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(54) **WEARABLE PATCH COMPRISING THREE ELECTRODES FOR MEASUREMENT AND CHARGING**

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(52) **U.S. Cl.**

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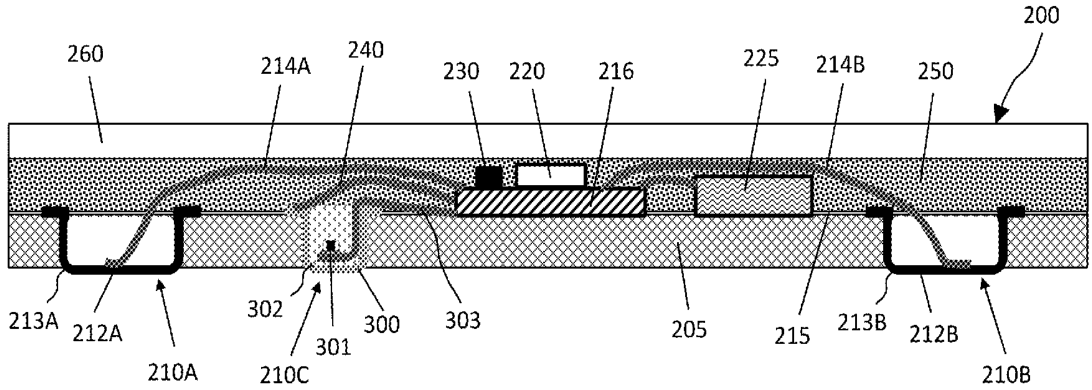
(57) **ABSTRACT**

A wearable patch includes a stretchable and permeable substrate, a temperature sensing unit mounted in the stretchable and permeable substrate, wherein the temperature sensing unit includes a first electrode configured to contact a user's skin, and a temperature sensor in thermal contact with the temperature sensor and configured to measure the user's skin temperature. The wearable patch includes a second electrode and a third electrode respectively attached to the stretchable and permeable substrate, a circuit substrate on the stretchable and permeable substrate, and a battery configured to supply power to the control circuit and the temperature sensor. The control circuit can select a first mode for measuring a user's skin temperature and a second mode for charging the battery by the charging station via the first electrode, the second electrode, and the third electrode.



