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(54) SYSTEM OF NETWORKED WEARABLE PATCHES FOR MEASUREMENT AND TREATMENT

(71) Applicant: **VivaLnk, Inc.**, Santa Clara, CA (US)

(72) Inventor: **Jiang Li**, Cupertino, CA (US)

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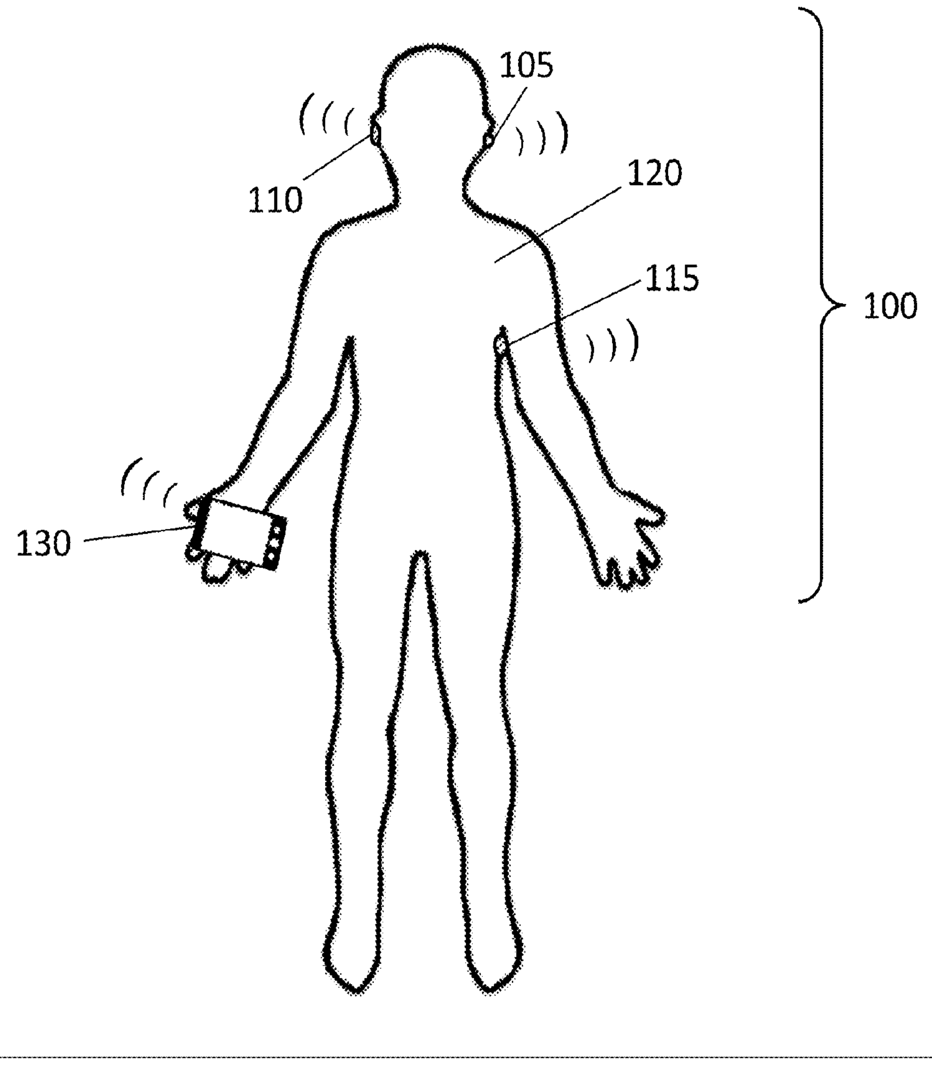
(57) **ABSTRACT**

A system of networked wearable patches includes a plurality of wearable patches each of which includes a stretchable and permeable substrate, a first sensing unit mounted in the stretchable and permeable substrate, the sensing unit that can conduct a first measurement of a user to produce a first measurement signal, and an antenna over the stretchable and permeable substrate and in electric communication with the first sensing unit. The antenna can wirelessly transmit measurement data based on the first measurement signal. A wireless control device includes a measurement controller that can wirelessly transmit a measurement control signal to the antenna, wherein the first sensing unit is configured to conduct the first measurement in response to the measurement control signal. The wireless control device can wirelessly receive the measurement data from the antenna.



