monitoring changes in a single elastomer.

[0056] FIG. 5A illustrates a variation of a force detecting device 150 positioned on a finger 22 to detect a blood pressure of a vessel 10 within the finger 22 using displacement of tissue adjacent to the blood vessel. The illustrated variation of the device 150 includes one or more light emitters 180 and one or more light detectors 182. FIG. 5B shows a cross sectional view of the device of FIG. 5A taken along line 5B-5B. This cross sectional view illustrates a variation of a device for detecting movement 150 as the transparent backing layer 154 is shaped or shapeable to conform to a finger 22. Accordingly, the elastomeric polymer 152 and opaque barrier layer 166 conform to tissue 12 that is adjacent to an artery 10 within the finger 22. In this variation, the two vessels 10 run along a bone 24 within the finger. Pulsatile flow of blood within the vessel 10 causes displacement of tissue 12, which produces deflection of the barrier layer 166 and first elastomer 152. As discussed herein, the optical properties of the elastomer 152 change upon deflection of the elastomer 152. Therefore, light 40 emitted from an illumination component 180 is absorbed by the compressed/displaced elastomer 152 and is reflected 42 to a light detector 182. The detector 182 can produce a signal that is then used to determine a force applied to the device 150 for calculation of blood pressure within the artery 10.

[0057] FIG. 5C is a cross sectional illustration taken along lines 5C-5C from FIG. 5A. As shown, the second elastomeric polymer 160, opaque barrier layer 166, and stiffening layer 162 conform to tissue 12 that is adjacent to the artery 10 within the finger 22. The pulsatile flow of blood within the vessel 10 causes displacement of tissue 12 but fails to produce deflection of the barrier layer 166 and second elastomer 160 because of the reinforcement or stiffening layer 162. Therefore, the optical properties of the second elastomer 160 do not change because there is no deflection of the elastomer 162 (alternatively, the deflection of the second elastomer 160 is insignificant). Therefore, light 40 emitted from the illumination component 180 is absorbed by the second elastomer 160 and is reflected 44 to a light detector 182 for use as a reference for comparison for the light reflected 42 from the first elastomer. Again, the detector 182 can produce a signal that is then used to determine a force applied to the device 150 for calculation of blood pressure within the artery 10.

[0058] FIGS. 6A to 6D illustrate another variation of a device 100 having a force detecting apparatus positioned on a ring body 102. As shown in FIG. 6A, the device 100 includes a body structure 102 that houses the force detecting apparatus as well as an emitting component 180 and a detecting component 182.

[0059] FIG. 6B illustrates a cross sectional view of the device 100 and finger 22 taken along the line 6B-6B of FIG. 6A. This sectional view illustrates the finger 22 having a bone 24 adjacent to two vessels where the ring body 102 is positioned such that the force detecting apparatus 150 is positioned adjacent to an artery 10 and where flow of blood in the artery 10 displaces adjacent tissue 12 causing movement at the tissue surface interface of the force detecting device 150. Similar to the variations discussed above, the force detecting device 150 includes an opaque cover 166 that is placed adjacent to a skin 14 of the finger 22. A first elastomer 152 is positioned adjacent to the cover 166 with an emitter 180 of electromagnetic radiation positioned adjacent to the elastomer 152 to provide electromagnetic radiation (e.g., light) to the first elastomer 152. As noted above, deformation of the first elastomer 152 occurs as a result of tissue 12 movement caused by blood flow in artery 10. The deformation of the first elastomer 152 alters optical properties of the elastomer 152 causing the elastomer 152 to change absorption of the electromagnetic radiation. This reflected illumination 42 is then used to determine a pressure acting upon the device 150 to determine a blood pressure within the artery 10.

[0060] As shown in FIG. 6B, the force detecting device 150 does not require an optically transparent backing material. Optionally, an optically transparent backing material can be used adjacent to the elastomer 152 and within the body 102 of the device.

[0061] FIG. 6C illustrates a cross sectional view of the device 100 and finger 22 taken along the line 6C-6C of FIG. 6A. This sectional view also illustrates the finger 22 with a bone 24 adjacent to two vessels where the ring body 102 is positioned such that the force detecting apparatus 150 is positioned adjacent to an artery 10 and where flow of blood in the artery 10 displaces adjacent tissue 12 causing movement at the tissue surface interface of the force detecting device 150. Again, as noted herein, the second elastomer 160 comprises a stiffening layer 162 (or is otherwise reinforced to prevent deformation). As a result, the displacement of tissue 12 and skin 14 does not affect the second elastomer (or only compresses the second elastomer an insignificant amount). The emitter 180 of electromagnetic radiation is positioned adjacent to the elastomer 160 to provide electromagnetic radiation 40 (e.g., light). Since the second elastomer 160 does not deform there is no change in any optical properties of the elastomer 160. Therefore, the reflected radiation or light 44 can be used as a reference relative to light reflected from the first elastomer. The reflected radiation 42 is then used to determine a pressure acting upon the device 150 to determine a blood pressure within the artery 10.