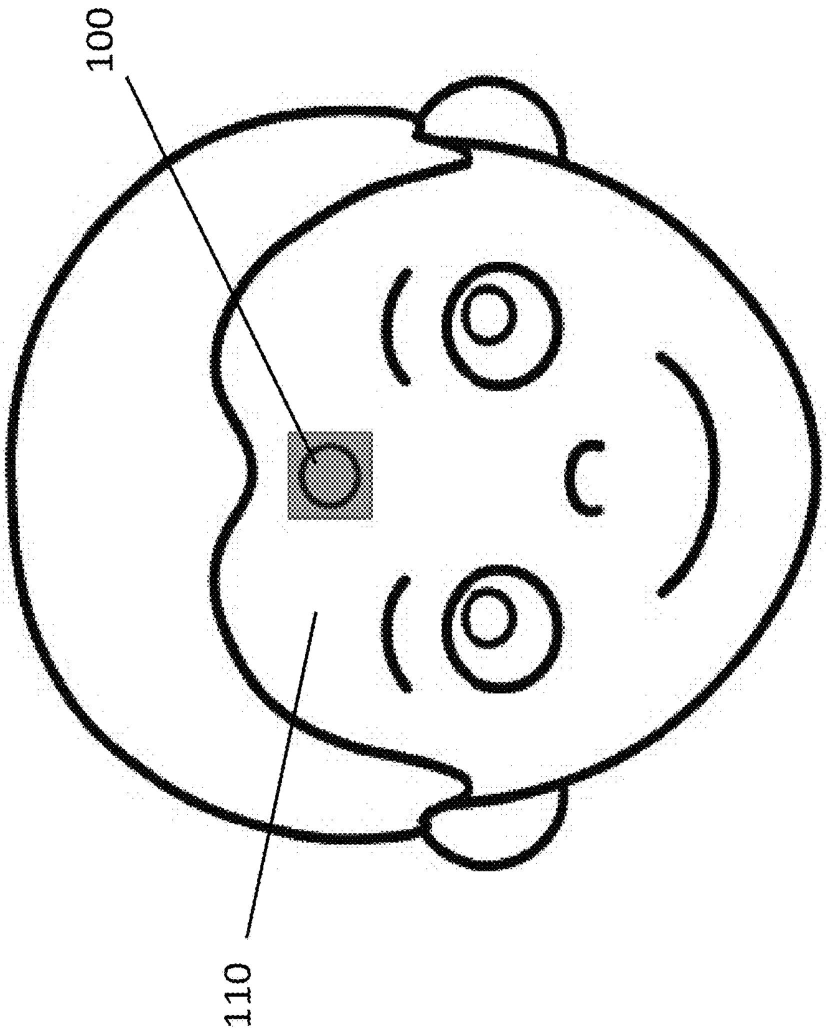


Figure 1

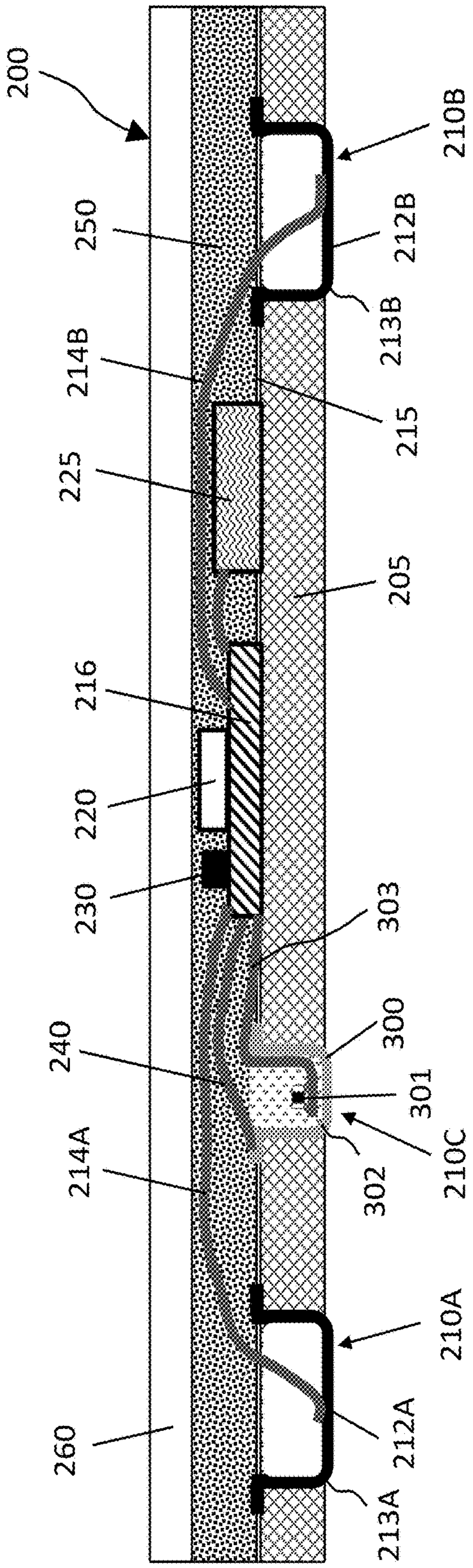

200
250
214B
225
216
220
230
240
214A
260
210B
212B
213B
215
205
303
300
301
210C
302
210A
212A
213A

Figure 2

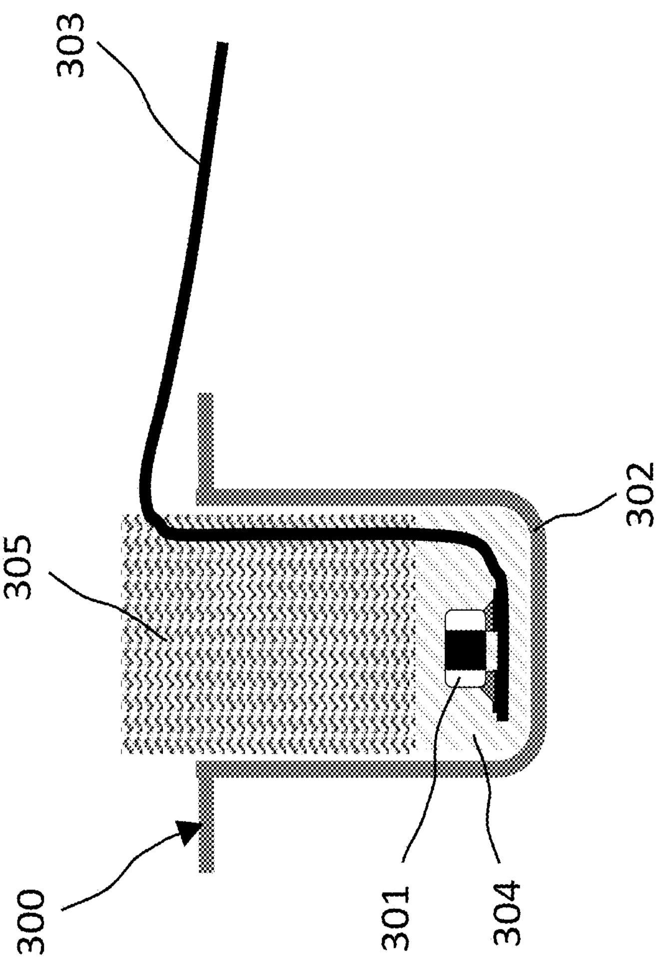


Figure 3

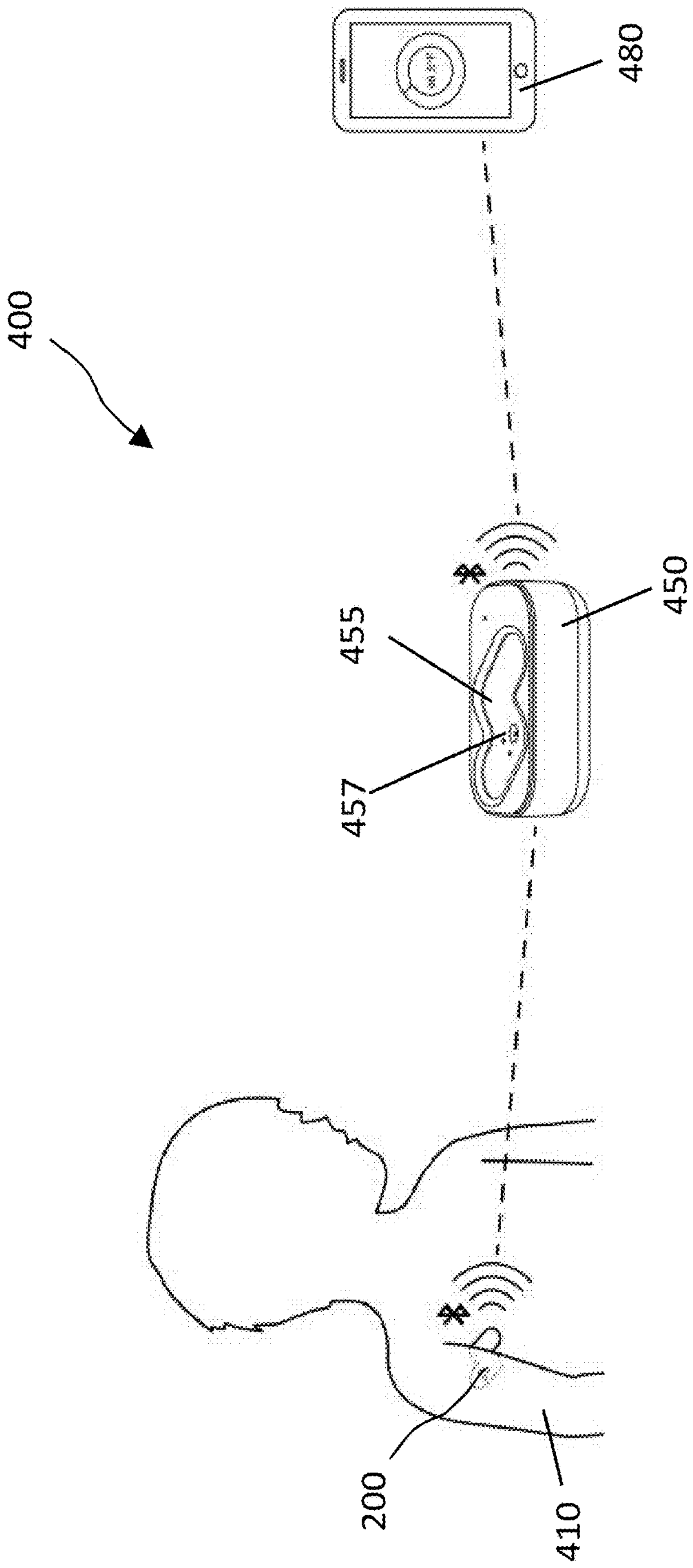


