



US 20180294552A1

(19) **United States**

(12) **Patent Application Publication**
Erentok et al.

(10) **Pub. No.: US 2018/0294552 A1**

(43) **Pub. Date: Oct. 11, 2018**

(54) **ANTENNA ON TRANSPARENT SUBSTRATE**

G06F 1/16 (2006.01)

H05K 1/09 (2006.01)

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

CPC **H01Q 1/273** (2013.01); **H01Q 7/00** (2013.01); **H01Q 1/241** (2013.01); **G06F 1/163** (2013.01); **H05K 1/09** (2013.01); **G06F 3/0412** (2013.01)

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(57) **ABSTRACT**

(21) Appl. No.: **15/485,035**

Apparatuses and methods associated with an antenna formed on a transparent substrate are disclosed herein. In embodiments, an electronic device may include a substrate, wherein at least a first region of a plurality of regions of the substrate is transparent; and a plurality of layers formed on the substrate, the plurality of layers including: a first transparent layer formed over the first region; and a second metal layer formed over a second region of the plurality of regions of the substrate, wherein the second metal layer comprises an antenna.. Other embodiments may be disclosed or claimed.

(22) Filed: **Apr. 11, 2017**

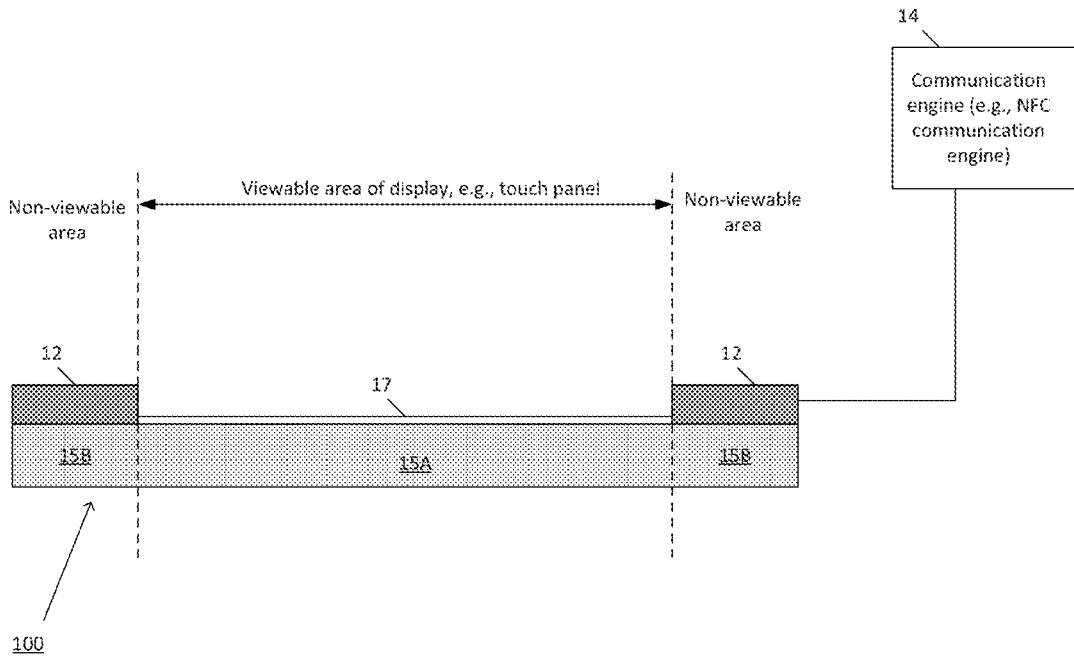
Publication Classification

(51) **Int. Cl.**

H01Q 1/27 (2006.01)

H01Q 7/00 (2006.01)

G06F 3/041 (2006.01)