[0062] FIG. 6D illustrates a variation of a force detecting device 150 used in FIGS. 6A to 6C. As shown, the device 150 does not require the use of a transparent backing material. Instead, the first elastomer 152 and the second elastomer 160 can be positioned adjacent to electromagnetic radiation emitters 180 and detectors 182. Therefore, the reflected radiation 42 from the first elastomer 152 and the reflected radiation 44 from the second elastomer 160 can be detected by the detector element 182 and used to ultimately determine a blood pressure of a vessel (or other force applied on the device 150).

[0063] Well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the described devices. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention. It should be noted that, without conflict, in the embodiment of the present invention and examples of features can be combined with each other. Therefore, it should be appreciated that the embodiments described herein are not intended to be exhaustive of all possible embodiments in accordance with the present disclosure, and that additional embodiments may be conceived based on the subject matter disclosed herein.

[0064] It is to be understood that, if any prior art is referred to herein, such reference does not constitute an admission that the prior art forms a part of the common general knowledge in the art, in Australia or any other country.

[0065] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

CLAIMS

1. A device for detecting a force in a surface region of tissue to measure and monitor a blood pressure of a wearer, the device comprising:

a transparent backing material comprising a planar shape, the transparent backing material comprising a first surface and a second surface on an opposite side of the planar shape;

a first elastomer on the first surface of the transparent backing material, where a light transmission property of the first elastomer changes upon application of force to the first elastomer;

a second elastomer on the first surface of the transparent backing material, where a light transmission property of the second elastomer changes upon application of force to the first elastomer; and

a stiffening layer on the second elastomer on a side opposite to the transparent backing material;

wherein when positioned on the surface region of tissue the force in the surface region causes a deformation of the first elastomer resulting in a change in the light transmission property of the first elastomer, and wherein when positioned on the surface region, the stiffening layer prevents at least a portion of the force from changing the light transmission property of the second elastomer such that the second elastomer provides a reference to determine a deformation of the first elastomer.

2. The device of claim 1, further comprising: an opaque divider between the first elastomer and the second elastomer to block propagation of light therebetween.

3. The device of claim 2, further comprising an opaque cover on the first elastomer and the second elastomer located on the side opposite to the transparent backing material, where the stiffening layer is located on the opaque cover and adjacent to the second elastomer.

4. The device of claim 2, further comprising an opaque cover on the first elastomer and the second elastomer located on the side opposite to the transparent backing material, where the stiffening layer is located on the second elastomer and the opaque divider and adjacent to the opaque cover.

5. The device of claim 2, further comprising a light emitting source and a light detecting element both located adjacent to the first elastomer and to the second elastomer, where the light emitting source is configured to illuminate the first elastomer and the second elastomer and where the light detecting element is configured to determine an absorption of light in the first elastomer and in the second elastomer.

6. The device of claim 5, where the light detecting element is configured to transmit a signal to a controller, where the signal comprises data of the absorption of light in the first elastomer and in the second elastomer to determine the force in the surface region.

7. The device of claim 1, further comprising a ring body housing configured to fit on a digit, a wrist or an arm of the wearer.

8. A method of measuring a blood pressure in an artery within a region of tissue, the method comprising:

positioning a wearable assembly adjacent to a surface of the region of tissue, wherein the wearable assembly comprises a transparent backing material, a first polymer, a light emitter, and a light detector, wherein the transparent backing material is conformable to a surface of the region of tissue, wherein the surface of the region of tissue comprises an external surface of the region of tissue, wherein the transparent backing material has a transparent backing material first surface and a transparent backing material second surface opposite the transparent backing material first surface, wherein when the wearable assembly is worn, the transparent backing material first surface faces a body part having the region of tissue and the transparent backing material second surface faces away from the body part having the region of tissue, wherein the first polymer has a first polymer first surface and a first polymer second surface opposite the first polymer first surface, wherein when the wearable assembly is worn, the first polymer extends from the transparent backing material first surface toward the surface of the region of tissue, wherein when the wearable assembly is worn, the first polymer first surface faces the body part having the region of tissue and the first polymer second surface faces away from the body part having the region of tissue, wherein the first polymer has an undeformed state and a deformed state, wherein an application of a force to the first polymer is configured to change a light absorption of the first polymer such that the light absorption of the first polymer is different when the first polymer is in the undeformed state than when the first polymer is in the deformed state, wherein deformation of the region of tissue causes the application of the force to the first polymer, and wherein the force is produced by the artery;

illuminating the first polymer via the light emitter;

observing an emission of light from the first polymer via the light detector during the application of the force to the first polymer; and

determining a change, via a controller, in the emission of light from the first polymer caused by application of the force to calculate a blood pressure in the artery based on signals received from the light detector.

9. The method of claim 8, wherein the wearable assembly further comprises a second polymer, and wherein the second polymer is configured such that deformation of the region of tissue does not cause deformation of the second polymer.

10. The method of claim 9, further comprising:

illuminating the second polymer via the light emitter during the illuminating of the first polymer via the light emitter; and

observing an emission of light from the second polymer,

wherein determining the change, via the controller, in the emission of light from the first polymer comprises comparing the emission of light of the first polymer to the emission of light from the second polymer.

11. The method of any one of claims 8 to 10, wherein positioning the wearable assembly adjacent to a surface of the region of tissue comprises positioning the wearable assembly adjacent to a digit of a hand or an arm.