Figure 4

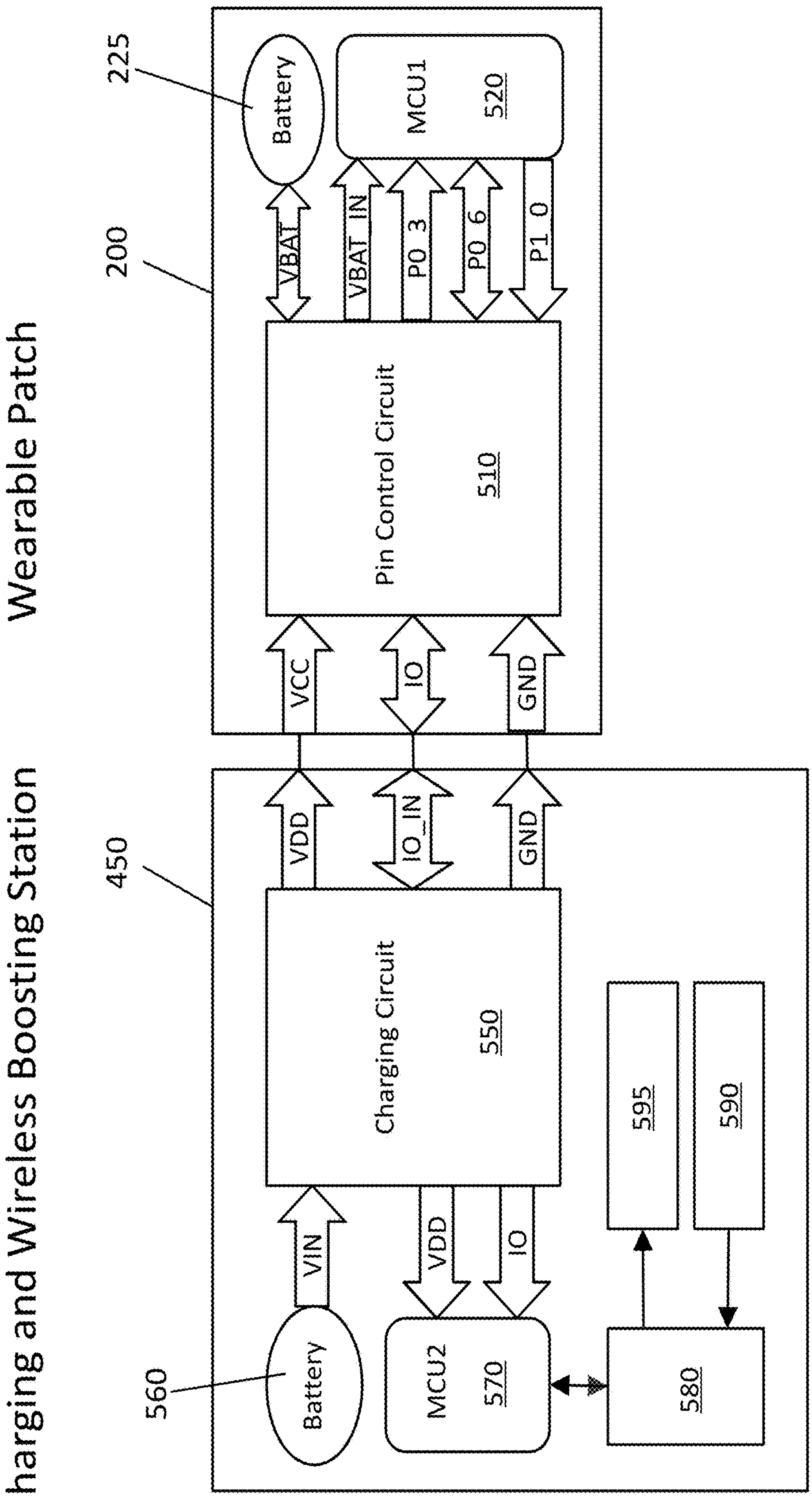

Wearable Patch
Charging and Wireless Boosting Station
225
200
450
560
Battery
MCU1
520
VBAT
VBAT_IN
P0_3
P0_6
P1_0
Pin Control Circuit
510
VCC
IO
GND
VDD
IO_IN
GND
Charging Circuit
550
VIN
VDD
IO
Battery
MCU2
570
580
595
590