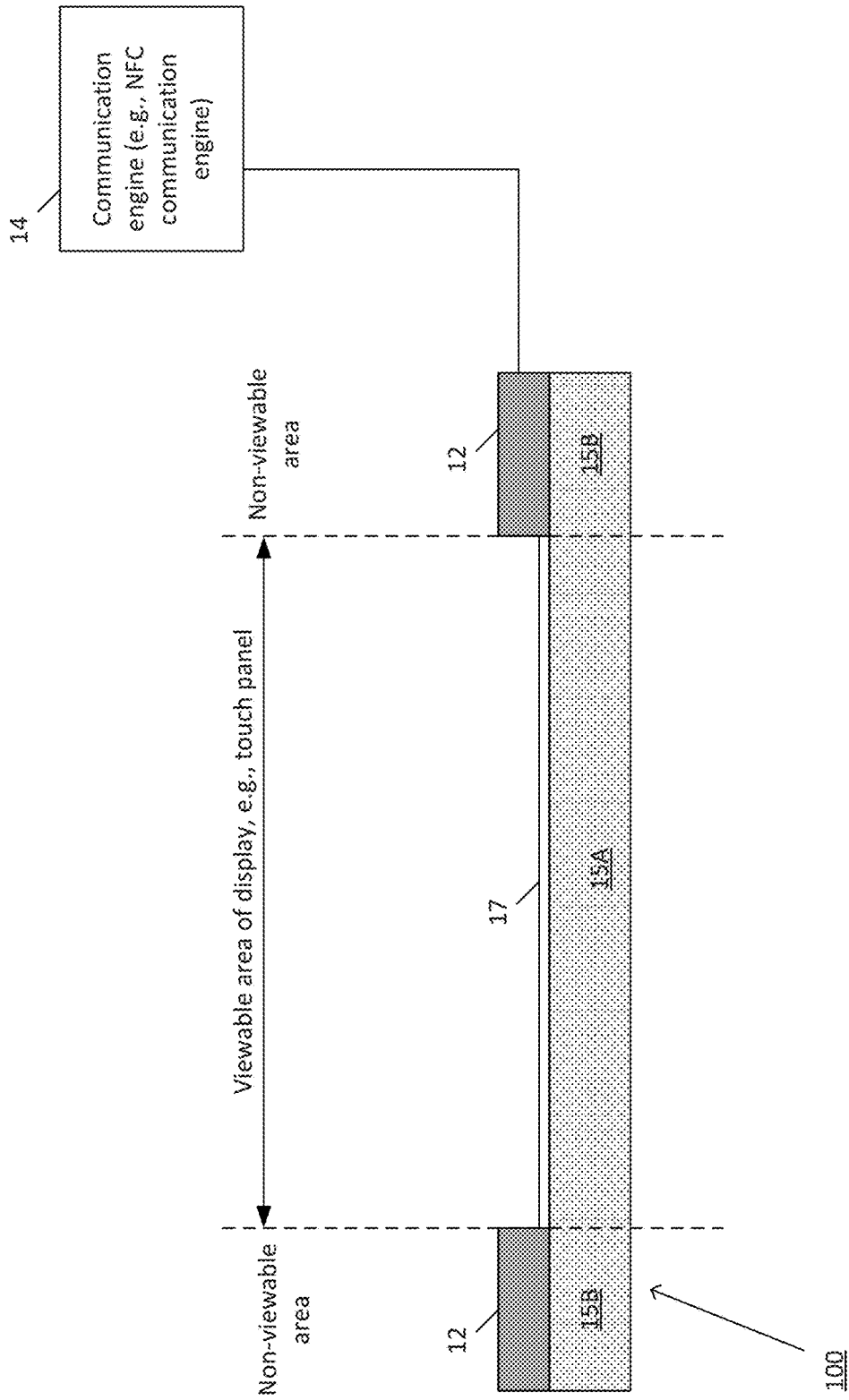


FIG. 1

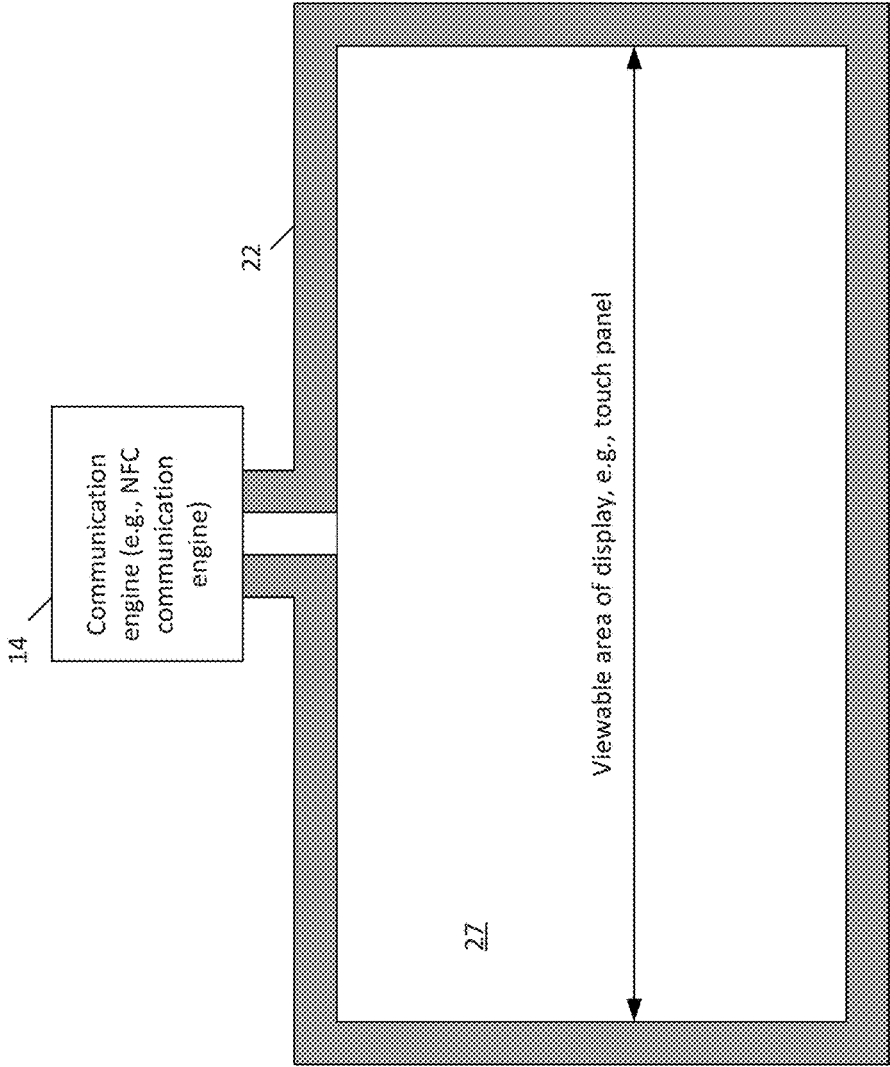