12. The method of any one of claims 8 to 11, further comprising transmitting the blood pressure to a personal electrical device after the blood pressure is calculated or

further comprising continuously illuminating the first polymer for a period of time to continuously calculate the blood pressure in the artery over the period of time.

13. A system that converts external forces into change of light absorption to measure and monitor a blood pressure of a wearer, the system comprising:

a wearable patch having a transparent backing and

a light-absorptive sensing elastomer, wherein

the light absorption of the light-absorptive sensing elastomer is indicative of deformation of the light-absorptive sensing elastomer subjected to static and fluctuating external forces, wherein the light-absorptive sensing elastomer has an undeformed state and a deformed state, wherein the light absorption of the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in the deformed state than when the light-absorptive sensing elastomer is in the undeformed state, wherein when the wearable patch is worn, the transparent backing is in contact with a tissue surface outside of a body and has a shape of the tissue surface outside of the body, wherein the transparent backing has a transparent backing first surface and a transparent backing second surface opposite the transparent backing first surface, wherein when the wearable patch is worn, the transparent backing first surface faces a body part having the tissue surface and the transparent backing second surface faces away from the body part having the tissue surface, wherein the light-absorptive sensing elastomer has a light-absorptive sensing elastomer first surface and a light-absorptive sensing elastomer second surface opposite the light-absorptive sensing elastomer first surface, wherein when the wearable patch is worn, the light-absorptive sensing elastomer first surface faces the body part having the tissue surface and the light-absorptive sensing elastomer second surface faces away from the body part having the tissue surface, wherein the light-absorptive sensing elastomer second surface is on the transparent backing first surface, and wherein when the wearable patch is worn, the light-absorptive sensing elastomer extends from the transparent backing first surface toward the tissue surface.

14. The system of claim 13, wherein the wearable patch further comprises a light-absorptive reference elastomer on the transparent backing first surface and adjacent to the light-absorptive sensing elastomer, wherein the light absorption of the light-

absorptive reference elastomer is indicative of deformation of the light-absorptive sensing elastomer subjected to static external forces.

15. The system of claim 14, wherein the wearable patch further comprises an opaque divider that prohibits light propagation between the light-absorptive reference elastomer and the light-absorptive sensing elastomer.

16. A method of measuring blood pressure in an artery within a tissue, the method comprising:

attaching a device on a skin under which an artery passes through, wherein the device comprises an elastomer, a transparent backing material, a light emitter, and a light detector, wherein the light emitter and the light detector are the same distance from the transparent backing material, wherein the transparent backing material is conformable to a surface of the tissue, wherein the surface of the tissue comprises an external surface of the tissue, wherein the transparent backing material has a transparent backing material first surface and a transparent backing material second surface opposite the transparent backing material first surface, wherein when the device is worn, the transparent backing material first surface faces a body part having the tissue and the transparent backing material second surface faces away from the body part having the tissue, wherein the elastomer has an elastomer first surface and an elastomer second surface opposite the elastomer first surface, wherein when the device is worn, the elastomer extends from the transparent backing material first surface toward the surface of the tissue, wherein when the device is worn, the elastomer first surface faces the body part having the tissue and the elastomer second surface faces away from the body part having the tissue, wherein when the device is worn, the elastomer is outside of the artery;

emitting, via the light emitter, at least a light into the elastomer;

measuring, via the light detector, a light propagating out from the elastomer, wherein an absorption of the light by the elastomer is different when the elastomer is in the deformed state than when the elastomer is in the undeformed state; and

determining, via a controller, a force applied to the device based on signals produced by the light detector for calculation of blood pressure within the artery, wherein when a force is produced by the artery, the force produced by the artery results in the force applied to the device, wherein the force applied to the device results in a deformation of the elastomer that results in a change of the absorption of the light by the elastomer such that the absorption of the light by the elastomer is indicative of the blood pressure within the artery.

17. A device for continuous blood pressure monitoring, the device comprising:

a light-absorptive sensing elastomer;

a light emitter that emits at least a light into the light-absorptive sensing elastomer;

a light detector that measures a light propagating out from the light-absorptive sensing elastomer, wherein an absorption of the light by the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in a deformed state than when the light-absorptive sensing elastomer is in an undeformed state, wherein when a force is produced by an artery, the force results in a force applied to the device, wherein the force applied to the device results in a deformation of the light-absorptive sensing elastomer that results in a change of the absorption of the light by the light-absorptive sensing elastomer such that the absorption of the light by the light-absorptive sensing elastomer is indicative of the blood pressure of a wearer; and

a controller that processes signals from the light detector to determine a force applied to the device for calculation of blood pressure, wherein the signals comprise data of the absorption of the light in the light-absorptive sensing elastomer.

18. The device of claim 17, further comprising:

a transparent backing; and

a light-absorptive reference elastomer, and an opaque divider, wherein the light-absorptive sensing elastomer and the light-absorptive reference elastomer are on a transparent backing, wherein the opaque divider is configured to prohibit light propagation between the light-absorptive reference elastomer and the light-absorptive sensing elastomer.