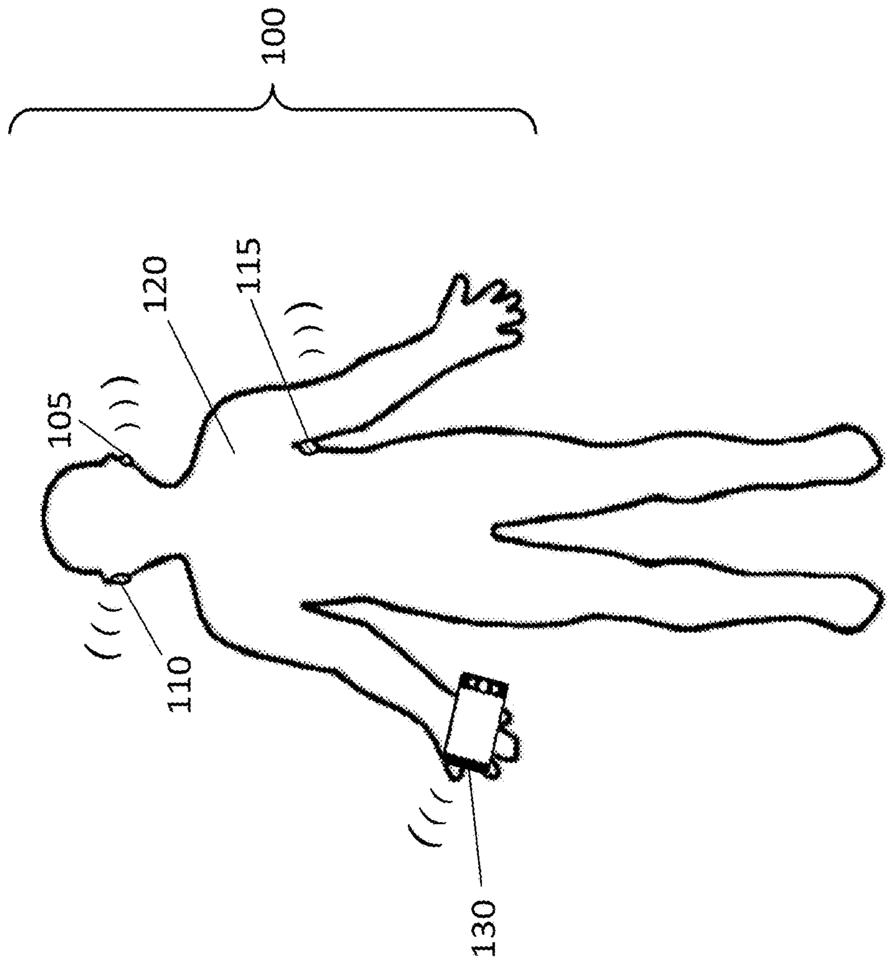


Figure 1A

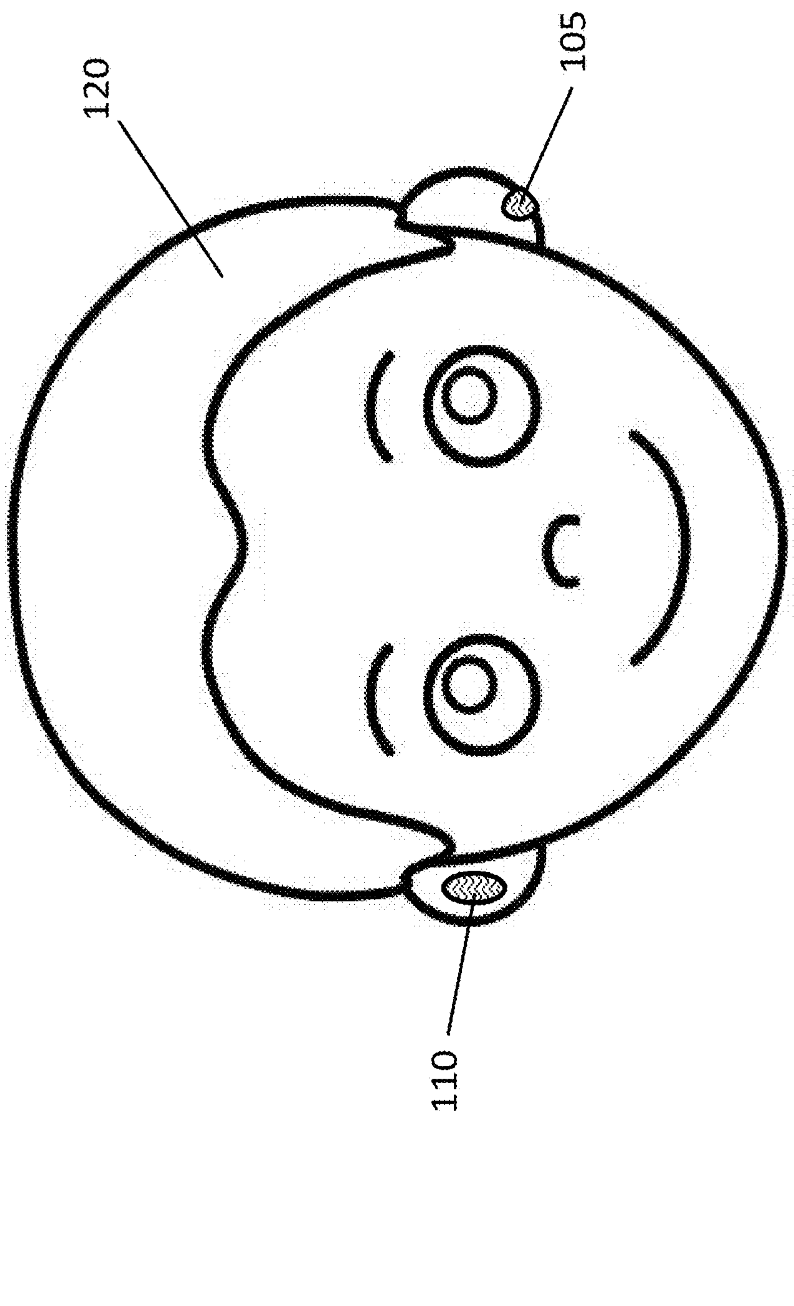


Figure 1B

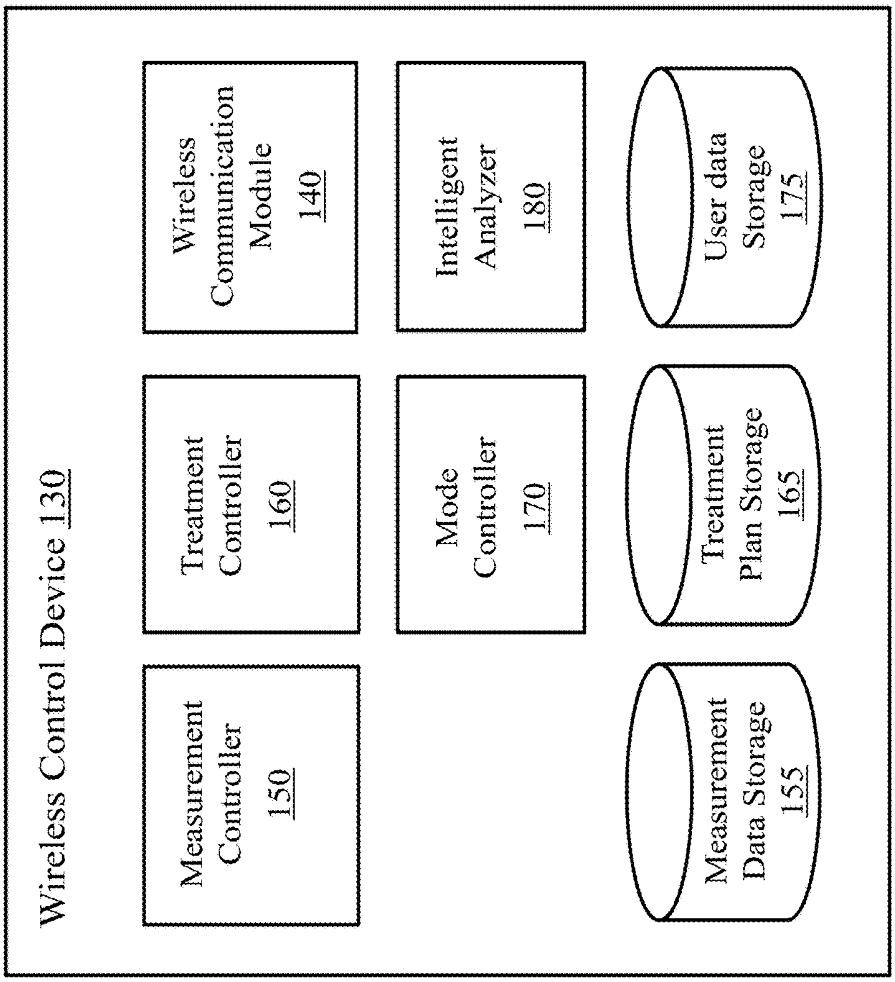
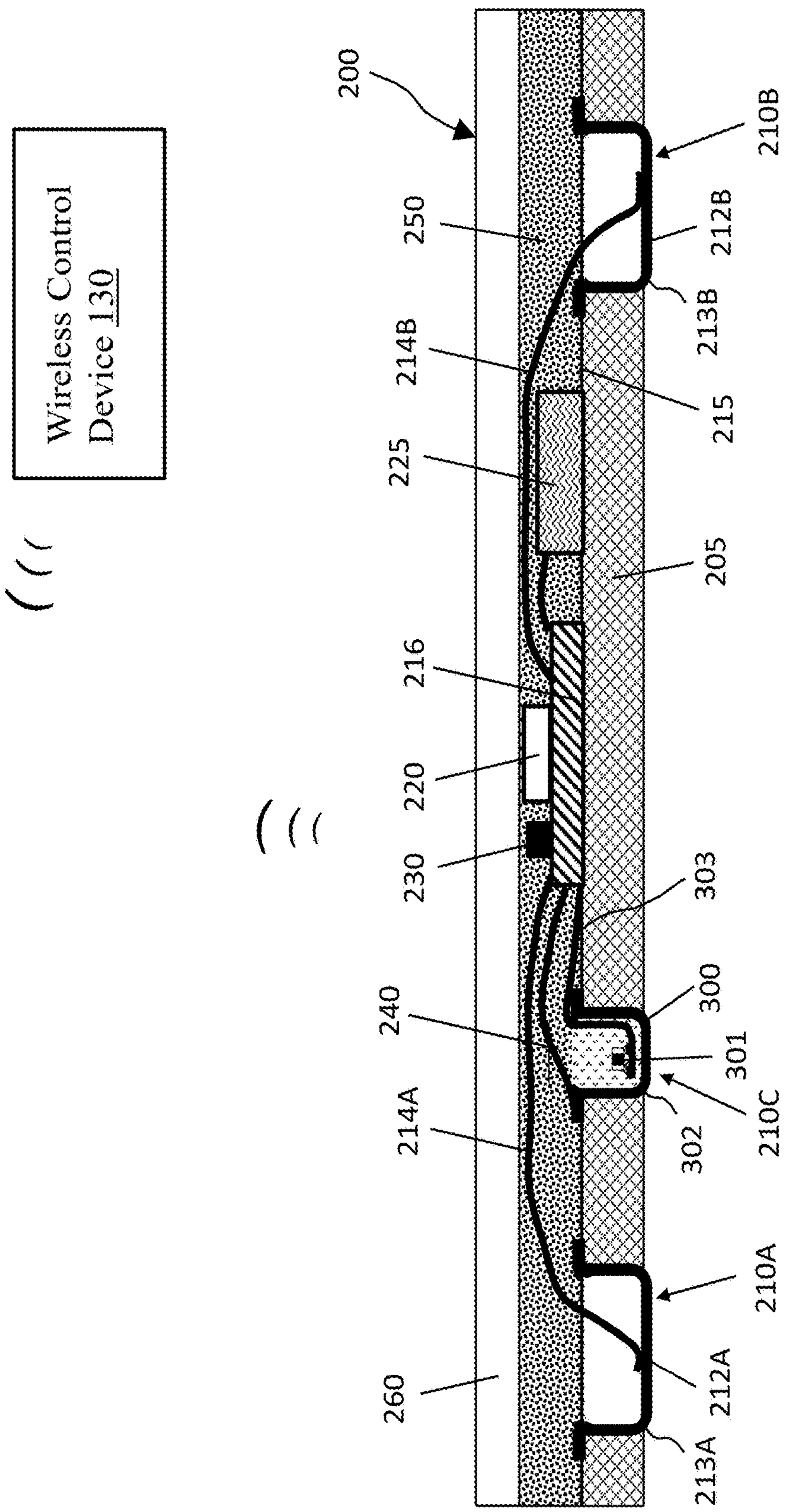

Wireless Control Device 130
Measurement Controller 150
Treatment Controller 160
Wireless Communication Module 140
Mode Controller 170
Intelligent Analyzer 180
Measurement Data Storage 155
Treatment Plan Storage 165
User data Storage 175

Figure 1C



Wireless Control Device 130
200
250
214B
225
216
220
230
240
214A
260
210B
212B
213B
215
205
303
300
301
210C
302
210A
212A
213A