FIG. 2

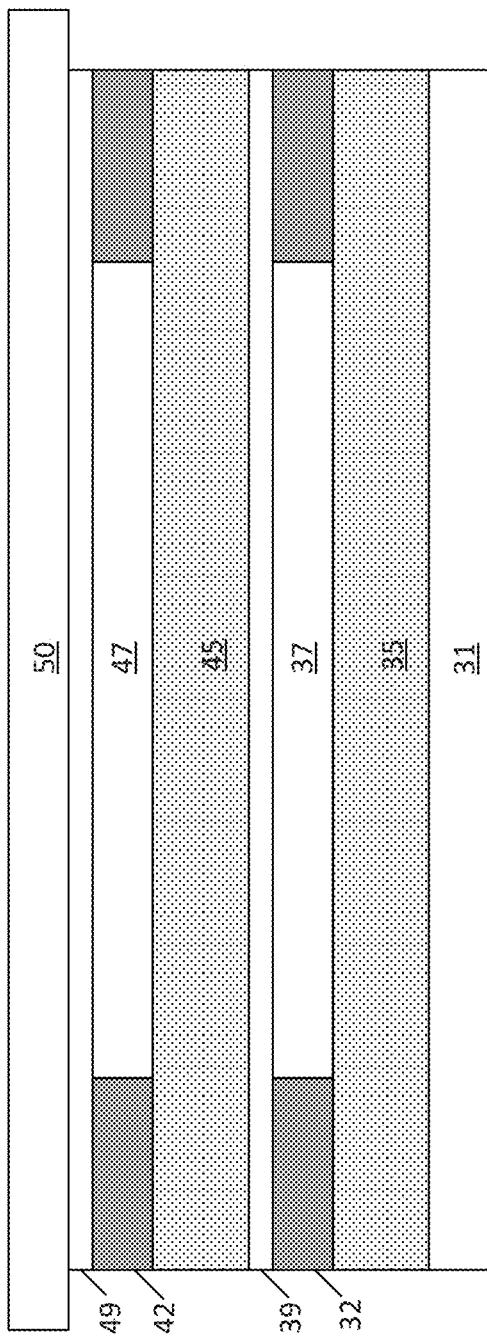
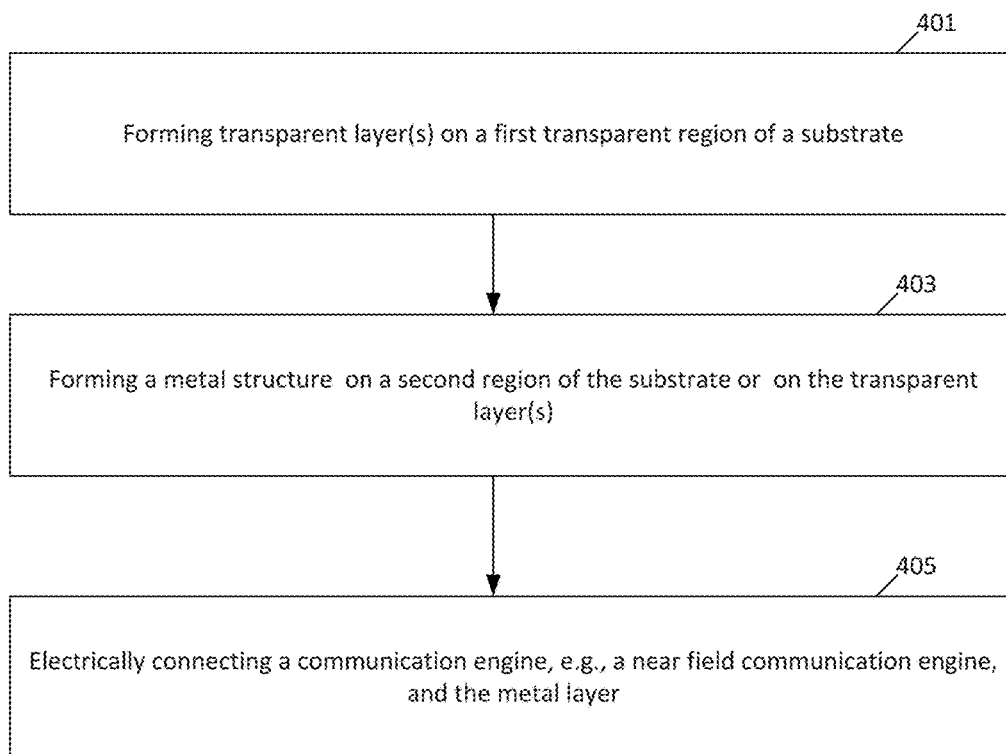