19. A wearable device that continuously monitors blood pressure, the wearable device comprising:

a ring body;

a light emitter disposed on a monitoring surface at an inner side of the ring body;

a light detector disposed on a monitoring surface at the inner side of the ring body and by a side of the light emitter;

a light-absorptive sensing elastomer covering the light emitter and the light detector; and

a controller,

wherein the light emitter is configured to emit a light into the light-absorptive sensing elastomer,

wherein the light detector is configured to measure a light propagating out from the light-absorptive sensing elastomer,

wherein an absorption of the light by the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in a deformed state than when the light-absorptive sensing elastomer is in an undeformed state,

wherein when a force is produced by an artery, the force results in a force applied to the device, wherein the force applied to the device results in a deformation of the light-absorptive sensing elastomer that results in a change of the the absorption of the light by the light-absorptive sensing elastomer is indicative of the blood pressure of a wearer,

wherein the controller is configured to process signals from the light detector to determine the force applied to the device for calculation of the blood pressure, and

wherein the signals comprise data of the absorption of the light in the light-absorptive sensing elastomer.

20. A wearable device that continuously monitors blood pressure, the wearable device comprising:

a ring body;

a light emitter disposed on a monitoring surface at an inner side of the ring body;

a light detector disposed on a monitoring surface at the inner side of the ring body and by a side of the light emitter;

a light-absorptive sensing elastomer covering a portion of the light emitter and a portion of the light detector;

a light-absorptive reference elastomer covering the remaining portion of the light emitter and the remaining portion of the light detector; and

a controller,

wherein the light emitter is configured to emit a light into the light-absorptive sensing elastomer,

wherein the light detector is configured to measure a light propagating out from the light-absorptive sensing elastomer,

wherein an absorption of the light by the light-absorptive sensing elastomer is different when the light-absorptive sensing elastomer is in a deformed state than when the light-absorptive sensing elastomer is in an undeformed state,

wherein the light-absorptive reference elastomer is configured to resist deformation such that the light-absorptive reference elastomer provides a reference to determine a deformation of the light-absorptive sensing elastomer,

wherein when a force is produced by an artery, the force results in a force applied to the device, wherein the force applied to the device results in a deformation of the light-absorptive sensing elastomer that results in a change of a comparative light absorption between the light-absorptive sensing elastomer and the light-absorptive reference elastomer such that the comparative light absorption between the light-absorptive sensing elastomer and the light-absorptive reference elastomer is indicative of the blood pressure of a wearer,

wherein the controller is configured to process signals from the light detector to determine the comparative light absorption between the light-absorptive sensing elastomer and the light-absorptive reference elastomer for calculation of the blood pressure, and

wherein the signals comprise data of the light absorption of the light-absorptive sensing elastomer and data of a light absorption of the light-absorptive reference elastomer.