Figure 5

State Machine for the Wearable Patch

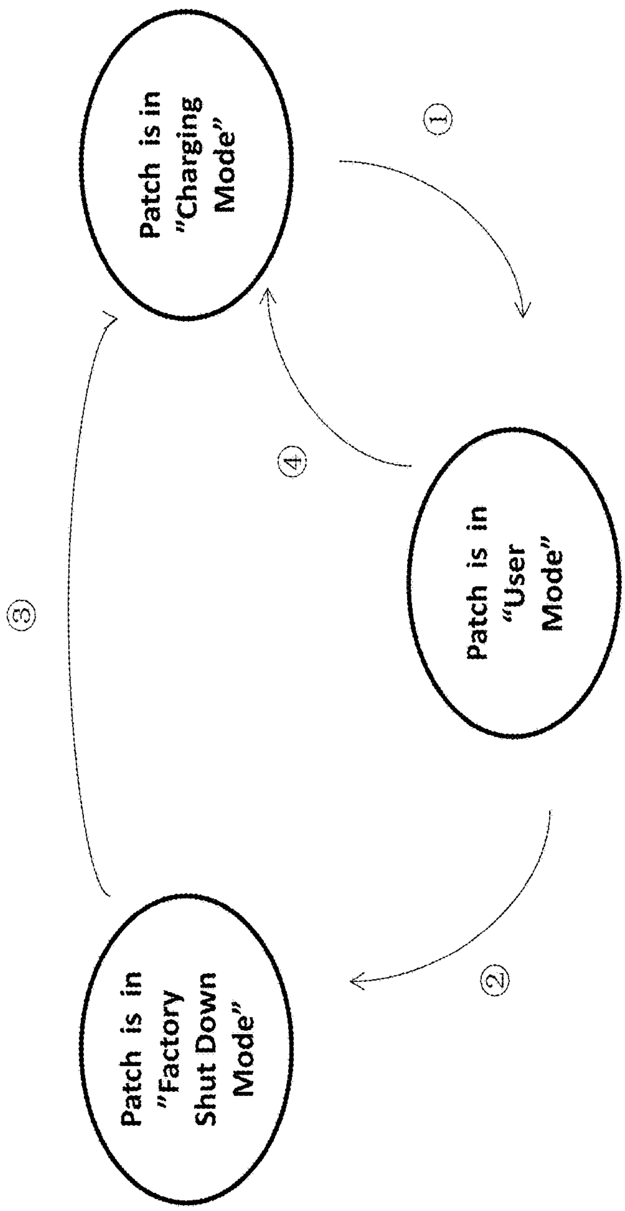


Figure 6

State Machine for Charging Circuit

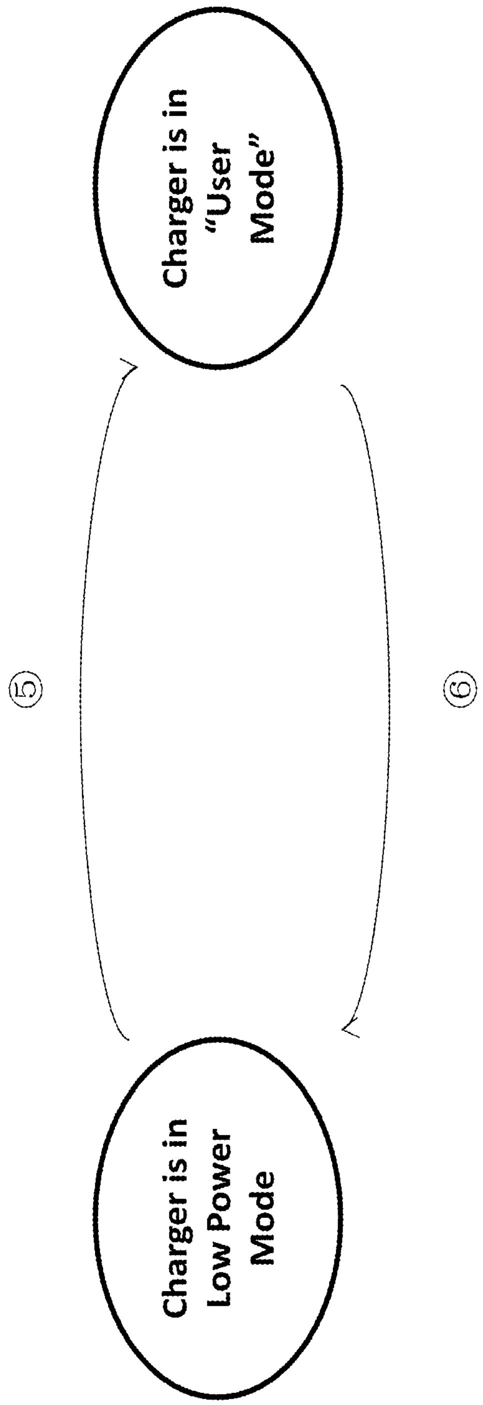


Figure 7

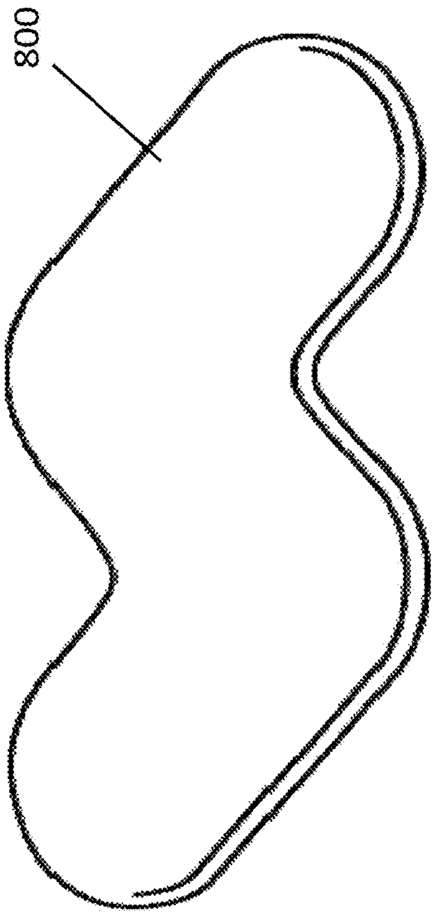


Figure 8A

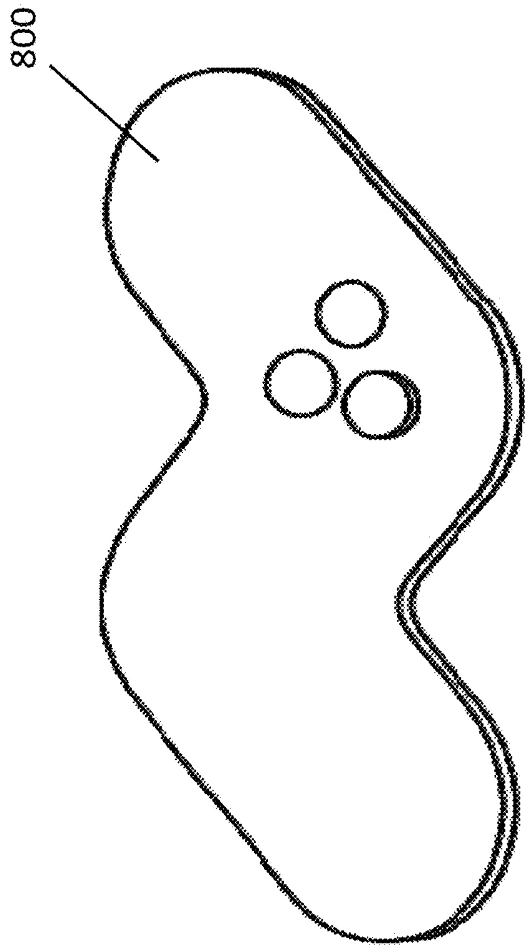


Figure 8B

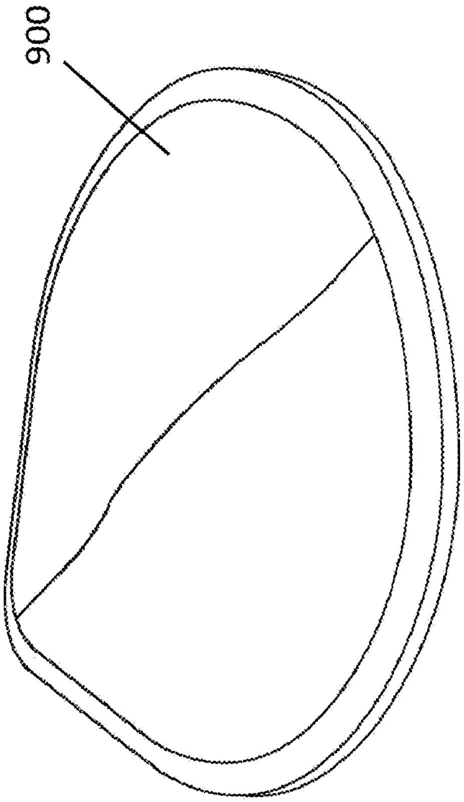


Figure 9A

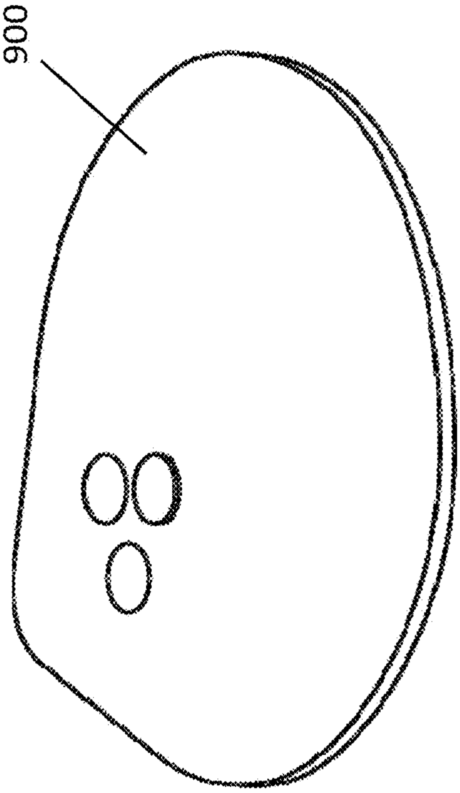


Figure 9B

WEARABLE PATCH COMPRISING THREE ELECTRODES FOR MEASUREMENT AND CHARGING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is also related to commonly assigned pending U.S. patent application Ser. No. 29/562,296, titled "Wearable thermometer having three electric pads", filed by the same inventors on Apr. 25, 2016, and commonly assigned pending U.S. patent application Ser. No. 29/562,367, titled "Wearable thermometer having three electric pads", filed by the same inventors on Apr. 25, 2016. The disclosures of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present application relates to electronic devices, and in particular, to wearable patches that can attach to human skin for conducting measurement.

[0003] 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.

[0004] Electronic patches can communicate with smart phones and other devices using WiFi, 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).

[0005] 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.

[0006] 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 of time from hours to months. A wearable patch can contain a micro-electronic system that can be accessed using NFC, Bluetooth, WiFi, or other wireless technologies. A wearable patch can be integrated with different sensors such as vital signs monitoring, motion track, skin temperature measurements, and ECG detection.

[0007] Despite recent development efforts, current wearable patches still suffer several drawbacks: they may not provide adequate comfort for users to wear them; they may not stay attached to user's body for the required length of time; and they are usually not aesthetically appealing. The conventional wearable patches also include rigid polymer substrates that are not very breathable. The build-up of sweat and moisture can cause discomfort and irritation to the skin, especially after wearing it for an extended period of time.

[0008] Conventional wearable thermometer patches have the additional challenge of inaccurate temperature measurement due to factors such as thermal resistance between the temperature sensor and the human skin, conduction loss of the temperature sensor to the ambient environment, as well as temperature reduction in the user skin caused by the thermal conduction to the wearable patch. Moreover, conventional wearable thermometer patches can also have slow measurement responses.