FIG. 3

200



400

FIG. 4

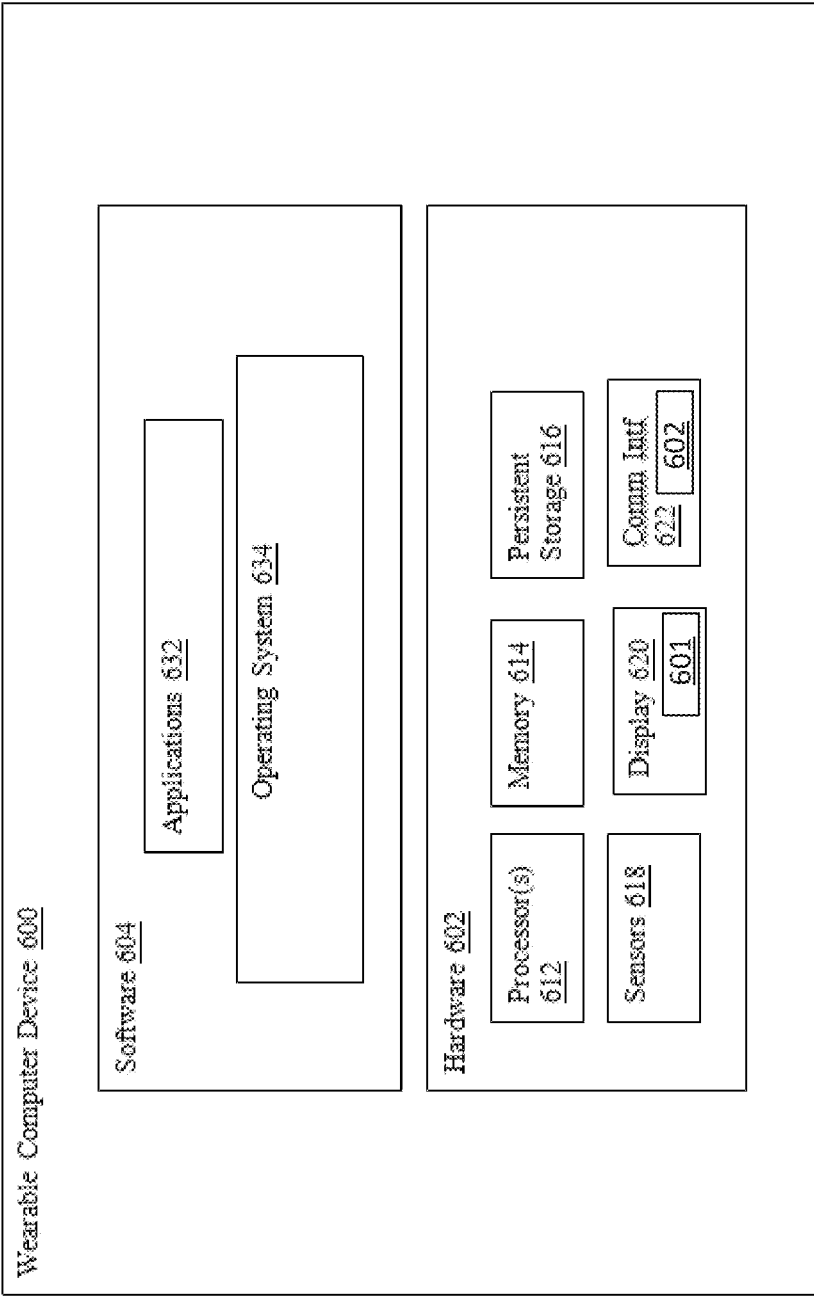


FIG. 5

ANTENNA ON TRANSPARENT SUBSTRATE

TECHNICAL FIELD

[0001] The present disclosure relates to the field of electronic devices utilizing antennas and displays, e.g., touch panels. More specifically, the present disclosure is related to an antenna on a transparent substrate.

BACKGROUND

[0002] The background description provided herein is for the purpose of generally presenting the context of the disclosure. Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0003] With advances in integrated circuits and computing technology, portable wearable computer devices, such as smart watches, are becoming increasingly popular. Some wearable computer devices such as connected wearable devices may support BT (Bluetooth®), BT LE (low energy), Wi-Fi, NFC (near field communications), LTE (long term evolution), or the like, or combinations thereof

[0004] To support these protocols and maintain a small form factor, antenna placement may be important. In a wrist worn device supporting Bluetooth and/or Wi-Fi, a metal body of the wrist worn device may be electrically coupled to the Bluetooth transceiver and/or Wi-Fi transceiver to be utilized as the antenna. In another example of compact design, in an electronic device including an NFC antenna and a touch panel, an indium tin oxide (ITO layer) of the touch panel may be electrically coupled to an NFC communication engine to be utilized as the NFC antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Embodiments will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

[0006] FIG. 1 illustrates a cross-section view of a system including an antenna on a transparent substrate.

[0007] FIG. 2 illustrates a top view of the antenna of the system of FIG. 1.

[0008] FIG. 3 illustrates a cross-section view of a touch module including antennas on transparent substrates of receive and transmits sections of the touch module.

[0009] FIG. 4 is a flow chart showing a process of forming an antenna on a transparent substrate.

[0010] FIG. 5 illustrates example architecture of a wearable computer device, in accordance to various embodiments.