Figure 2

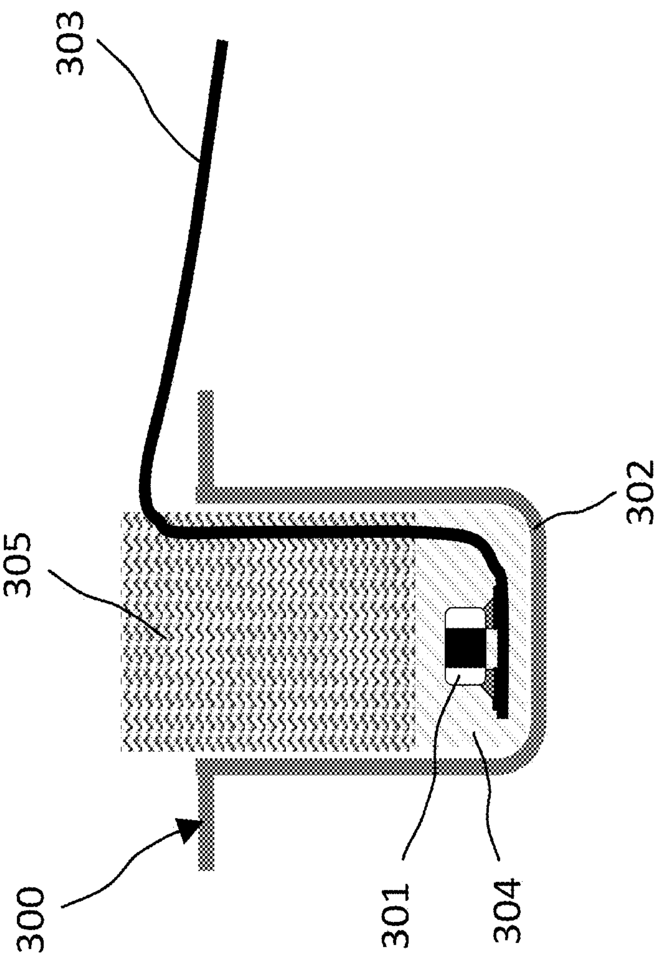


Figure 3

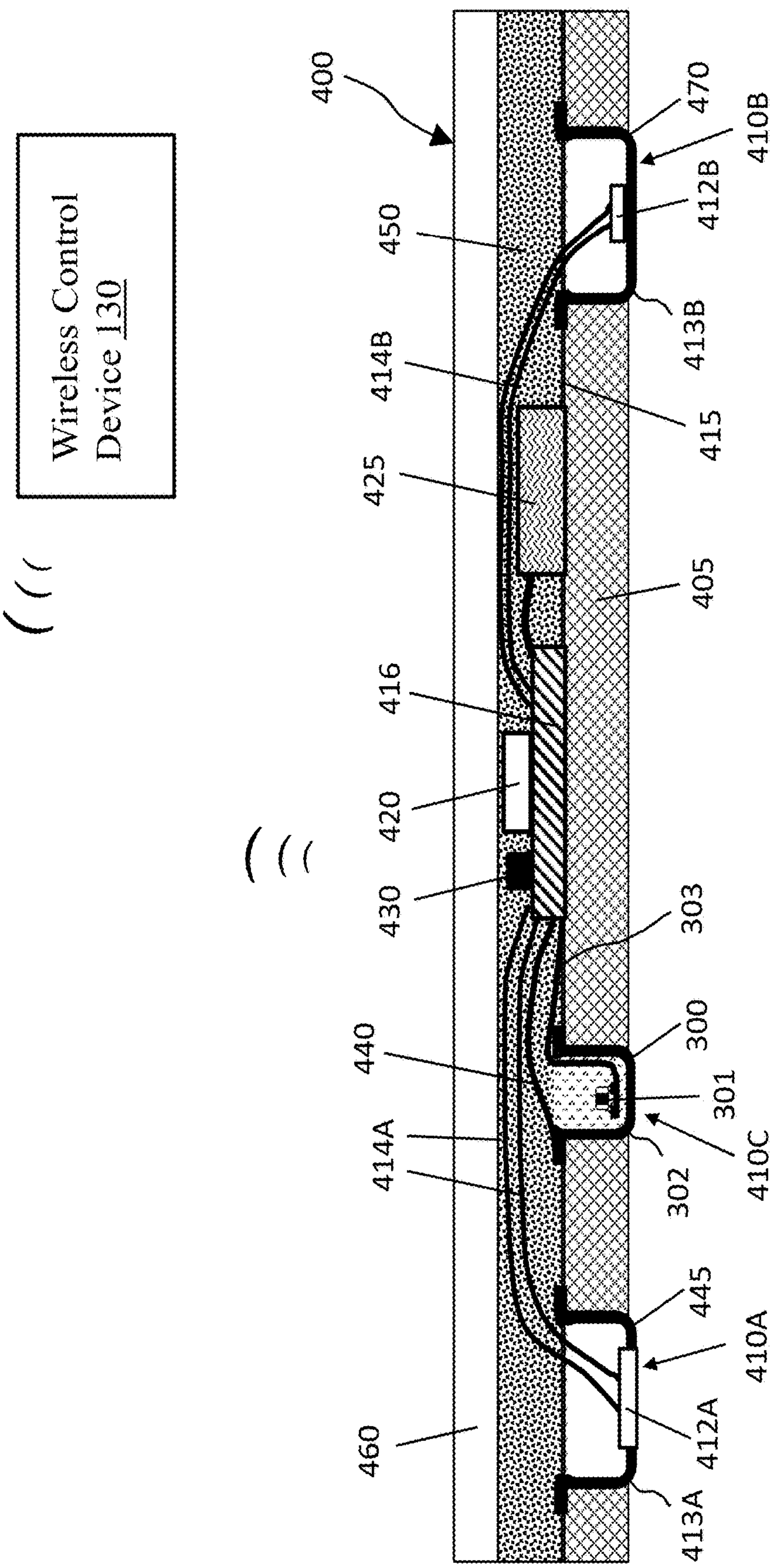

Wireless Control Device 130
400
450
414B
425
416
420
430
440
414A
460
470
410B
412B
413B
415
405
303
300
301
410C
302
445
410A
412A
413A

Figure 4

SYSTEM OF NETWORKED WEARABLE PATCHES FOR MEASUREMENT AND TREATMENT

BACKGROUND OF THE INVENTION

[0001] The present application relates to wearable electronic devices, and in particular, to wearable patches that can attach to human skin.

[0002] Electronic patches can be used for tracking objects and for performing functions such as producing sound, light or vibrations, and so on. As applications and human needs become more sophisticated and complex, electronic patches are required to perform a rapidly increasing number of tasks. Electronic patches are often required to be conformal to curved surfaces, which in the case of human body, can vary overtime.

[0003] Electronic patches can communicate with smart phones and other devices using Wi-Fi, Bluetooth, Near Field Communication (NFC), and other wireless technologies. NFC is a wireless communication standard that enables two devices to quickly establish communication within a short range around radio frequency of 13.56 MHz. NFC is more secure than other wireless technologies such as Bluetooth and Wi-Fi because NFC requires two devices in close proximity (e.g. less than 10 cm). NFC can also lower cost comparing to other wireless technologies by allowing one of the two devices to be passive (a passive NFC tag).

[0004] Bluetooth is another wireless communication standard for exchanging data over relatively longer distances (in tens of meters). It employs short wavelength UHF radio waves from 2.4 to 2.485 GHz from fixed or mobile devices. Bluetooth devices have evolved to meet the increasing demand for low-power solutions that is required for wearable electronics. Benefited from relatively longer reading distance and active communication, Bluetooth technologies allow wearable patches to continuously monitoring vital information without human interference, which is an advantage over NFC in many applications.

[0005] Wearable patch (or tag) is an electronic patch to be worn by a user. A wearable patch is required to stay on user's skin and operate for an extended period from hours to months. A wearable patch can contain a micro-electronic system can be accessed using NFC, Bluetooth, Wi-Fi, or other wireless technologies. A wearable patch can include different sensors for measurements such as vital signs monitoring.

[0006] Traditionally, treatments can be conducted on persons using probes wire connected with heavy immobile equipment. For example, Cranial Electrotherapy Stimulation (CES) utilizes extremely small levels of electrical stimulation across the head of a person for therapeutic treatment of anxiety, depression, insomnia and chronic pain.

[0007] There is therefore a need for convenient measurement of a person's vital signs and other signals and timely treatment of the person's sickness, discomfort, and symptoms.

SUMMARY OF THE INVENTION

[0008] The presently application discloses a system or networked wearable patches that can collectively measure and monitor a person's vital signs and other signals. The networked wearable patches can also apply treatment signals to treat the person's sickness, discomfort, or symptoms. The system can include a wireless control device that communicate with the networked wearable patches, and can dynamically control the measurement and treatment functions according to a treatment plan.