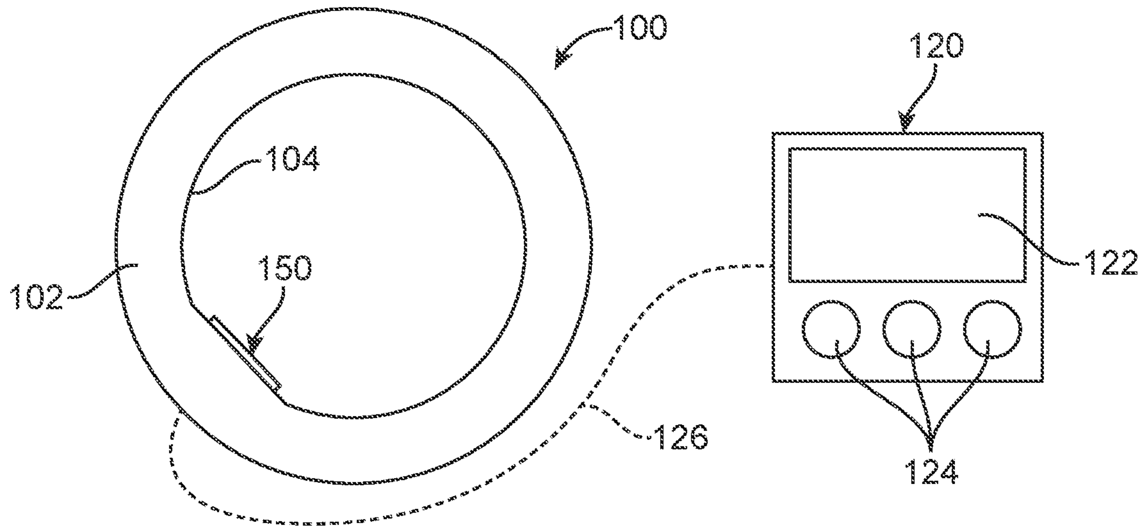

FIG. 1A

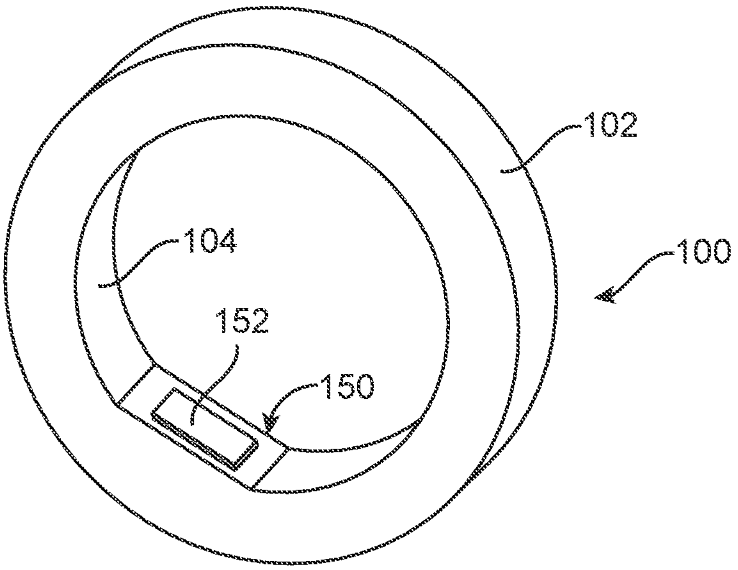

FIG. 1B

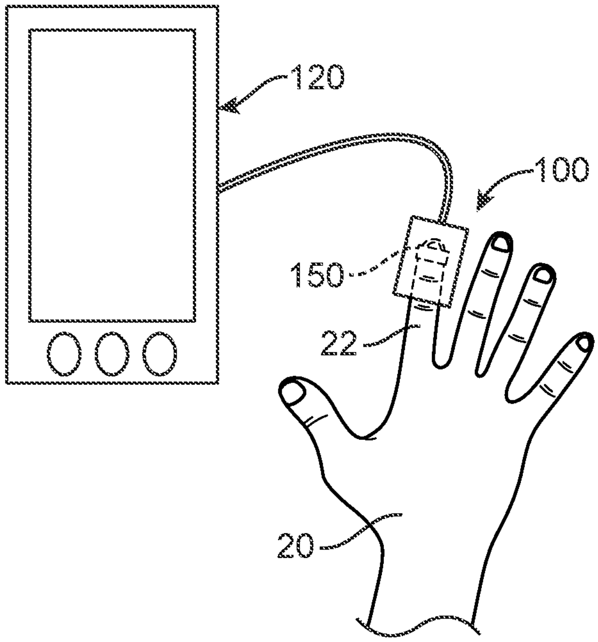

FIG. 2A

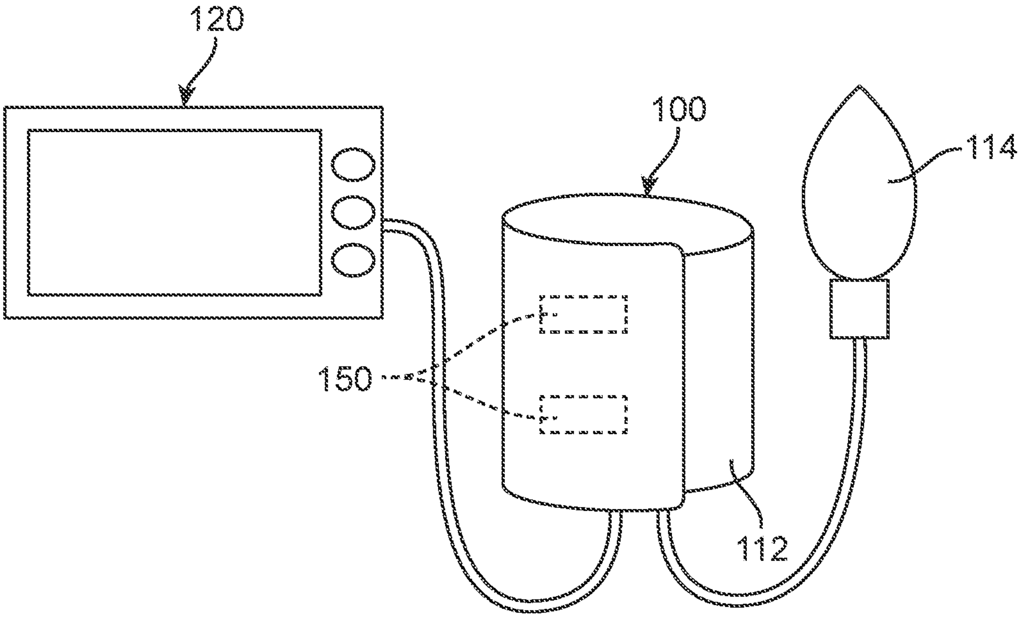

FIG. 2B

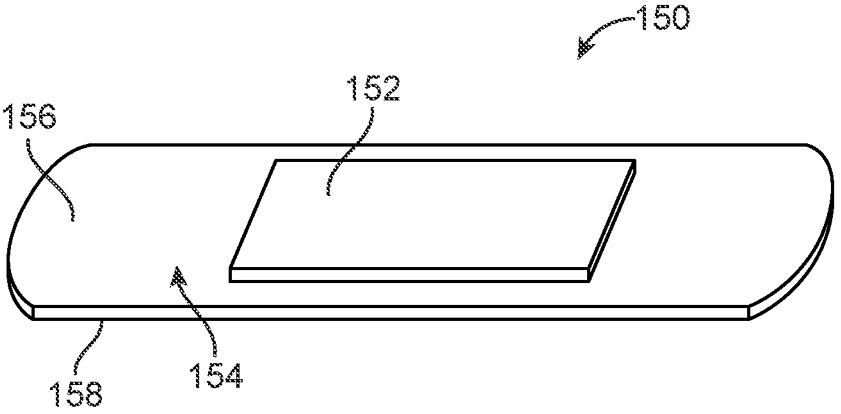

FIG. 3A