DETAILED DESCRIPTION

[0011] Apparatuses, methods and storage medium associated with an antenna on a transparent substrate are disclosed herein. In embodiments, an electronic device may include a substrate, wherein at least a first region of a plurality of regions of the substrate is transparent; and a plurality of layers formed on the substrate, the plurality of layers including: a first transparent layer formed over the first region; and a second metal layer formed over a second region of the

plurality of regions of the substrate, wherein the second metal layer comprises an antenna.

[0012] In the description to follow, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of embodiments is defined by the appended claims and their equivalents.

[0013] Operations of various methods may be described as multiple discrete actions or operations in turn, in a manner that is most helpful in understanding the claimed subject matter. However, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations may not be performed in the order of presentation. Operations described may be performed in a different order than the described embodiments. Various additional operations may be performed and/or described operations may be omitted, split or combined in additional embodiments.

[0014] For the purposes of the present disclosure, the phrase “A and/or B” means (A), (B), or (A and B). For the purposes of the present disclosure, the phrase “A, B, and/or C” means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0015] The description may use the phrases “in an embodiment,” or “in embodiments,” which may each refer to one or more of the same or different embodiments. Furthermore, the terms “comprising,” “including,” “having,” and the like, as used with respect to embodiments of the present disclosure, are synonymous.

[0016] As used hereinafter, including the claims, the term “module” or “routine” may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs having executable instructions, a combinational logic circuit, and/or other suitable components that provide the described functionality.

[0017] An NFC antenna design may integrate an NFC antenna with a display via placement of a ferrite backed coil under a low density LCD (liquid-crystal display) display. The use of the ferrite backed coil under a low density LCD display may provide a sufficient quality factor (Q) value to fulfill NFC system properties needed for proper Tx/Rx functionalities. The Q value of an antenna refers to a ratio of stored energy to lost energy for a given periodic cycle of the given system. However, in a higher density display, use of the ferrite backed coil may be undesirable and/or unfeasible for a variety of reasons.

[0018] In another NFC antenna design for a device including a touch panel, a transparent conducting oxide film of the touch panel may be electrically coupled to an NFC communication engine to be utilized as the antenna. However, the transparent conducting oxide may have a relatively high resistivity and for this and/or other reasons, such a system may also have an undesirably low Q value. Some embodiments herein may include low impedance and/or a high Q value integrated single-ended and/or differential fed NFC

antenna within a touch module layer. The antenna may be composed of a material having higher conductivity than a transparent conducting oxide.

[0019] In some embodiments, an NFC stack-up of some embodiments may be thinner than a legacy NFC stack-up that includes ferrite polymer composite (FPC), ferrite, and adhesives. The reduced thickness NFC stack-up may be used for a thin device including a touch panel and an antenna formed on a transparent substrate of the touch panel.

[0020] FIG. 1 illustrates a cross-section view of a system including an antenna on a transparent substrate **100**, such as polyethylene terephthalate (PET). The transparent substrate **100** may include a first substrate region **15A** of a viewable area of a display (e.g., a touch panel), and a second substrate region **15B**, which may surround (e.g., fully surround) the first substrate region **15A** and may or may not be transparent. A transparent layer **17**, e.g., a transparent conductive oxide such as an ITO film, may be formed on (e.g., deposited on) the first substrate region **15A**.

[0021] One or more layers **12** to provide a conductive structure (e.g., a metal, such as Ag) may be formed on the second substrate region **15B**. In some embodiments, the one or more layers **12** may not include any portion of the transparent layer **17**, and in such examples the conductive structure of the one or more layers **12** may be formed directly on the substrate region **15B**. In other embodiments, the transparent layer **17** may extend over both substrate regions **15A-B**, and the conductive structure may be formed on a dielectric layer formed on a portion of the transparent layer **17** on the second substrate region **15B**. The conductive structure of the one or more layers **12** may be electrically connected to a communication engine **14** (e.g., to differential outputs of an NFC communication engine, an RF engine, or the like, or combination thereof).

[0022] FIG. 2 illustrates a top view of an antenna **22** that includes the conductive structure of the one or more layers **12** of FIG. 1. In the illustrated embodiment, the antenna **22** is a single loop antenna; however, in other examples the antenna may include more than one loop (e.g., a dual loop antenna). In the illustrated embodiment, a shape of the antenna **22** corresponds to a perimeter of a rectangular display **27**. However, in other examples an antenna may be a shape that does not correspond to the perimeter of a rectangular display. For instance, a round shaped antenna may be utilized in a watch with a rectangular display (for instance a rectangle coinciding with a perimeter of a rectangular display may fit inside a circle to which a round-shaped antenna corresponds). The antenna **22** may include terminals coupled directly to the communication engine **14**, or in other embodiments the terminals may be connected through other components (wires and/or a touch panel flex, etc.) that connect the antenna **22** and the communication engine **14**.

[0023] Some embodiments include a touch module (e.g., a resistive touch module and/or a capacitive touch panel module) with an integrated differential fed NFC antenna pattern. The antenna pattern may incorporate a same metal used for touch panel routing and may include a differential feeding design. The antenna pattern may run along an outer periphery of sensor electrode routing, and may be separated from sensor lines of the touch panel via ground lines. Referring to FIG. 1, the one or more layers **12** may include

the antenna **22** and at least one of a routing component and/or an ESD (electrostatic discharge) protection component.