[0009] The present disclosure teaches wireless multi-purpose wearable patches suitable for such a system of networked wearable patches. The multi-purpose wearable patches can conveniently measure a person's vital signs and other signals and apply treatment to the person's sickness or symptoms. The disclosed wearable patches are easy and comfortable to wear and do not require wire connections to heavy equipment.

[0010] Moreover, measurements and treatments can be conducted by the disclosed system of networked wearable patches while a person fulfills his or her normal daily activities. Thus treatments can be timely and dynamically applied when such needs arise according to measurements of vital body signals and other signals.

[0011] Furthermore, effects of treatments can be immediately monitored by the dual-purpose wearable patch and the disclosed system of networked wearable patch while or after a treatment has been applied.

[0012] In one general aspect, the present invention relates to a system of networked wearable patches that includes a plurality of wearable patches each comprising: a stretchable and permeable substrate; a first sensing unit mounted in the stretchable and permeable substrate, the sensing unit configured to conduct a first measurement of a user to produce a first measurement signal; and an antenna over the stretchable and permeable substrate and in electric communication with the first sensing unit, wherein the antenna can wirelessly transmit measurement data based on the first measurement signal; and a wireless control device that includes a measurement controller that can wirelessly transmit a measurement control signal to the antenna, wherein the first sensing unit can conduct the first measurement in response to the measurement control signal, wherein the wireless control device can wirelessly receive the measurement data from the antenna.

[0013] Implementations of the system may include one or more of the following. The wireless control device can include a treatment controller, wherein at least one of the plurality of wearable patches can further include a treatment unit configured to produce a first treatment field in the user's body according to a treatment control signal, wherein the treatment controller in the wireless control device can wirelessly transmit the treatment control signal to the antenna. The treatment unit can include a heater, wherein the treatment unit can control the heater to produce heat in the user's body. The treatment unit can include one or more electrodes, wherein the treatment unit can apply a voltage between the one or more electrodes across the user's skin. The treatment unit can produce a second treatment field in the user's body based on the treatment control signal. The treatment unit can produce the first treatment field in the user's body in response to the first measurement signal. The wireless control device can further include an intelligent analyzer configured to analyze the measurement data to produce an analysis result, wherein the treatment controller in the wireless control device can vary a type, timing, a frequency, or duration of the first treatment field in the user's body based on the analysis result. The wireless control device can include a mode controller that can switch one of the networked wearable patches into a measurement mode based on the analysis result. The measurement controller can control the first sensing unit to vary a type, timing, a frequency, or duration of the first measurement of the user based on the first treatment field applied across the user's body. The wireless control device can include a mode controller configured to switch one of the networked wearable patches into a treatment mode based on a type of the first measurement. The wireless control device can include a mode controller that can set at least one of the plurality of wearable patches in a measurement mode, or a treatment mode, or a combination thereof by controlling the treatment unit and the first sensing unit in the one of the plurality of wearable patches. The first sensing unit can include a mechanical sensor that can measure a pulse or blood pressure of the user's body. The first sensing unit can include a temperature sensor that can measure a temperature of the user's skin or body. The system of networked wearable patches can further include a second sensing unit to conduct a second measurement of a user to produce a second measurement signal, wherein the antenna can wirelessly transmit measurement data based on the first measurement signal and the second measurement signal. The measurement controller in the wireless control device can control the treatment unit to produce the first treatment field in the user's body in response to the first measurement signal and the second measurement signal. The wireless control device can further include an intelligent analyzer configured to analyze the measurement data to produce an analysis result, wherein the measurement controller in the wireless control device can vary a type, a timing, a frequency, or duration of the first treatment field in the user's body based on the analysis result. The second sensing unit can include a mechanical sensor that can measure a pulse or blood pressure of the user's body, or a temperature sensor configured to measure a temperature of the user's skin or body. At least one of the plurality of wearable patches can further include a circuit electrically connected with the first sensing unit and the antenna; and a semiconductor chip in connection with the circuit and configured to receive the first measurement signal from the first sensing unit, wherein the semiconductor chip can produce electric signals to enable the antenna to transmit the measurement data based on the first measurement signal. At least one of the plurality of wearable patches can further include a treatment unit that can produce a first treatment field in the user's body, wherein the antenna can receive the treatment control signal from the wireless control device, wherein the semiconductor chip can control the treatment unit to produce the first treatment field in response to the treatment control signal. at least one of the plurality of wearable patches can further include a circuit substrate comprising the circuit and on the stretchable and permeable substrate, wherein the semiconductor chip and the antenna are mounted on the circuit substrate; and a battery configured to supply power to the circuit and the semiconductor chip. At least one of the plurality of wearable patches can further include an elastic layer formed on the stretchable and permeable substrate, the circuit substrate, and the first sensing unit.

[0014] In another general aspect, the present invention relates to a multi-purpose wearable patch that includes a stretchable and permeable substrate, a first sensing unit mounted in the stretchable and permeable substrate, the sensing unit that can conduct a first measurement of a user to produce a first measurement signal, a treatment unit that can produce a first treatment field in the user's body; a circuit electrically connected with the treatment unit and the sensing unit; and a semiconductor chip in connection with the circuit and configured to receive the first measurement signal from the sensing unit, wherein the semiconductor chip can produce a first treatment control signal to control the treatment unit to produce a first treatment field in the user's body

[0015] Implementations of the system may include one or more of the following. The treatment unit can include a heater, wherein the semiconductor chip can produce the first treatment control signal to control the heater to produce heat in the user's body. The treatment unit can include one or more electrodes, wherein the semiconductor chip can produce the first treatment control signal to control the one or more electrodes to apply a voltage across the user's body. The semiconductor chip can produce a second treatment control signal to control the treatment unit to produce a second treatment field in the user's body. The semiconductor chip can control to control the treatment unit to produce the first treatment field in the user's body in response to the first measurement signal. The semiconductor chip can vary a type, timing, a frequency, or duration of the first treatment field in the user's body based on the first measurement signal. The semiconductor chip can control the first sensing unit to vary a type, timing, a frequency, or duration of the first measurement of the user based on the treatment field applied across the user's body. The semiconductor chip can switch the treatment unit and the sensing unit between a measurement mode and a treatment mode. The first sensing unit can include a mechanical sensor configured to measure a pulse or blood pressure of the user's body. The first sensing unit can include a temperature sensor configured to measure a temperature of the user's skin or body. The multi-purpose wearable patch can further include a second sensing unit to conduct a second measurement of a user to produce a second measurement signal. The semiconductor chip can control to control the treatment unit to produce the first treatment field in the user's body in response to the first measurement signal and the second measurement signal. The semiconductor chip can vary a type, timing, a frequency, or duration of the first treatment field in the user's body based on the first measurement signal and the second measurement signal. The second sensing unit can include a mechanical sensor configured to measure a pulse or blood pressure of the user's body, or a temperature sensor configured to measure a temperature of the user's skin or body. The multi-purpose wearable patch can further include a circuit substrate comprising the circuit and on the stretchable and permeable substrate, wherein the semiconductor chip is mounted on the circuit substrate; and a battery configured to supply power to the circuit and the semiconductor chip. The multi-purpose wearable patch can further include an antenna in electric connection with the semiconductor chip, wherein the semiconductor chip can produce electric signals to enable the antenna to wirelessly exchange measurement data based on the first measurement signal with a wireless control device, wherein the semiconductor chip can produce electric signals to enable the antenna to wirelessly exchange treatment data with a wireless control device, wherein the treatment control signal is at least in part based on the treatment data. The multi-purpose wearable patch can further include an adhesive layer between the stretchable and permeable substrate and the circuit substrate. The multi-purpose wearable patch can further include an elastic layer formed on the stretchable and permeable substrate, the circuit substrate, and the sensing unit.

[0016] In another aspect, the present invention relates to a dual purpose wearable patch that includes a stretchable and permeable substrate; a sensing unit mounted in the stretchable and permeable substrate, wherein the sensing unit is configured to conduct a measurement of a user to produce a measurement signal; one or more electrodes respectively attached to the stretchable and permeable substrate; a circuit substrate on the stretchable and permeable substrate, wherein the circuit substrate comprises a circuit electrically connected with the one or more electrodes and the sensing unit; and a semiconductor chip mounted on the circuit substrate and in connection with the circuit, wherein the semiconductor chip can receive the measurement signal from the sensing unit, wherein the semiconductor chip can produce a treatment control signal to control the one or more electrodes to apply a voltage across the user's body.