[0009] Another drawback of some conventional wearable patches is that they contain batteries that are charged by USB cable. This charging method is inconvenient when the user is not near a power source such as a power outlet or laptop.

[0010] Moreover, come conventional wearable patches have limited ranges of wireless communications because their compact sizes usually put constraints on the capacity of the batteries and amplifiers on board.

[0011] There is therefore a need for a flexible wearable electronic patch that can correctly measure temperatures of user's skin with high accuracy and fast response time, while capable of performing wireless communications in a required range.

SUMMARY OF THE INVENTION

[0012] The presently disclosure attempts to address the aforementioned limitations in conventional electronic patches. The presently disclosed wearable wireless patch that can be attached to human skin to conduct temperature measurements with high accuracy and faster respond time.

[0013] Moreover, disclosed wireless patch and charging station enable convenient charging of the disclosed wearable patch. The disclosed wearable patch includes three electrodes that can be electrically controlled to set the wearable patch to different states to accomplish the measurements and charging functions.

[0014] Furthermore, the present disclosure provides a system to effectively increase the wireless communication range of the disclosed wearable patch with external devices.

[0015] In one general aspect, the present invention relates to a wearable patch that includes a stretchable and permeable substrate, a temperature sensing unit mounted in the stretchable and permeable substrate, wherein the temperature sensing unit includes a first electrode configured to contact a user's skin; and a temperature sensor in thermal contact with the temperature sensor and configured to measure the user's skin temperature; a second electrode and a third electrode respectively attached to the stretchable and permeable substrate; a circuit substrate on the stretchable and permeable substrate, wherein the circuit substrate can include a control circuit electrically connected with the first electrode, the second electrode, and the third electrode; and a battery configured to supply power to the control circuit and the temperature sensor, wherein the first electrode, the second electrode, and the third electrode can form electric contacts with charging pins in a charging station when the wearable patch is docked in the charging station, wherein the control circuit can select a first mode for measuring a user's skin temperature and a second mode for charging the battery by the charging station via the first electrode, the second electrode, and the third electrode.