[0024] A differential fed NFC antenna pattern may be connected to a circuit board corresponding to the communication engine using available touch panel flex. A galvanic connection between the NFC antenna pattern and NFC signal lines on the touch panel flex may be formed using an ACF (anisotropic conductive film) bonding process in some embodiments.

[0025] The improved Q-value differential fed NFC antenna design as compared to an ITO line based design may be substantial. Some embodiments including the features described herein may have **300nH** and **1** for the inductance and Q values, respectively, and/or may have ten times or more improvement of at least some parameters such as the Q value compared to an ITO line based design. The utilization of metals of touch panel routing technology may reduce losses due to the lower metal sheet resistance. A single-fed NFC antenna design can be also utilized by terminating one of the antenna lines with available grounding traces.

[0026] The NFC antenna may be part of one or both of an Rx layer and/or Tx layer of a touch module. For instance, the transparent substrate **100** may be of a transparent substrate of an Rx layer or a Tx layer of a touch module.

[0027] Transparent substrate **100** may be formed from a single layer or may include more than one layer laminated together or otherwise integrated to form the transparent substrate **100**. A layer or material described as transparent may be optically permissible to at least some wavelengths of visible light. A transparent layer or material may appear non-opaque, e.g., clear, tinted, translucent, or the like.

[0028] FIG. 3 illustrates a cross-section view of a touch module **200** including antennas on transparent substrates **35** and **45** of receive and transmits sections of the touch module **200**. Transparent substrate **35** may be similar to the transparent substrate **100** (FIG. 1). Transparent substrate **35** may correspond to one of receive or transmit sections of the touch module **200**, and may be formed on a display stack **31** of a touch module. The other substrate **45** may be of the other of the receive section and transmit section of the touch module **200**. Transparent layers **37** and **47** may be formed on transparent substrates **35** and **45**, respectively, and may be similar to transparent layer **17** (FIG. 1). One or more layers **32** and one or more layers **42** may be formed on the transparent substrates **35** and **45**, respectively, and may be similar to one or more layers **12** (FIG. 1). Antennas corresponding to the illustrated one or more layers **32** and the one or more layers **42** may be electrically coupled to transmit and receive modules of a transceiver and/or communication engine.

[0029] A cover lens **50** (e.g., glass) may be coupled to the one or more layers **42** and/or the transparent layer **47** via an OCA (optical clear adhesive) **49**. Also, an OCA **39** may couple the receive section and the transmit sections (e.g., OCA **39** may couple transparent substrate **45** to one or more layers **32** and/or transparent layer **37**, as illustrated).

[0030] FIG. 4 is a flow chart showing a process **400** of forming an antenna on a transparent substrate. In block **401**, a transparent layer(s) is/are formed on (e.g., directly on) a first transparent region of a substrate. In some examples, an IMO layer may be deposited on a transparent substrate, which may include PET.

[0031] In block **403**, a metal structure is formed on (e.g., directly on) a second region of the substrate, or on (e.g., directly on) the transparent layer(s). In some embodiments, the transparent layer(s) include a transparent conducting oxide layer and a transparent dielectric layer, and the metal structure may be formed on the transparent dielectric layer. In some embodiments, formation of the metal structure may include deposition of dielectric layers, deposition of conductive layers, etching, or the like, or combinations thereof, to form a high efficiency antenna made of a conductor having conductivity greater than ITO and/or transparent conducting oxides. These conductive and/or dielectric layers may be formed during a same process in which conductive and/or dielectric layers of routing and/or ESD protection components are formed. In some examples, the metal structure is used for touch panel routing and/or ESD protection and/or may be formed together with formation of routing and/or ESD protection structures. Some embodiments herein may utilize touch panel routing metal manufacturing technology. In some examples, the antenna may be made of more than one layer of the conductor, e.g., in a dual loop antenna implementation.

[0032] In block **405**, a transceiver or communication engine (e.g., an NFC communication engine) is electrically connected to the metal structure. Block **405** may include forming a wire to couple the metal structure to provide the electrical connection.

[0033] FIG. 5 illustrates example architecture of a wearable computer device **500**, in accordance to various embodiments. The wearable computer device **600** may include a communication interface **622** including an antenna **602** and a display **620** may include a touch panel component **601** including a transparent substrate on which the antenna **602** is formed on.

[0034] As illustrated, in embodiments, wearable computer device **600** may include hardware **602** and software **604**. Hardware **602** may include one or more components such as processor(s) **612**, memory **614**, persistent storage **616**, sensors **618**, the display **620**, and the communication interface **622**. Communication interface **622** may include any number of wireless communication or networking interfaces known, such as WiFi, 3G/4G, Bluetooth®, Near Field Communication, LiFi, and so forth. In some examples, the antenna **602** may be an antenna to support one or more of the wireless communication or networking interfaces of the communication interface **622** (such as an NFC antenna). Display **620** may be any known display device, including e.g., a touch panel or touch sensitive screen.