[0017] Implementations of the system may include one or more of the following. The semiconductor chip can produce a treatment control signal to control the one or more electrodes to apply a voltage across the user's body in response to a measurement signal. The dual-purpose wearable patch can further include a battery configured to supply power to the circuit and the semiconductor chip. The semiconductor chip can switch the circuit, the one or more electrodes, and the sensing unit into or off from a measurement mode and a treatment mode. The one or more electrodes can include a second electrode and a third electrode configured to apply a voltage across the user's body. The sensing unit can include a temperature sensor configured to measure the user's skin temperature, wherein the measurement signal comprises temperature data. The sensing unit can further include a thermally conductive cup having a bottom portion mounted in a first opening in the stretchable and permeable substrate, wherein the temperature sensor is positioned inside and is in thermal conduction cup with the conductive cup. The sensing unit can include a thermally conductive adhesive that fixes the temperature sensor to an inner surface of the conductive cup; and a thermally insulating material in a top portion of the conductive cup. The sensing unit can include an accelerometer configured to measure movement of the user. The sensing unit can include a pressure sensor or a force sensor configured to measure blood pressure or pulse of the user. The semiconductor chip can control a type, a frequency, or duration of a measurement of the user by the sensing unit based on the voltage applied across the user's body. The dual purpose wearable patch can further include an antenna mounted on the circuit substrate and in electric connection with the semiconductor chip, wherein the semiconductor chip is configured to produce electric signals to enable the antenna to wirelessly exchange measurement data based on the measurement signal with a wireless control device, wherein the semiconductor chip can produce electric signals to enable the antenna to wirelessly exchange treatment data with a wireless control device, wherein the treatment control signal is at least in part based on the treatment data. At least one of the one or more electrodes can include an electrically conductive cup that is electrically connected to the control circuit in the circuit substrate, wherein the stretchable and permeable substrate comprises a second opening in which the electrically conductive cup is mounted. The electrically conductive cup can be electrically connected with the circuit. The dual-purpose wearable patch can further include an adhesive layer between the stretchable and permeable substrate and the circuit substrate. The dual-purpose wearable patch can further include an elastic layer formed on the stretchable and permeable substrate, the circuit substrate, and the sensing unit. The sensing unit includes an accelerometer can measure the user's movement, wherein the measurement signal comprises movement data. The sensing unit can include a pressure sensor or a force sensor configured to measure the user's blood pressure and/or the user's pulse, wherein the measurement signal comprises pulse data and blood pressure data.

[0018] These and other aspects, their implementations and other features are described in detail in the drawings, the description and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIGS. **1**A and **1**B illustrate a system of networked wearable patches attached to a user's body.

[0020] FIG. **1**C is a system block diagram for a wireless control device in wireless communications of the networked wearable patches in accordance with some embodiments of the present invention.

[0021] FIG. **2** is a cross-sectional view of an exemplified dual-purpose wearable patch for measurement and treatment in communication with a wireless control device in accordance with some embodiments of the present invention.

[0022] FIG. **3** is a detailed cross-sectional view of an exemplified sensing unit in the dual-purpose wearable patch of FIG. **2**.

[0023] FIG. **4** is a cross-sectional view of an exemplified multi-purpose wearable patch for measurement and treatment in communication with a wireless control device in accordance with some embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Referring to FIGS. **1**A and **1**B, a system **100** of networked wearable patches **105**, **110**, **115** are attached to the body or the skin of a user **120** for measuring body vital signs and other signals. The wearable patches **105**, **110**, **115** can be placed on the ears, the forehead, the hands, the shoulder, the waist, the leg, or the foot, under the armpit, around the wrist, on or around the arm, or other parts of a user's body. The wearable patches **105**, **110**, **115**, as described in the examples below, include sensors that can sense a variety of signals such as temperature, electric voltage, blood pressure, heart pulse, force, acceleration, blood oxygen level, blood glucose level, etc. The wearable patches **105**, **110**, **115**, as described in the examples below, can also apply treatment signals such as heat, electrical, force or pressure, etc. In the present disclosure, the term "wearable patch" can also be referred to as "wearable sticker", "wearable tag", or "wearable band", etc. In the present disclosure, "a multi-purpose wearable patch" also includes "a dual purpose wearable patch".

[0025] As discussed in more detail below, the networked wearable patches **105**, **110**, **115** can operate individually, or in a group to provide certain desired treatment or measurement. For example, one of the wearable patch **105**, **110**, **115** can wrap around a user's ear for applying an electric field through certain location of the ear. Similar, the disclosed wearable patch can wrap around a user's wrist for providing treatment and measurement. Moreover, the wearable patches **105**, **110**, **115** can be attached to different parts of a user's body such as on the two ears or the two temples of the user **120**, which allows a low electric voltage signal to be applied across the user's head.

[0026] In accordance to the present invention, the disclosed multi-purpose wearable patch includes a treatment portion and a measurement portion. The measurement portion can measure vital signs, motion track, skin temperature, and ECG signals. The treatment portion can apply electrical signals, heat, and sometimes force or pressure to user's body.

[0027] The system **100** also includes a wireless control device **130** that can wirelessly exchange data with the networked wearable patches **105**, **110**, **115**. The wireless communications can be conducted using Wi-Fi, Bluetooth, Near Field Communication (NFC), and other wireless technologies. The wireless control device **130** can be a portable mobile device, which the user **120** can carry with him or her. The wireless control device **130** can also be a stationary device that can be placed at home or office where the user **120** may stay for an extended period. The portable mobile device can be implemented with specialized hardware and software units built in a smart phone, a tablet computer (including devices such as iPod), or a dedicated health or sport monitoring device. The wireless control device **130** can be in communication with a network server in which a user account is stored for the user.

[0028] The wireless control device **130**, referring to FIG. **1**C, includes a wireless communication module **140** that can wirelessly communicate with the networked wearable patches (**105**, **110**, **115** in FIGS. **1**A-**1**B) using above described wireless technologies. The wireless control device **130** includes a measurement controller **150** that controls the wireless communication module **140** to transmit measurement control signals to networked wearable patches (**105**, **110**, and **115** in FIGS. **1**A-**1**B). The measurement controller **150** can vary parameters of the measurements by the networked wearable patches. As described in more detail below, such measurement parameters can include types, timing, frequencies, durations of measurements, coordination between measurements of the same of different networked wearable patches, and coordination between measurements and treatments by the networked wearable patches. A measurement data storage **155** stores the measurement data obtained by the networked wearable patches (**105**, **110**, and **115** in FIGS. **1**A-**1**B).

[0029] The wireless control device **130** includes a treatment controller **160** that can control the treatment functions of the networked wearable patches based on a treatment plan stored in the treatment plan storage **165**. The treatment controller **160** can control the wireless communication module **140** to transmit treatment control signals to networked wearable patches (**105**, **110**, and **115** in FIGS. **1**A-**1**B). A treatment plan can define types, timing, frequencies, durations of treatments, coordination between treatments of the same of different networked wearable patches, and coordination between treatments and measurements by the networked wearable patches.

[0030] Still referring to FIG. **1**C, a mode controller **170** is configured to set the networked wearable patches in measurement modes and/or treatment modes, or a combination thereof by controlling the treatment unit and the sensing unit. Some treatment and measurements can be conducted in parallel, but some should be implemented at separate time periods. In some applications, a portion of the networked wearable patches (**105**, **110**, and **115** in FIGS. **1**A-**1**B) applies treatments while another portion of the networked wearable patches (**105**, **110**, and **115** in FIGS. **1**A-**1**B) conducts measurements. The coordination between measurement and treatment modes is controlled by the mode controller **170**.

[0031] The mode controller **170** plays a particular important role in dynamic treatments and dynamic measurements as described below. The mode controller **170** is configured to mobilize treatment units and switch on treatment modes in the networked wearable patches in response to measurement data collected by the sensing units in the networked wearable patches. Conversely, the mode controller **170** is configured to mobilize sensing units and switch on measurement modes in the networked wearable patches in response to treatments applied to the user by the treatment units in the networked wearable patches.

[0032] A user data storage **175** stores user data such as user's weight, height, bone density, historic range for blood pressure, heart beat, body temperature, daily patterns of exercises and rests by the user, sickness or symptoms suffered by the user, etc. In some embodiments, as described below, personalized medical treatment can be applied, sometimes dynamically, based on such user data.

[0033] An intelligent analyzer **180** can process and analyze the measurement data from different networked wearable patches in reference to the user data and the treatment plan (in **175**) and treatment plan (in **165**) for the user. Using the measurement data and optionally historic user data, the intelligent analyzer **180** identifies improvement, issues, and risks in the user based on the measurement data to generate an analysis result, which could lead to timely reporting to the user or a central server, timely treatment, and/or improvement in the existing treatment. A portion of the analysis functions can be accomplished by a network server in communication with the wireless control device **130**. Based on the analysis result, the treatment controller **160** can vary a type, timing, a frequency, or duration of the treatment field in the user's body by the networked wearable patches.