[0016] Implementations of the system may include one or more of the following. The wearable patch can further include a semiconductor chip mounted on the circuit substrate, wherein the semiconductor chip is configured to receive an electric signal from the temperature sensor in response to a temperature measurement of the user's skin. The wearable patch can further include an antenna mounted on the circuit substrate and in electric connection with the semiconductor chip, wherein the semiconductor chip can produce electric signals to enable the antenna to wirelessly exchange data with an external device, wherein the data include the temperature measurement of the user's skin. At least part of the control circuit can be fabricated in the semiconductor chip. The battery can be mounted on the stretchable and permeable substrate or the circuit substrate. The temperature sensing unit can include a conductive cup having a bottom portion mounted in a first opening in the stretchable and permeable substrate, wherein the conductive cup is thermally and electrically conductive, wherein the first electrode is in part formed by the conductive cup. The temperature sensor can be positioned inside and is in thermal conduction with the conductive cup. The temperature 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 second electrode and the third electrode each 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 and a third opening in which the electrically conductive cups are respectively mounted. The electrically conductive cups can be respectively electrically connected with the control circuit. The first electrode can be assigned to function as one of a power supply pin, an input/output pin, or a ground pin in the control circuit. The second electrode and the second electrode can be assigned to function as two of the power supply pin, the input/output pin, or the ground pin in the control circuit that are not selected by the first electrode. The wearable patch can further include an adhesive layer between the stretchable and permeable substrate and the circuit substrate. The wearable patch can further include an elastic layer formed on the stretchable and permeable substrate, the circuit substrate, and the temperature sensing unit.

[0017] In another general aspect, the present invention relates to a charging and wireless boosting station that includes a charging circuit comprising charging pins that can form electric contacts with electrodes on a wearable patch that is docked in the charging station; a first antenna that can receive a first wireless signal from a wearable patch and to produce a reception electric signal; a controller that can control the charging circuit to charge the wearable patch or to control conversion and amplification of the first wireless signal transmitted by the wearable patch; an amplifier module that can amplify the reception electric signal to produce an amplified electric signal under the control of the controller; and a second antenna that can transmit a second wireless signal in response to the amplified electric signal.

[0018] Implementations of the system may include one or more of the following. The charging and wireless boosting station can further include a charging port comprising the charging pins and configured dock the wearable patch. The charging and wireless boosting station can further include a first battery in connection with the charging circuit, the first battery that can charge a second battery in the wearable patch when the wearable patch is docked in the charging station. The charging pins can include a ground pin, a power supply pin, and an input/output pin. The charging circuit can control voltages of the charging pins to set the wearable patch in at least the following modes: a first mode for measuring signals from a user, a second mode in which the wearable patch is shut off, or a third mode in which the wearable patch is being charged by the charging and wireless boosting station.

[0019] 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

[0020] FIG. **1** illustrates a wearable patch attached to a user's skin.

[0021] FIG. **2** is an exemplified cross-sectional view of a wearable patch comprising three electrodes enabling temperature measurement and battery charging in accordance with some embodiments of the present invention.

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

[0023] FIG. **4** shows a station for charging and wireless boosting the disclosed wearable patch in accordance with some embodiments of the present invention.

[0024] FIG. **5** is a block circuit diagram showing circuits in the wearable patch and in the charging and wireless boosting station in accordance with some embodiments of the present invention.

[0025] FIG. **6** shows the states of the wearable patch in accordance with some embodiments of the present invention.

[0026] FIG. **7** shows the states of the charging and wireless boosting station in accordance with some embodiments of the present invention.

[0027] FIGS. **8**A and **8**B are respectively top and bottom perspective views of an exemplified wearable patch compatible with the present invention.

[0028] FIGS. **9**A and **9**B are respectively top and bottom perspective views of another exemplified wearable patch compatible with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0029] Referring to FIG. **1**, a wearable patch **100** is attached to a user's skin **110** for measuring body vital signs. The wearable patch **100** can be placed on forehead, hand, wrist, arm, shoulder, waist, leg, foot, armpit, or other parts of the body. In the present disclosure, the term "wearable patch" can also be referred to as "wearable sticker" or "wearable tag".

[0030] As discussed above, wearable electronic patches face several challenges: the user's skin **110** may interfere with their proper operations. For example, the wearable patch **100** may include an antenna for wireless communications with other devices. The antenna's communication range can be significantly reduced when an antenna is placed in contact with the user's skin **110**.

[0031] The presently disclosed wearable patch and system aim to overcome the drawbacks in conventional wearable patches, and to provide highly stretchable, compliant, durable, breathable, and comfortable wearable electronic patches while performing more accurate and more responsive measurements and communication functions.

[0032] Referring to FIGS. **2** and **3**, a wearable patch **200** includes a stretchable and permeable substrate **205** that include 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. A temperature sensing unit **300**, with details shown in FIG. **3**, is mounted in the opening **210**C. Two electrodes **212**A, **212**B, respectively comprising electrically conductive cups **213**A, **213**B, are mounted in the openings **210**A, **210**B. 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**. A semiconductor chip **220** and an antenna **230** are mounted on the circuit substrate **216**. The circuit substrate **216** includes an electric circuit therein and can for example be implemented with a printed circuit board.

[0033] 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.

[0034] The temperature sensing unit **300**, as described above, includes a conductive cup **302** having its bottom portion mounted into the large opening **210**C and fixed to the stretchable and permeable substrate **205** by an adhesive. A temperature sensor **301** is electrically connected to the electric circuit in the circuit substrate **216** by a flexible conductive ribbon **303**.

[0035] Referring to FIG. **3**, the conductive cup **302** has its bottom portion mounted into the large opening **210** and fixed to the stretchable and permeable substrate **205** by an adhesive. The bottom portion of the conductive cup **302** protrudes out of the lower surface of the stretchable and permeable substrate **205**. The lips of the 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 conductive cup **302** is both thermally and electrically conductive. The conductive cup **302** can be made of a thermally conductive metallic or alloy material such as copper, stainless steel, ceramic or carbide composite materials.

[0036] A temperature sensor **301** is attached to an inner surface near the bottom of the 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 conductive cup **302**. When an outer surface of the bottom portion of the conductive cup **302** is in contact with a user's skin, the 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 conductive cup **302** and to the electric circuit in the stretchable and permeable substrate **205**. 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 which enables the antenna **230** to transmit a wireless signal carrying the measurement data to another external device such as a mobile phone or a computer (its wireless signals, as described below, can be boosted by a charging and wireless boosting station). The wireless signal can be based on using WiFi, 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**.

[0037] The temperature sensor **301** can be fixed to an inner surface at the bottom of the conductive cup **302** by a thermally-conductive adhesive **304**, which allows effective heat transfer from the bottom of the 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 conductive cup **302** fixes the thermally-conductive adhesive **304** at the bottom of the 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 conductive cup **302**.

[0038] Further details of the temperature 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.

[0039] Referring back to FIG. **2**, the conductive cup **302** in the temperature sensing unit **300** is electrically connected with the circuit substrate **216** by a conductive line **240**, which in turn establishes electrical communication between the conductive cup **302** and the semiconductor chip **220**. In usage, as described in more detail below, the conductive cup **302** can be used as a third electrode in addition to the electrodes **212**A, **212**B.