[0035] Processor(s) **612** may be any one of a number of processors known in the art, each having one or more processor cores. Memory **614** may be any known volatile or non-volatile memory in the art, suitable for storing instructions for execution and working data, in particular, instructions and data of applications **632** and OS **634**. Memory **614** may include a hierarchy of cache memory and system memory. Both the cache and system memory may be respectively organized into segments and pages. Persistent storage **616** may be any known persistent mass storage suitable for providing persistent storage of instructions and data of applications **632** and OS **634**, e.g., solid state storage, magnetic or optical disk drives. Sensors **618** may include any known sensors of a wearable device. Software **604** may include operating system (OS) **634** and application **632**. OS **634** may be any one of a number of wearable computer

device OS known in art. Applications **632** may likewise be any one of a number of known applications for wearable computer devices, e.g., personal health application, calendar or other personal information management (PIM) applications.

EXAMPLES

[0036] Example 1 may be an electronic device, comprising: a substrate, wherein at least a first region of a plurality of regions of the substrate is transparent; and a plurality of layers formed on the substrate, the plurality of layers including: a first transparent layer formed over the first region; and a second metal layer formed over a second region of the plurality of regions of the substrate, wherein the second metal layer comprises an antenna.

[0037] Example 2 may include the subject matter of example 1, and a near field communication engine electrically connected to the antenna.

[0038] Example 3 may include the subject matter of any of example 1-2, and the second metal layer is formed on the first transparent layer.

[0039] Example 4 may include the subject matter of any of example 1-3, and the first transparent layer comprises a transparent conductive oxide.

[0040] Example 5 may include the subject matter of any of example 1-4, and the transparent conductive oxide comprises indium tin oxide.

[0041] Example 6 may include the subject matter of any of example 1-5, and the second metal layer comprises Ag.

[0042] Example 7 may include the subject matter of any of examples 1-6, and the first region corresponds to an active area of a touch display panel and the second region corresponds to a non-active area on a periphery of the active area.

[0043] Example 8 may include the subject matter of any of examples 1-7, and the plurality of layers and the substrate are of one of a receive section and a transmit section of a touch display panel, and wherein the other of the receive section and the transmit section comprises: an additional substrate, wherein at least a region of a plurality of regions of the additional substrate is transparent; and one or more layers formed on the additional substrate, the one or more layers including a transparent layer formed over the region of the additional substrate.

[0044] Example 9 may include the subject matter of any of examples 1-8, and an optical clear adhesive (OCA) between the receive section and the transmit section.

[0045] Example 10 may include the subject matter of any of examples 1-9, and an additional OCA between a cover lens and at least one of the receive section and the transmit section.

[0046] Example 11 may be an electronic device, comprising: a touch panel display receive section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; and a touch panel display transmit section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; wherein at least one of the routing areas is electrically coupled to a wireless communication module of the electronic device and includes wiring arranged in one or more loops to operate as an antenna for the wireless communication module.

[0047] Example 12 may include the subject matter of example 11, and the wireless communication module comprises a near field communication engine.

[0048] Example 13 may include the subject matter of any of examples 11-12, and the active area comprises a transparent conductive layer of a first material and the routing area comprises a metal layer of a second material that is different than the first material.

[0049] Example 14 may include the subject matter of any of examples 11-13, and the first material comprises indium tin oxide (ITO) and the second material comprises silver (Ag).

[0050] Example 15 may include the subject matter of any of examples 11-14, and the metal layer is formed on the transparent conductive layer.

[0051] Example 16 may be a method, comprising: providing a substrate, wherein at least a first region of a plurality of regions of the substrate is transparent; forming one or more transparent layers on the first region of the substrate; and forming a metal layer on a second region of the plurality of regions of the substrate or on the one or more transparent layers, over the second region.

[0052] Example 17 may include the subject matter of example 16, and the metal layer comprises a wire formed in one or more loops to be coupled to a wireless communication module and to operate as an antenna for the wireless communication module.

[0053] Example 18 may include the subject matter of any of examples 16-17, and the metal layer is electrically coupled to at least one of the one or more transparent layers.

[0054] Example 19 may include the subject matter of any of examples 16-18, and the one or more one or more transparent layers comprises an optical clear adhesive (OCA).

[0055] Example 20 may include the subject matter of any of examples 16-19, and coupling a cover lens to the one or more transparent layers.

[0056] Example 21 may be a system, comprising: a touch panel display; and a processor to output data to be displayed on the touch panel display, to receive an input from the touch panel display; wherein the touch panel display includes: a touch panel display receive section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; and a touch panel display transmit section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; wherein at least one of the routing areas is electrically coupled to a wireless communication module and includes wiring arranged in one or more loops to operate as an antenna for the wireless communication module.

[0057] Example 22 may include the subject matter of example 21, and the wireless communication module comprises a near field communication engine.

[0058] Example 23 may include the subject matter of any of examples 21-22, and the active area comprises a transparent conductive layer of a first material and the routing area comprises a metal layer of a second material that is different than the first material.

[0059] Example 24 may include the subject matter of any of examples 21-24, and the first material comprises indium tin oxide (ITO) and the second material comprises silver (Ag).

[0060] Example 25 may include the subject matter of any of examples 21-24, and the metal layer is formed on the transparent conductive layer.