[0034] In some embodiments, referring to FIGS. **1**C-**3**, an exemplified dual purpose wearable patch **200**, which is suitable for the wearable patches **105**, **110**, **115** (FIG. **1**A-**1**B), includes a stretchable and permeable substrate **205** that includes openings **210**A, **210**B, **210**C. The stretchable and permeable substrate **205** can be made of soft foam materials such as EVA, PE, CR, PORON, EPD, SCF or fabric textile, to provide stretchability and breathability. The measurement portion of the disclosed dual-purpose wearable patch **200** includes a sensing unit **300** mounted in the opening **210**C, which is under the control of the measurement controller **150** in the wireless control device **130**. The treatment portion of the disclosed dual-purpose wearable patch **200** includes two electrodes **212**A, **212**B, respectively comprising electrically conductive cups **213**A, **213**B, are mounted in the openings **210**A, **210**B. The treatment portion is under the control of the treatment controller **160** in the wireless control device **130**. A circuit substrate **216** and a battery **225** are bonded to the stretchable and permeable substrate **205** by an adhesive layer **215** pre-laminated on the stretchable and permeable substrate **205**. The circuit substrate **216** includes an electric circuit therein and, for example, can be implemented with a printed circuit board. A semiconductor chip **220** and an antenna **230** are mounted on the circuit substrate **216**. Under the control of the semiconductor chip **220**, the antenna **230** can wirelessly communicate with the wireless control device **130**. Measurement control signals are received from the measurement controller **150** to control the measurements conducted by the sensing unit(s) in the wearable patches **105**, **110**, **115**. The measurement data is transmitted to the wireless control device **130** to store in the measurement data storage **155** and analyzed by the intelligent analyzer **180** in the wireless control device **130**.

[0035] The thermal conductive cup **302** in the sensing unit **300** is electrically connected with the circuit substrate **216** by a conductive line **240**, which in turn establishes electrical communication between the thermal conductive cup **302** and the semiconductor chip **220**.

[0036] An elastic layer **250** is bonded to the stretchable and permeable substrate **205** by the adhesive layer **215** to the stretchable and permeable substrate **205**, and is also formed on the circuit substrate **216**, the sensing unit **300**, and the electrodes **212**A, **212**B. The elastic layer **250** can be formed by soft stretchable and permeable foam materials such as EVA, PE, CR, PORON, EPD, SCF, or fabric textile. A thin film **260** is formed on the elastic layer **250** for protection and cosmetic purposes.

[0037] In usage, an adhesive material formed on the lower surface of the stretchable and permeable substrate **205** is attached the user's skin, so that the bottom of the thermal conductive cup **302** is in tight contact with a user's skin to accurately measure temperature, electrical, or pressure signals from the user's skin, or apply electrical, thermal, or mechanical signals to the user's skin. The semiconductor chip **220** receives an electric signal from the temperature sensor **301** in response to a temperature measurement of the user's skin.

The Treatment Portion

[0038] In some embodiments, the electrically conductive cups **213**A, **213**B in the electrodes **212**A, **212**B are respectively electrically connected to the electric circuit in the circuit substrate **216** by conductive lines **214**A, **214**B (e.g. flexible ribbons embedded with conductive circuits). In accordance with the present application, the electrodes **212**A, **212**B can also be implemented in other configurations such as conductive pins, conductive pads, conductive buttons, or conductive strips. In response to a treatment control signal received by the antenna **230** from the treatment controller **160**, the semiconductor chip **220** can produce treatment electric signals, which can be amplified by an amplifier (not shown in FIG. **2**) with power supplied by the battery **225**, which are sent to the electrodes **212**A, **212**B via the conductive lines **214**A, **214**B.

[0039] In some embodiments, the electric voltage (typically in low amplitude) generated across the electrodes **212**A, **212**B is applied across the user's skin for therapeutic treatment. For example, such Cranial Electrotherapy Stimulation treatment can be applied across the electrode in one disclosed dual purpose wearable patch across a user's ear lobe (e.g. **110** in FIG. **1**) or across a user's wrist. In another example, electrical voltage signals can be applied across electrodes in two disclosed dual-purpose wearable patches (e.g. **105**, **110** in FIG. **1**). In this case, a thin conductive wire behind the user's neck can be tethered to the two dual-purpose wearable patches to provide proper ground for the voltage signals.

[0040] The semiconductor chip **220** can communicate with the wireless control device **130** via the antenna **230** in wireless signals. For example, the semiconductor chip **220** can receive a treatment sequence from the wireless control device **130**. The wireless signal can be based on using Wi-Fi, Bluetooth, Near Field Communication (NFC), and other wireless standards. The semiconductor chip **220** can general the treatment electric signals at durations, intervals, and amplitudes as defined in the treatment plan.

[0041] When the dual-purpose wearable patch **200** is worn by a user, the antenna **230** is separated from the user's skin by the circuit substrate **216** and the stretchable and permeable substrate **205**, which minimizes the impact of the user's body on the transmissions of wireless signals by the antenna **230**.

Dynamic Treatment

[0042] In some embodiments, measurement data obtained by the sensing unit **300** are analyzed by the intelligent analyzer **180** to product an analysis result. Based on the analysis result, the mode controller **170** can switch a networked wearable patch into a treatment mode. In response to a treatment control signal from the treatment controller **160** based on the measurement data, the semiconductor chip **220** can general treatment electric signals to control the durations, intervals, and amplitudes of the treatment field. For example, the electrotherapy stimulation treatment can be adjusted based on the user's skin temperature, heart beats, and blood pressure measured by the sensing unit **300**. User's bio vital signals may indicate user's stress levels, which can be treated by appropriate waveforms of electrical signals.

The Measurement Portion

[0043] In some embodiments, in the measurement portion of the disclosed dual-purpose wearable patch **200**, the sensing unit **300** includes a temperature sensor **301** in a thermal conductive cup **302**, which has its bottom portion mounted into the large opening **210**C and fixed to the stretchable and permeable substrate **205** by an adhesive. The temperature sensor **301** is electrically connected to the electric circuit in the circuit substrate **216** by a flexible conductive ribbon **303**. Referring to FIG. **3**, the bottom portion of the thermal conductive cup **302** protrudes out of the lower surface of the stretchable and permeable substrate **205**. The lips of the thermal conductive cup **302** near its top portion are fixedly attached or bonded to bonding pads (not shown) on the stretchable and permeable substrate **205** by soldering or with an adhesive. The thermal conductive cup **302** is both thermally and electrically conductive. The thermal conductive cup **302** can be made of a thermally conductive metallic or alloy material such as copper, stainless steel, ceramic or carbide composite materials.

[0044] The temperature sensor **301** is attached to an inner surface near the bottom of the thermal conductive cup **302**. The temperature sensor **301** can be implemented, for example, by a thermistor, a Resistor Temperature Detector, or a Thermocouple. The temperature sensor **301** is in thermal conduction with the thermal conductive cup **302**. When an outer surface of the bottom portion of the thermal conductive cup **302** is in contact with a user's skin, the thermal conductive cup **302** thus effectively transfers heat from a user's skin to the temperature sensor **301**. A flexible conductive ribbon **303** is connected to the temperature sensor **301** in the thermal conductive cup **302** and to the electric circuit in the stretchable and permeable substrate **205**.

[0045] The temperature sensor **301** can send an electric signal to the semiconductor chip **220** via the electric circuit in response to a measured temperature. The semiconductor chip **220** processes the electric signal and output another electrical signal that enables the antenna **230** to transmit a wireless signal carrying the measurement data to the wireless control device **130** (its wireless signals can be boosted by a charging and wireless boosting station). The measurement data is stored in the measurement data storage **155**. The wireless signal can be based on using Wi-Fi, Bluetooth, Near Field Communication (NFC), and other wireless standards. The battery **225** powers the semiconductor chip **220**, the antenna **230**, the first and the second electric circuits, and possibly the temperature sensor **301**.

[0046] The temperature sensor **301** can be fixed to an inner surface at the bottom of the thermal conductive cup **302** by a thermally conductive adhesive **304**, which allows effective heat transfer from the bottom of the thermal conductive cup **302** to the temperature sensor **301**. Examples of the thermally conductive adhesive **304** can include electrically insulative thermally conductive epoxies and polymers. A thermally insulating material **305** filling the top portion of the thermal conductive cup **302** fixes the thermally-conductive adhesive **304** at the bottom of the thermal conductive cup **302** and reduces heat loss from the temperature sensor **301** to the elastic layer (described below) or the environment. The flexible conductive ribbon **303** can be bent and laid out along the wall the thermal conductive cup **302**.

[0047] Further details of the sensing unit are disclosed in the commonly assigned co-pending U.S. patent application Ser. No. 15/224,121 "Wearable thermometer patch for accurate measurement of human skin temperature", filed Jul. 29, 2016, the disclosure of which is incorporated herein by reference.

[0048] In some embodiments, the sensing unit **300** includes an accelerometer that can measure acceleration and movement of the user. In some embodiments, the sensing unit **300** includes a pressure sensor or a force sensor that can measure the user's pulses or blood pressure during or outside treatments.