[0040] An elastic layer **250** is formed on the stretchable and permeable substrate **205**, the circuit substrate **216**, the temperature 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.

[0041] 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 conductive cup **302** is in tight contact with a user's skin to accurately measure temperature and electric signals from 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.

[0042] The semiconductor chip **220** processes the electric signal and output another electrical signal which enables the antenna **230** to transmit a wireless signal carrying the measurement data to another external device such as a mobile phone or a computer. The wireless signal can be based on using WiFi, Bluetooth, Near Field Communication (NFC), and other wireless standards. When the 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**.

[0043] In some embodiments, referring to FIGS. **2** and **4**, a wireless sensing system **400** includes the wearable patch **200** and a charging and wireless boosting station **450**. The charging and wireless boosting station **450** includes a charging port **455** and charging pins **457** in the charging port **455**. The wearable patch **200** can be worn by a user **410**, or can be mounted on the charging and wireless boosting station **450** for charging its battery **225**.

[0044] When the wearable patch **200** is mounted onto the charging and wireless boosting station **450**, the bottom surfaces of the electrically conductive cups **213**A, **213**B in the electrodes **212**A, **212**B and the conductive cup **302** in temperature sensing unit **300** come to contact with the charging pins **457**, which allows the charging and wireless boosting station **450** to charge the battery **225** in the wearable patch **200**. More details about control and circuit for charging of the battery **225** are described in more detail below.

[0045] In operation, the wearable patch **200** is attached to the skin of the user **410**. The antenna **230** in the wearable patch **200** can transmit a wireless signal carrying measurement, status, or control data to an external device **480** such as a mobile phone or a computer device. In some embodiments, the charging and wireless boosting station **450** can be positioned near the user **410** and the wearable patch **200** and to boost the wireless signals of the wearable device. The wireless signals transmitted by the wearable patch **200** is received and then boosted or amplified by the charging and wireless boosting station **450**. Amplified wireless signals carrying the same measurement, status, or control data are transmitted by the charging and wireless boosting station **450** and received by the external device **480**. The boosting of wireless signals from the wearable patch **200** enables much wider range of communication between the wearable patch **200** and the external device **480**.

[0046] FIG. **5** is a block circuit diagram showing circuits in the wearable patch **200** and in the charging and wireless boosting station **450**. A pin control circuit **510** is configured to control the switching between the sensing mode (i.e. measurement of user skin temperature) and the charging mode (when the wearable patch **200** is docked on the charging and wireless boosting station **450**). The pin control circuit **510** can be part of the electric circuit in the circuit substrate **216** (FIG. **2**) or can be fabricated in the semiconductor chip **220** (FIG. **2**). The pin control circuit **510** powered by the battery **225** via pin VBAT in the wearable patch **200**. The pin control circuit **510** can supply power to a microcontroller **520** (MCU1) via pins VBAT_IN and communicate with the microcontroller **520** via several other pins. The microcontroller **520** can be implemented in the semiconductor chip **220** (FIG. **2**). In the charging and wireless boosting station **450**, the charging circuit **550** is powered by a battery **560** via pin VIN, and controlled by a micro controller **570** (MCU2). The battery **560** has much larger capacity than the battery **225** in the wearable patch **200**, and can be charged by a power outlet.

[0047] The pin control circuit **510** includes: a power supply pin VCC, an input/output pin IO, and a ground pin GND respectively corresponding to the electrodes **212**A, **212**B and the conductive cup **302** in temperature sensing unit **300** (FIG. **2**). For example, the conductive cup **302** can be designed to perform as one of a power supply pin VCC, an input/output pin IO, or a ground pin GND in the pin control circuit **510**. The electrodes **212**A, **212**B can be assigned to perform the functions of the rest of the two pins.

[0048] The charging circuit **550** includes: a power supply pin VDD, an input/output pin IO_IN, and a ground pin GND corresponding to the three charging pins **457** in the charging and wireless boosting station **450**. When the wearable patch **200** is docked on the charging and wireless boosting station **450**, the power supply pin VCC, IO, and GND pins of the pin control circuit **510** are respectively connected to the power supply pin VDD, IO_IN, and GND pins in the charging circuit **550**.

[0049] The different modes of the wearable patch and the corresponding logic states of the pin control circuit are summarized in Table I below and in FIG. **6**. When both the power supply pin VCC and IO are low, the wearable patch is in a normal working mode (i.e. it can measure temperature and other signals in normal operation). When the wearable patch is docked on a station with VCC set low and IO set high, the wearable patch is turned off in a factor shut-down mode, which can preserve the wearable patch in a long shelf life. When VCC is set high and IO set low, the wearable patch is in a charging mode in which the battery **225** is being charged; its wireless function (e.g. Bluetooth) is turned off. When both VCC and IO are set high, the wearable patch is in a charging mode; its wireless function (e.g. Bluetooth) is turned off.

TABLE I

Pin Control and Modes in the Wearable Patch

States	VCC	IO	Status
①	0 (input)	0 (input)	Patch normal working
②	0 (input)	1 (input)	Patch turned off
③	1 (input)	0 (output)	Patch is activated, charging, wireless function off
④	1 (input)	1 (output)	Patch charging and the wireless function off

[0050] Referring to FIGS. **5** and **7**, the charging circuit **550** can be in at least two modes: a user mode in which its charger is capable of charging a wearable patch **200**; and a lower power mode in which the battery **560** does not have enough power to charge a wearable patch **200**. The charging circuit **550** monitors the voltage level of the battery **560** and can prevents charging operation of the voltage level drops to below a threshold. In the user mode, the power in the battery **560** is enough for charging the battery **225** in the wearable patch **200**. Via pins VDD and VCC, and the GND pins. Moreover, the charging circuit **550** can be in a separate wireless boosting mode in which the charging circuit **550** is not charging and the controller **570** controls an amplifier module **580** to boost wireless signals from the wearable patch **200**.

[0051] In some embodiments, referring to FIGS. **4** and **5**, an antenna **590** receives wireless signals (comprising measurement, status of control data) from the antenna **230** in the wearable patch **200** and outputs reception electric signals. The amplifier module **580** amplifies the reception electric signals under the control of the controller **570**. The amplified reception electric signals are sent to another antenna **595** for a secondary wireless transmission with strong transmission power, which can be received by the external device **480**.