[0061] Example 26 may include an apparatus comprising means for electrically sensing contact with a display of an electronic device; and means for converting one of electromagnetic radiation and electrical power into the other of the electromagnetic radiation and power to perform at least one of transmission or reception of a signal to or from a device in proximity to the electronic device; wherein the electrically sensing means is formed over a first transparent region of a substrate of the electronic device and the converting means is formed over a second region of the substrate.

[0062] Example 27 may include the subject matter of example 26, and the converting means is formed on the electrically sensing means.

[0063] Example 28 may include the subject matter of any of examples 26-27, and a material of the electrically sensing means comprises a transparent conductive oxide.

[0064] Example 29 may include the subject matter of any of examples 26-28, and a material of the converting means comprises a metal that is different than the transparent conductive oxide.

[0065] Example 30 may include the subject matter of any of examples 26-29, and the material of the converting means comprises Ag.

[0066] Although certain embodiments have been illustrated and described herein for purposes of description, a wide variety of alternate and/or equivalent embodiments or implementations calculated to achieve the same purposes may be substituted for the embodiments shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that embodiments described herein be limited only by the claims.

[0067] Where the disclosure recites “a” or “a first” element or the equivalent thereof, such disclosure includes one or more such elements, neither requiring nor excluding two or more such elements. Further, ordinal indicators (e.g., first, second or third) for identified elements are used to distinguish between the elements, and do not indicate or imply a required or limited number of such elements, nor do they indicate a particular position or order of such elements unless otherwise specifically stated.

What is claimed is:

1. An electronic device, comprising:
 - a substrate, wherein at least a first region of a plurality of regions of the substrate is transparent; and
 - a plurality of layers formed on the substrate, the plurality of layers including:
 - a first transparent layer formed over the first region; and
 - a second metal layer formed over a second region of the plurality of regions of the substrate, wherein the second metal layer comprises an antenna.
2. The electronic device of claim 1, further comprising a near field communication engine electrically connected to the antenna.
3. The electronic device of claim 1, wherein the second metal layer is formed on the first transparent layer.
4. The electronic device of claim 1, wherein the first transparent layer comprises a transparent conductive oxide.
5. The electronic device of claim 4, wherein the transparent conductive oxide comprises indium tin oxide.
6. The electronic device of claim 1, wherein the second metal layer comprises Ag.

7. The electronic device of claim 1, wherein the first region corresponds to an active area of a touch display panel and the second region corresponds to a non-active area on a periphery of the active area.

8. The electronic device of claim 1, wherein the plurality of layers and the substrate are of one of a receive section and a transmit section of a touch display panel, and wherein the other of the receive section and the transmit section comprises:

an additional substrate, wherein at least a region of a plurality of regions of the additional substrate is transparent; and

one or more layers formed on the additional substrate, the one or more layers including a transparent layer formed over the region of the additional substrate.

9. The electronic device of claim 8, further comprising an optical clear adhesive (OCA) between the receive section and the transmit section.

10. The electronic device of claim 9, further comprising an additional OCA between a cover lens and at least one of the receive section and the transmit section.

11. An electronic device, comprising:

a touch panel display receive section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; and

a touch panel display transmit section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; wherein at least one of the routing areas is electrically coupled to a wireless communication module of the electronic device and includes wiring arranged in one or more loops to operate as an antenna for the wireless communication module.

12. The electronic device of claim 11, wherein the wireless communication module comprises a near field communication engine.

13. The electronic device of claim 11, wherein the active area comprises a transparent conductive layer of a first material and the routing area comprises a metal layer of a second material that is different than the first material.

14. The electronic device of claim 13, wherein the first material comprises indium tin oxide (ITO) and the second material comprises silver (Ag).

15. The electronic device of claim 13, wherein the metal layer is formed on the transparent conductive layer.

16. A method, comprising:

providing a substrate, wherein at least a first region of a plurality of regions of the substrate is transparent;

forming one or more transparent layers on the first region of the substrate; and

forming a metal layer on a second region of the plurality of regions of the substrate or on the one or more transparent layers, over the second region.

17. The method of claim 16, wherein the metal layer comprises a wire formed in one or more loops to be coupled to a wireless communication module and to operate as an antenna for the wireless communication module.

18. The method of claim 16, wherein the metal layer is electrically coupled to at least one of the one or more transparent layers.

19. The method of claim 16, wherein the one or more one or more transparent layers comprises an optical clear adhesive (OCA).

20. The method of claim 16, further comprising coupling a cover lens to the one or more transparent layers.

21. A system, comprising:

a touch panel display; and

a processor to output data to be displayed on the touch panel display, to receive an input from the touch panel display;

wherein the touch panel display includes:

a touch panel display receive section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area; and

a touch panel display transmit section including an active area and a routing area formed on a periphery of the active area and electrically coupled to said active area;

wherein at least one of the routing areas is electrically coupled to a wireless communication module and includes wiring arranged in one or more loops to operate as an antenna for the wireless communication module.

22. The system of claim 21, wherein the wireless communication module comprises a near field communication engine.

23. The system of claim 21, wherein the active area comprises a transparent conductive layer of a first material and the routing area comprises a metal layer of a second material that is different than the first material.

24. The system of claim 23, wherein the first material comprises indium tin oxide (ITO) and the second material comprises silver (Ag).

25. The system of claim 23, wherein the metal layer is formed on the transparent conductive layer.

* * * * *