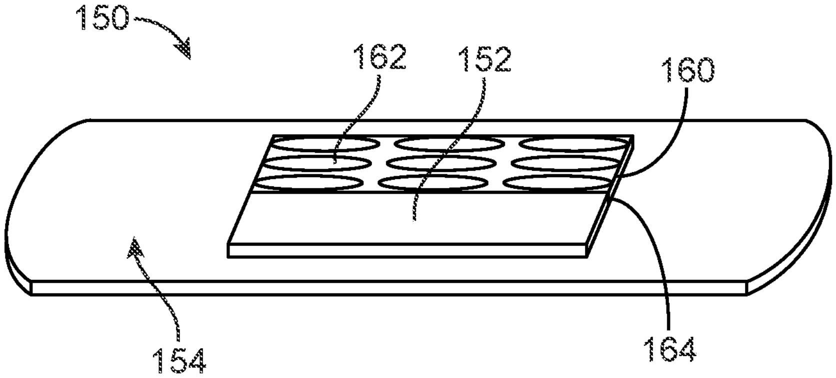

FIG. 3B

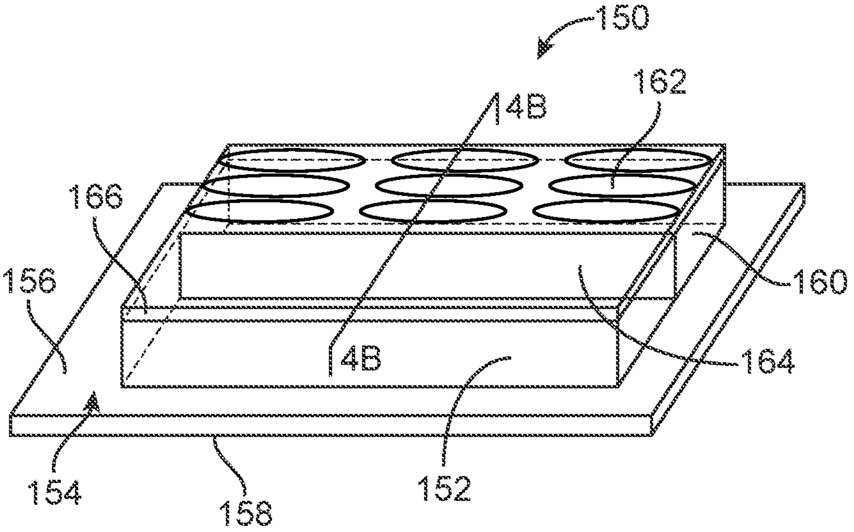
150
4B
162
166
156
160
4B
164
154
158
152

FIG. 4A

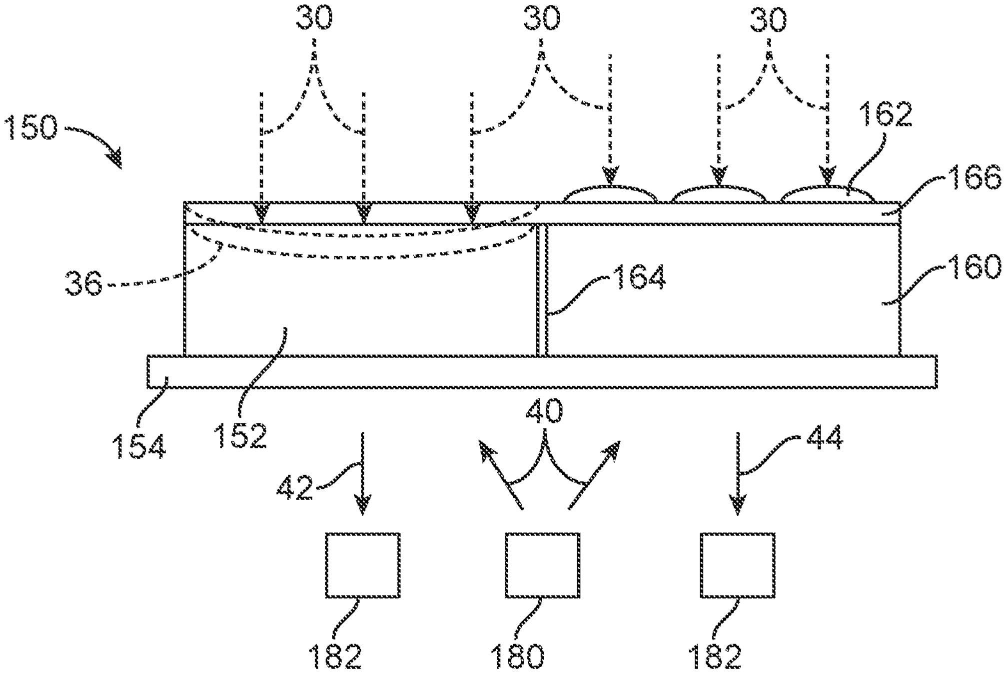
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FIG. 4B