[0049] In some embodiments, the sensing unit **300** includes one or more electrodes for measuring ECG signals. The electrode can for example be structured in an electrically conductive cup similar to the thermal conductive cup **302** described above. The ECG signal (voltage) can be measured across two of the electrodes or across one of the electrodes and one of the electrodes **212**A, **212**B (used as ground). In particular, the ECG signals can be measured when the electrotherapy simulation treatment is not conducted.

[0050] In some embodiments, the sensing unit **300** can include multiple sensors for temperature, movement, blood pressure, moisture, and pulse measurements.

Dynamic Measurement

[0051] In some embodiments, the mode controller **170** can switch a networked wearable patch into a measurement mode in response to the types of treatment applied. Under the control of the measurement controller **150**, the semiconductor chip **220** can control the type(s), the timing, and frequencies of the measurement(s) by the sensing unit **300** based on the types of treatment applied. For example, based on the timing, the durations, intervals, and amplitudes of the treatment electric signals, the frequencies, the durations and the type(s) of the measurement(s) can be varied to more accurately and more timely monitor the user's health conditions.

Mode Switching

[0052] Under the control of the mode controller **170**, the semiconductor chip **220** can control the circuit to switch the sensing unit **300** and the electrodes **210**A, **210**B into or off from a measurement mode, or into or off from a treatment mode. The mode switching can be specified in the treatment plan received from the mode controller **170** in the wireless control device **130**, or dynamically adjusted according to the user's vital signals and responsiveness to treatment.

Personalized Medicine

[0053] Since the disclosed dual-purpose wearable patch is worn by an individual person, the disclosed dual-purpose patch is ideal for personalized medical treatment. Each treatment plan stored in the wireless control device **130** used to control treatment unit sin the networked wearable patches can be individualized according to the person's needs.

[0054] Moreover, the disclosed dual-purpose wearable patch can significantly enhance the effectiveness of individualized treatments for people. In particular, treatments can be dynamically adjusted according to the current condition of the user as indicated by the bio vital signals currently measured from the user.

Multi-Purpose Wearable Patch

[0055] In some embodiments, referring to FIGS. **1**C, **3**, **4**, a multi-purpose wearable patch **400**, which is suitable for the wearable patches **105**, **110**, **115** (FIG. **1**A, **1**B), includes a stretchable and permeable substrate **405** that includes openings **410**A, **410**B, **410**C. The stretchable and permeable substrate **405** can be made of soft foam materials such as EVA, PE, CR, PORON, EPD, SCF or fabric textile, to provide stretchability and breathability. A circuit substrate **416** and a battery **425** are bonded to the stretchable and permeable substrate **405** by an adhesive layer **415** prelaminated on the stretchable and permeable substrate **405**. The circuit substrate **416** includes an electric circuit therein and can for example be implemented with a printed circuit board. A semiconductor chip **420** and an antenna **430** are mounted on the circuit substrate **416**. Under the control of the semiconductor chip **420**, the antenna **430** can wirelessly communicate with the wireless control device **130**.

[0056] In the multi-purpose wearable patch **400**, the semiconductor chip **420** receives and processes different types of measurement signals from different sensing units. The measurement signals can reflect the user's health, mental, and psychological states. Under the control of the treatment controller **160**, the semiconductor chip **420** can also send out treatment signals for controlling treatment portion to conduct treatments on the user (e.g. thermal, electrical, mechanical, etc.).

[0057] The multi-purpose wearable patch **400** includes a measurement portion that includes a sensor unit **445** mounted in the opening **410**A and a sensing unit **300**

mounted in the opening **410**C, which is under the control of the measurement controller **150** in the wireless control device **130**. Under the control of the semiconductor chip **420**, the antenna **430** can wirelessly communicate with the wireless control device **130**. Measurement control signals are received from the measurement controller **150** to control the measurements conducted by the sensing unit **300** and other sensing unit(s) in the multi-purpose wearable patch **400**. The sensing unit **300** includes a temperature sensor **301** in a thermal conductive cup **302**, which has its bottom portion mounted into the large opening **410**C and fixed to the stretchable and permeable substrate **405** by an adhesive. The temperature sensor **301** is electrically connected to the electric circuit in the circuit substrate **416** by a flexible conductive ribbon **303**. When an outer surface of the bottom portion of the thermal conductive cup **302** is in contact with a user's skin, the thermal conductive cup **302** thus effectively transfers heat from a user's skin to the temperature sensor **301**. A flexible conductive ribbon (**303** in FIG. **3**) is connected to the temperature sensor **301** in the thermal conductive cup **302** and to the electric circuit in the stretchable and permeable substrate **405**. The temperature sensor **301** can send an electric signal to the semiconductor chip **420** via the electric circuit in response to a measured temperature. The measurement data is transmitted to the wireless control device **130** to store in the measurement data storage **155** and analyzed by the intelligent analyzer **180** in the wireless control device **130**. Details about the sensing unit **300** are described above in relation to FIG. **3**.

[0058] The thermal conductive cup **302** in the sensing unit **300** can be electrically conductive. The thermal conductive cup **302** is electrically connected with the circuit substrate **416** by a conductive line **440**, which establishes electrical communication between the thermal conductive cup **302** and the semiconductor chip **420**. When the thermally and electrically conductive cup **302** is in electric contact with a user's skin, the conductive cup **302** can pick up an EEG signal from the user's skin and then sends it to the semiconductor chip **420**. The measurement data is transmitted to the wireless control device **130** to store in the measurement data storage **155** and analyzed by the intelligent analyzer **180** in the wireless control device **130**.

[0059] The sensor unit **445** includes a cup **413**A and a mechanical sensor **412**A mounted in a window at the bottom of the cup **413**A. The mechanical sensor **412**A can detect a pressure or a vibration in the user skin or body when the bottom of the cup **413**A is in contact of the user's skin. The mechanical sensor **412**A can include a piezoelectric material that produce electrical signal in response to pressure or stress. In one implementation, the mechanical sensor **412**A can include a membrane coated with a piezoelectric material that produces an electrical signal in response to pressure, mechanical disturbances, or vibrations. In some implementations, the mechanical sensor **412**A is an integrated micro-mechanical electrical system (MEMS) device that can be micro-fabricated on a semiconductor substrate. When the mechanical sensor **412**A is in contact with user's skin, the vibrations or pressure variations caused by the user's heartbeats and blood pressure can be detected; the mechanical sensor **412**A sends a measurement signal to the semiconductor chip **420** via conductive lines **414**A. Once the measurement data is received from the semiconductor chip **420** and the antenna **430**, the measurement controller **150** and the intelligent analyzer **180** in the wireless control device **130**can extract the user's pulse and blood pressure information from the measurement data.

[0060] Other measurements compatible with the multi-purpose wearable patch can include movement, acceleration, moisture, etc.

[0061] The disclosed multi-purpose wearable patch **400** includes a treatment unit **470** under the control of the treatment controller **160** in the wireless control device **130** (FIG. **1**C). The treatment unit **470** includes a heater **412**B attached to a thermally conductive cup **413**B mounted in the opening **410**B. The heater **412**B can be a thermal resistor that produces heat when applied with a voltage. The heater **412**B is electrically connected to the electric circuit in the circuit substrate **416** via conductive lines **414**B can be controlled by the semiconductor chip **420**, which receives treatment sequences from the treatment controller **160**. In response to a treatment control signal received by the antenna **430** from the treatment controller **160**, the semiconductor chip **420** can produce treatment electric signals, which can be amplified by an amplifier (not shown in FIG. **4**) with power supplied by the battery **425**, which is sent to control the heater **412**B via the conductive lines **414**B. Under the control the treatment electric signals, the heater **412**B can produce heat to treat the user's skin and body. The heating can be applied in different waveforms such as static, pulses, and waveforms of varying frequencies. Heat treatments can be used to reduce or cure muscle or joint pains, mental stress, and to increase blood circulation, etc. As described above, the treatment unit **470** can also include electrodes that produce electrical voltage across the user's skin or body under the control of the semiconductor chip **420**. In general, the treatment unit **470** can produce treatment field(s) in the user the skin or body, such treatments including electrical, heat, mechanical, magnetic and other fields, which can provide therapy or relaxation to the user.

[0062] An elastic layer **450** is also bonded to the stretchable and permeable substrate **405** by the adhesive layer **415** to the stretchable and permeable substrate **405**, and is also formed on the circuit substrate **416**, the sensing unit **300**, the mechanical sensor **412**A, and the heater **412**B. The elastic layer **450** can be formed by soft stretchable and permeable foam materials such as EVA, PE, CR, PORON, EPD, SCF, or fabric textile. A thin film **460** is formed on the elastic layer **450** for protection and cosmetic purposes.