[0052] In some embodiments, still referring to FIGS. **4** and **5**, the charging and wireless boosting station **450** can include a down-converter that can convert reception RF signal from the antenna **590** to a base band reception signal. The controller **570** can process and analyze the base band reception signal before it sends another base band transmission signal to an up-converter (not shown) which converts it into an RF transmission signal such as BLE or WiFi, which is in turn transmitted by the antenna **595**.

[0053] The disclosed wearable patch is compatible with a variety of exterior designs. FIGS. **8**A and **8**B shows an exemplified design of a wearable patch **800** that is compatible with the above described wearable patch **200**, and the charging and wireless boosting station **450** in FIGS. **2** and **4**. FIGS. **9**A and **9**B shows another exemplified design of a wearable patch **900** that is compatible with the above described wearable patch **200** in FIG. **2**. The wearable patch in accordance with the present invention can be implemented in many other configurations. For example, the three electrodes can be positioned along a line or in a triangular fashion as shown in FIGS. **8**A-**9**B.

[0054] The disclosed wearable patch can significantly enhance measurement accuracy and responsiveness, and reduce thermal noise. The temperature sensor is positioned very close to a user's skin. The temperature sensor is placed at the bottom of a thermally conductive cup and in good thermal conduction with the user's skin. The minimized thermal resistance between the temperature sensor and the user's skin reduces temperature measurement error and also decreases measurement response time. Moreover, the temperature sensor is secured fixed by an adhesive to the bottom of the thermally conductive cup such that the temperature sensor is not affected and detached by user's body movements, which improves durability of the wearable patch. Furthermore, the temperature sensor is thermally isolated with the ambient environment by a thermal insulating material in the top portion of the thermally conductive cup. The reduced thermal capacity helps further reduces background noise in the measurements of user's skin temperature and increase response rate of measurement. A layer of soft perforated polymer material under the flexible substrate minimizes heat conduction from the user's skin to the wearable patch, thus reducing the "cooling effect" of the user's skin by the wearable patch.

[0055] Another advantage of the disclosed wearable patch is that it is 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.

[0056] Yet another advantage of the disclosed 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.

[0057] The disclosed wearable patches can also include electronic components such as the semiconductor chips, resistors, capacitors, inductors, diodes (including for example photo sensitive and light emitting types), other types of sensors, transistors, amplifiers. The sensors can also measure temperature, acceleration and movements, force, strain and stress, and chemical or biological substances. The semiconductor chips can perform communications, logic, signal or data processing, control, calibration, status report, diagnostics, and other functions.

[0058] 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.

[0059] 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 wearable patch, comprising:

a stretchable and permeable substrate;

a temperature sensing unit mounted in the stretchable and permeable substrate, wherein the temperature sensing unit comprises:

a first electrode configured to contact a user's skin; and

a temperature sensor in thermal contact with the temperature sensor and configured to measure the user's skin temperature;

a second electrode and a third electrode respectively attached to the stretchable and permeable substrate;

a circuit substrate on the stretchable and permeable substrate, wherein the circuit substrate comprises a control circuit electrically connected with the first electrode, the second electrode, and the third electrode; and

a battery configured to supply power to the control circuit and the temperature sensor, wherein the first electrode, the second electrode, and the third electrode are configured to form electric contacts with charging pins in a charging station when the wearable patch is docked in the charging station, wherein the control circuit is configured to select a first mode for measuring a user's skin temperature and a second mode for charging the battery by the charging station via the first electrode, the second electrode, and the third electrode.

2. The wearable patch of claim **1**, further comprising:

a semiconductor chip mounted on the circuit substrate, wherein the semiconductor chip is configured to receive an electric signal from the temperature sensor in response to a temperature measurement of the user's skin.

3. The wearable patch of claim **2**, further comprising:

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 data with an external device, wherein the data include the temperature measurement of the user's skin.

4. The wearable patch of claim **2**, wherein at least part of the control circuit is fabricated in the semiconductor chip.

5. The wearable patch of claim **1**, wherein the battery is mounted on the stretchable and permeable substrate or the circuit substrate.

6. The wearable patch of claim **1**, wherein the temperature sensing unit includes a conductive cup having a bottom portion mounted in a first opening in the stretchable and permeable substrate, wherein the conductive cup is thermally and electrically conductive, wherein the first electrode is in part formed by the conductive cup.

7. The wearable patch of claim **6**, wherein the temperature sensor is positioned inside and is in thermal conduction with the conductive cup.

8. The wearable patch of claim **7**, wherein the temperature sensing unit comprises:

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.

9. The wearable patch of claim **1**, wherein the second electrode and the third electrode each comprising 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 and a third opening in which the electrically conductive cups are respectively mounted.

10. The wearable patch of claim **9**, wherein the electrically conductive cups are respectively electrically connected with the control circuit.

11. The wearable patch of claim **1**, wherein the first electrode is assigned to function as one of a power supply pin, an input/output pin, or a ground pin in the control circuit.

12. The wearable patch of claim **11**, wherein the second electrode and the second electrode are assigned to function as two of the power supply pin, the input/output pin, or the ground pin in the control circuit that are not selected by the first electrode.

13. The wearable patch of claim **1**, further comprising:

an adhesive layer between the stretchable and permeable substrate and the circuit substrate.

14. The wearable patch of claim **1**, further comprising:

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

15. A charging and wireless boosting station, comprising:

a charging circuit comprising charging pins configured to form electric contacts with electrodes on a wearable patch that is docked in the charging station;

a first antenna configured to receive a first wireless signal from a wearable patch and to produce a reception electric signal;

a controller configured to control the charging circuit to charge the wearable patch or to control conversion and amplification of the first wireless signal transmitted by the wearable patch;

an amplifier module configured to amplify the reception electric signal to produce an amplified electric signal under the control of the controller; and

a second antenna configured to transmit a second wireless signal in response to the amplified electric signal.

16. The charging and wireless boosting station of claim **15**, further comprising:

a charging port comprising the charging pins and configured dock the wearable patch.

17. The charging and wireless boosting station of claim **15**, further comprising:

a first battery in connection with the charging circuit, the first battery configured to charge a second battery in the wearable patch when the wearable patch is docked in the charging station.

18. The charging and wireless boosting station of claim **15**, wherein the charging pins comprise a ground pin, a power supply pin, and an input/output pin.

19. The charging and wireless boosting station of claim **15**, wherein the charging circuit is configured to control voltages of the charging pins to set the wearable patch in at least the following modes: a first mode for measuring signals from a user, a second mode in which the wearable patch is shut off, or a third mode in which the wearable patch is being charged by the charging and wireless boosting station.

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