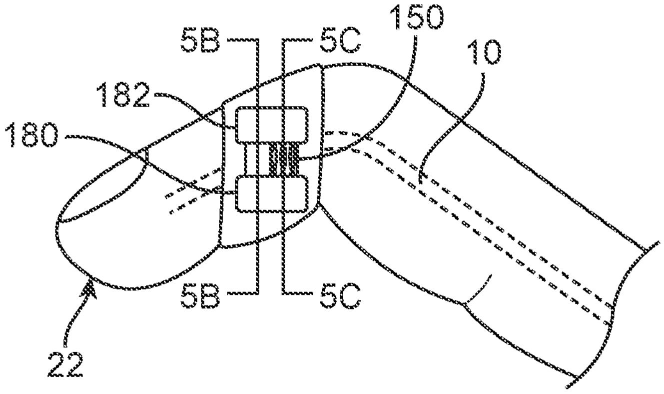


FIG. 5A

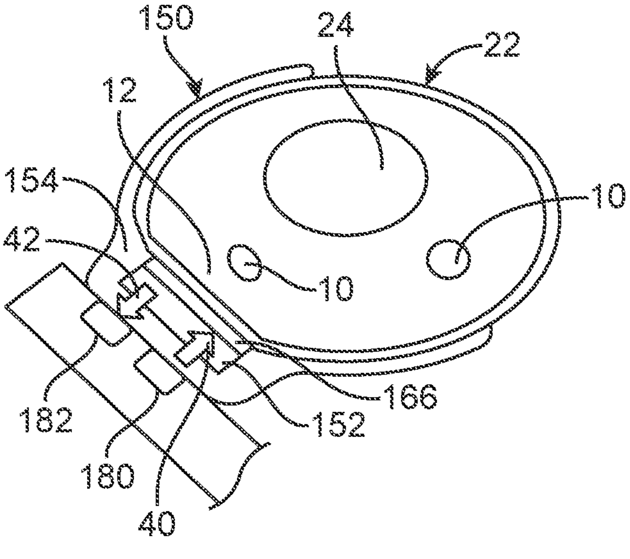


FIG. 5B

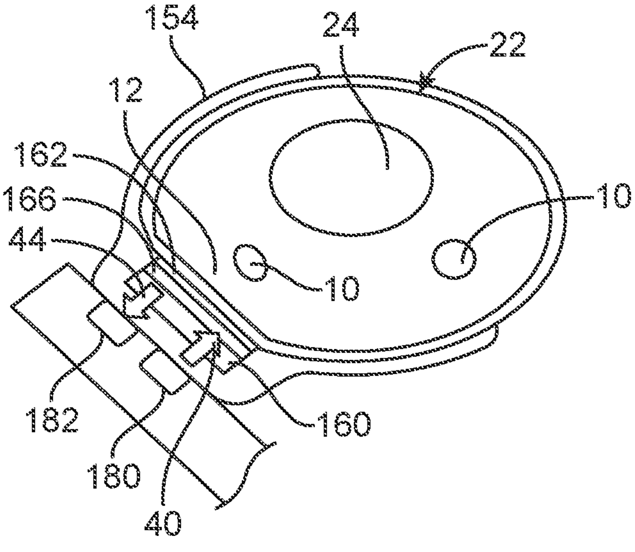
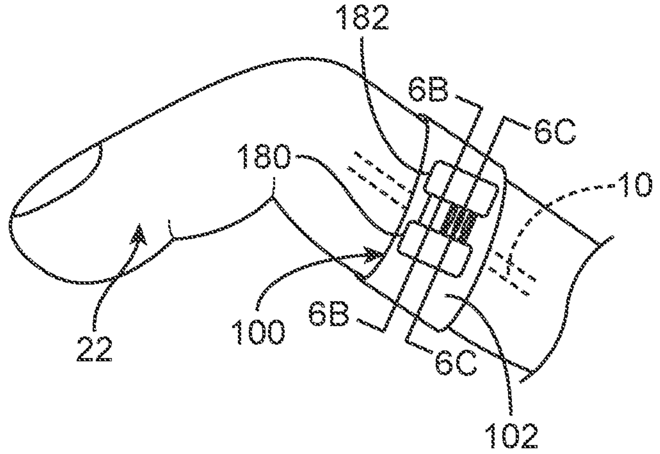