[0063] In usage, an adhesive material formed on the lower surface of the stretchable and permeable substrate **405** is attached the user's skin, so that the bottom of the thermal conductive cup **302** is in tight contact with a user's skin to accurately measure temperature, electrical, or pressure signals from the user's skin, or apply electrical, thermal, or mechanical signals to the user's skin. The semiconductor chip **420** receives an electric signal from the temperature sensor **301** in response to a temperature measurement of the user's skin.

[0064] Similar to the description above, the multi-purpose wearable patch **400** can conduct dynamic measurement and dynamic treatment for applications in personalized medicine. In dynamic measurement, the sensing unit **300** and the sensor unit **445** the type(s), the timing, and frequencies of the measurement(s) by the sensing unit **300** in response to the types of treatment applied by the heater **412**B under the control of the semiconductor chip **420**. For example, based on the timing, the durations, intervals, and amplitudes of the treatment electric signals, the timing, the frequencies, the durations and the type(s) of the measurement(s) can be varied to more accurately and more timely monitor the user's health conditions.

[0065] Similarly, in dynamic treatment, under the control of the treatment controller **160**, the semiconductor chip **420** can general the treatment electric signals at durations, intervals, and amplitudes based on the measurement data obtained from the sensing units **300**, **445**, as described below. For example, the electrotherapy stimulation treatment can be adjusted based on the user's skin temperature, heartbeats, and blood pressure measured by the sensing units **300**, **445**. User's bio vital signals may indicate user's stress levels, which can be treated by appropriate waveforms of electrical signals for heat or electrical treatments.

[0066] Furthermore, the mode controller **170** can control the semiconductor chip **420**, which in turn controls the circuit to switch the sensing units **300**, **445** and the heater **412**B between measurement mode, a treatment mode, a simultaneous measurement and treatment, an off mode, or a dynamic mode. The mode switching is controlled by commands from the mode controller **170** in the wireless control device **130**, or dynamically adjusted according to the user's vital signals and responsiveness to treatment.

[0067] Other details about wearable patches capable of performing measurement and charging functions are disclosed in commonly assigned U.S. patent application Ser. No. 15/423,585, titled "A wearable patch comprising three electrodes for measurement and charging", filed Feb. 3, 2017, commonly assigned U.S. patent application Ser. No. 15/406,380, titled "A wearable thermometer patch for correct measurement of human skin temperature", filed Jan. 13, 2017, and commonly assigned U.S. patent application Ser. No. 15/414,549, titled "A wearable thermometer patch for measuring temperature and electrical signals", filed Jan. 24, 2017. Other details about wearable patches capable of performing measurement and treatments are disclosed in commonly assigned U.S. patent application Ser. No. 15/457,532, titled "Dual purpose wearable patch for measurement", filed Mar. 13, 2017. The disclosures in the above applications are incorporated herein by reference.

[0068] The disclosed dual-purpose wearable patch and multi-purpose wearable patch are stretchable, compliant, durable, and comfortable to wear by users. The disclosed wearable thermometer patch includes a flexible substrate covered and protected by an elastic layer that increases the flexibility and stretchability.

[0069] Another advantage of the disclosed dual-purpose wearable patch and multi-purpose wearable patch is that it can significantly increase wireless communication range by placing the antenna on the upper surface of the circuit substrate. The thickness of the substrate as well as the height of the thermally conductive cup can be selected to allow enough distance between the antenna and the user's skin to minimize interference of user's body to the wireless transmission signals.

[0070] While this document contains many specifics, these should not be construed as limitations on the scope of an invention that is claimed or of what may be claimed, but rather as descriptions of features specific to particular embodiments. Certain features that are described in this document in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or a variation of a sub-combination.

[0071] Only a few examples and implementations are described. Other implementations, variations, modifications and enhancements to the described examples and implementations may be made without deviating from the spirit of the present invention.

What is claimed is:

1. A system of networked wearable patches, comprising:

a plurality of wearable patches each comprising:

a stretchable and permeable substrate;

a first sensing unit mounted in the stretchable and permeable substrate, the sensing unit configured to conduct a first measurement of a user to produce a first measurement signal; and

an antenna over the stretchable and permeable substrate and in electric communication with the first sensing unit, wherein the antenna is configured to wirelessly transmit measurement data based on the first measurement signal;

and

a wireless control device comprising a measurement controller configured to wirelessly transmit a measurement control signal to the antenna, wherein the first sensing unit is configured to conduct the first measurement in response to the measurement control signal, wherein the wireless control device is configured to wirelessly receive the measurement data from the antenna.

2. The system of networked wearable patches of claim **1**, wherein the wireless control device comprises a treatment controller,

wherein at least one of the plurality of wearable patches further comprises:

a treatment unit configured to produce a first treatment field in the user's body according to a treatment control signal,

wherein the treatment controller in the wireless control device is configured to wirelessly transmit the treatment control signal to the antenna.

3. The system of networked wearable patches of claim **2**, wherein the treatment unit includes a heater, wherein the treatment unit is configured to control the heater to produce heat in the user's body.

4. The system of networked wearable patches of claim **2**, wherein the treatment unit includes one or more electrodes, wherein the treatment unit is configured to apply a voltage between the one or more electrodes across the user's skin.

5. The system of networked wearable patches of claim **2**, wherein the treatment unit is configured to produce a second treatment field in the user's body based on the treatment control signal.

6. The system of networked wearable patches of claim **2**, wherein the treatment unit is configured to produce the first treatment field in the user's body in response to the first measurement signal.

7. The system of networked wearable patches of claim **2**, wherein the wireless control device further comprises an intelligent analyzer configured to analyze the measurement data to produce an analysis result, wherein the treatment controller in the wireless control device is configured to vary a type, timing, a frequency, or duration of the first treatment field in the user's body based on the analysis result.

8. The system of networked wearable patches of claim **7**, wherein the wireless control device comprises a mode controller configured to switch one of the networked wearable patches into a measurement mode based on the analysis result.

9. The system of networked wearable patches of claim **2**, wherein the measurement controller is configured to control the first sensing unit to vary a type, timing, a frequency, or duration of the first measurement of the user based on the first treatment field applied across the user's body.

10. The system of networked wearable patches of claim **9**, wherein the wireless control device comprises a mode controller configured to switch one of the networked wearable patches into a treatment mode based on a type of the first measurement.

11. The system of networked wearable patches of claim **2**, wherein the wireless control device comprises a mode controller that is configured to set at least one of the plurality of wearable patches in a measurement mode, or a treatment mode, or a combination thereof by controlling the treatment unit and the first sensing unit in the one of the plurality of wearable patches.

12. The system of networked wearable patches of claim **1**, wherein the first sensing unit includes a mechanical sensor configured to measure a pulse or blood pressure of the user's body.

13. The system of networked wearable patches of claim **1**, wherein the first sensing unit includes a temperature sensor configured to measure a temperature of the user's skin or body.

14. The system of networked wearable patches of claim **1**, further comprising:

a second sensing unit to conduct a second measurement of a user to produce a second measurement signal, wherein the antenna is configured to wirelessly transmit measurement data based on the first measurement signal and the second measurement signal.

15. The system of networked wearable patches of claim **14**, wherein the measurement controller in the wireless control device is configured to control the treatment unit to produce the first treatment field in the user's body in response to the first measurement signal and the second measurement signal.

16. The system of networked wearable patches of claim **14**, wherein the wireless control device further comprises an intelligent analyzer configured to analyze the measurement data to produce an analysis result, wherein the measurement controller in the wireless control device is configured to vary a type, a timing, a frequency, or duration of the first treatment field in the user's body based on the analysis result.

17. The system of networked wearable patches of claim **14**, wherein the second sensing unit includes a mechanical sensor configured to measure a pulse or blood pressure of the user's body, or a temperature sensor configured to measure a temperature of the user's skin or body.

18. The system of networked wearable patches of claim **1**, wherein at least one of the plurality of wearable patches further comprises:

a circuit electrically connected with the first sensing unit and the antenna; and

a semiconductor chip in connection with the circuit and configured to receive the first measurement signal from the first sensing unit,

wherein the semiconductor chip is configured to produce electric signals to enable the antenna to transmit the measurement data based on the first measurement signal.

19. The system of networked wearable patches of claim **18**, wherein at least one of the plurality of wearable patches further comprises:

a treatment unit configured to produce a first treatment field in the user's body,

wherein the antenna is configured to receive the treatment control signal from the wireless control device,

wherein the semiconductor chip is configured to control the treatment unit to produce the first treatment field in response to the treatment control signal.

20. The system of networked wearable patches of claim **18**, wherein at least one of the plurality of wearable patches further comprises:

a circuit substrate comprising the circuit and on the stretchable and permeable substrate, wherein the semiconductor chip and the antenna are mounted on the circuit substrate; and

a battery configured to supply power to the circuit and the semiconductor chip.

21. The system of networked wearable patches of claim **1**, wherein at least one of the plurality of wearable patches further comprises:

an elastic layer formed on the stretchable and permeable substrate, the circuit substrate, and the first sensing unit.

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