FIG. 5C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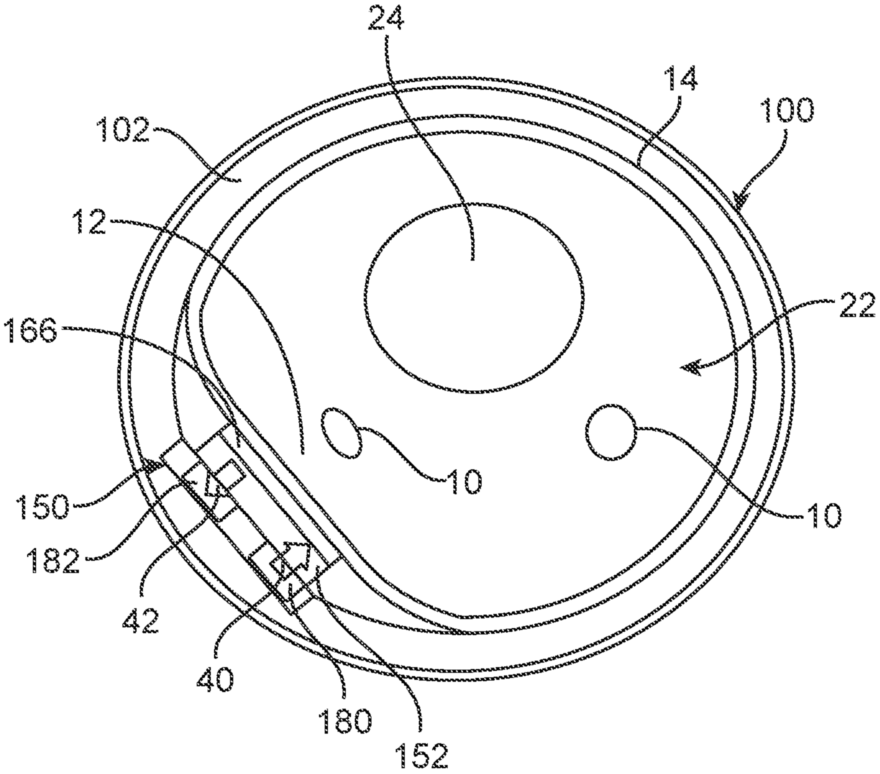
6B
6C
180
10
100
6B
6C
22
102

FIG. 6A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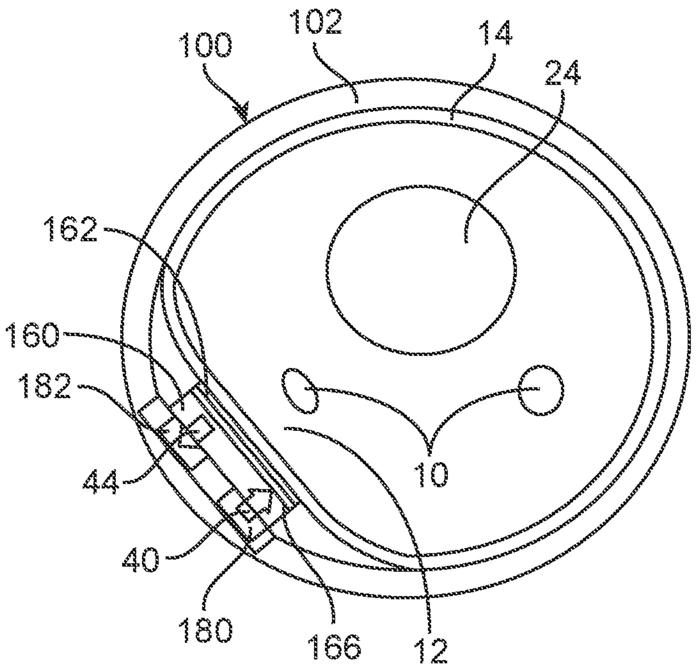
152

FIG. 6B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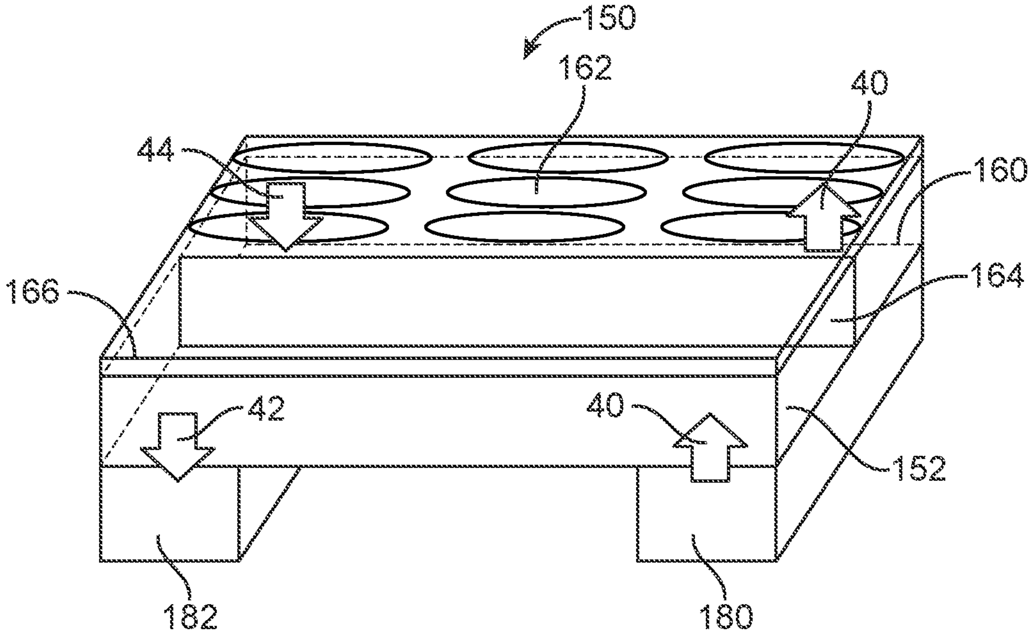
12
10

FIG. 6C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162
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164
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152
182
180

FIG. 6D