(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 February 2022 (10.02.2022)

(10) International Publication Number
WO 2022/027156 A1

(51) International Patent Classification:
G06F 3/044 (2006.01) *G06F 3/041* (2006.01)

(21) International Application Number:
PCT/CN2020/106480

(22) International Filing Date:
01 August 2020 (01.08.2020)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title:** CAPACITIVE SENSING APPARATUS

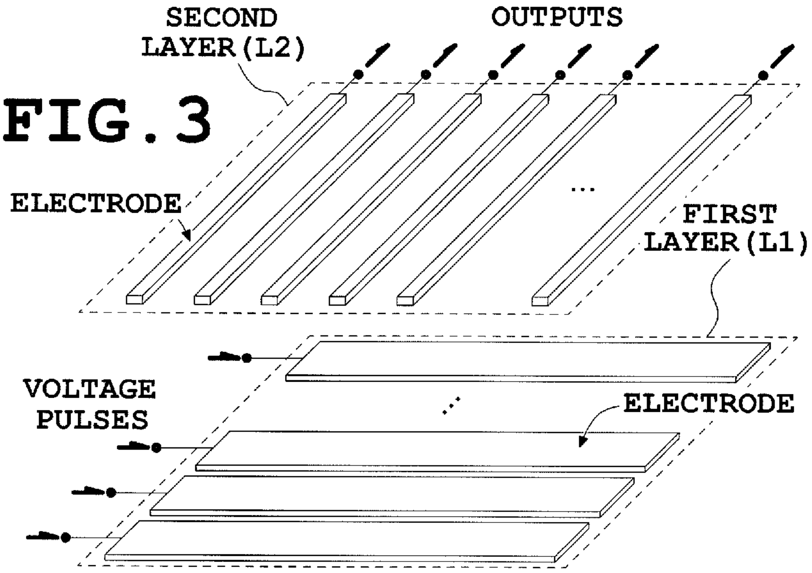

FIG.3

(57) **Abstract:** Provided is a capacitive sensing apparatus, where the apparatus includes a plurality of driving electrodes to which a first voltage is applied, wherein the plurality of driving electrodes are arranged side by side along a first direction; a plurality of sensing electrodes arranged side by side along a second direction crossing the first direction; a plurality of forming electrodes to which a second voltage having an opposite sign to the first voltage is applied, where a forming electrode among the plurality of forming electrodes is located between adjacent two driving electrodes; and processing circuitry configured to detect variation of capacitance between the driving and sensing electrodes.

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DESCRIPTION

CAPACITIVE SENSING APPARATUS

TECHNICAL FIELD

[0001] The present disclosure relates to a capacitive sensing apparatus, a device having the capacitive sensing apparatus, and a method for generating an image such as a fingerprint image by the apparatus. The device may be a mobile phone, a smart phone, a tablet computer, a personal computer, a digital camera, a navigation system or the like.

BACKGROUND

[0002] In recent years, authentication technology implemented in various electronic devices such as a mobile phone, a smart phone, a tablet computer, a personal computer, a digital camera, and a navigation system becomes important more and more in order to prevent unauthorized use thereof. In this regard, a fingerprint authentication is a strong candidate of the authentication technology used for such devices since a fingerprint sensor (FPS) is advantageous in size and energy efficiency. Although there exists several types of FPS sensors, a capacitive FPS is attracting attention from the viewpoint of a thin shape, low cost and high reliability.

[0003] The capacitive FPS may be implemented in a device that a display panel covers almost all of a front surface thereof. In this case, the sensor should be arranged under an overlay such as a transparent glass or film of the display panel. If a thickness of the overlay is 200μm or less, an existing capacitive FPS may detect surface irregularities of a finger located on the overlay with sufficient resolution to recognize a fingerprint. However, the overlay with the thickness of 200μm or less breaks easily even with a weak impact. Thus, it is necessary to improve sensitivity of the capacitive FPS so as to accurately detect the fingerprint via a thick overlay, in order to implement the capacitive FPS in the full-display type device.

SUMMARY

[0004] Embodiments provide a capacitive sensing apparatus, a device having the apparatus and a method for generating an image such as a fingerprint image. The device may be a mobile phone, a smart phone, a tablet computer, a personal computer, a digital camera, a navigation system, or the like.

[0005] A first aspect of the embodiments provides a capacitive sensing apparatus. In a first possible implementation form of the first aspect, a capacitive sensing apparatus comprises: a plurality of driving electrodes to which a first voltage is applied, wherein the plurality of driving electrodes are arranged side by side along a first direction; a plurality of sensing electrodes arranged side by side along a second direction crossing the first direction; a plurality of forming electrodes to which a second voltage having an opposite sign to the first voltage is applied, where a forming electrode among the plurality of forming electrodes is located between adjacent two driving electrodes; and processing circuitry configured to detect variation of capacitance between the driving and sensing electrodes. In some examples, a pitch of electrodes may be within a range of 30μm to 150μm, and the apparatus may be preferably used for generating a fingerprint image. Also, the first voltage and the second voltage may be applied to the driving and forming electrodes respectively during predetermined driving periods to drive the driving and forming electrodes synchronously. On the other hand, reading signals from the sensing electrodes is performed during predetermined reading periods different from the driving periods.

[0006] When the first voltage is applied to the driving electrode, an electric field is generated between the driving and sensing electrodes, and the sensing electrode receives charge from the driving electrode. Also, when a finger is located on an overlay above the apparatus, the finger causes to change the electric field and reduce mutual capacitance between the driving and sensing electrodes. Resolution on detecting

surface irregularities of the finger may relate to directivity of the electric field between the driving and sensing electrodes adjacent to each other. Specifically, increasing the directivity may improve resolution on detection of the surface irregularities of the finger. In the first possible implementation form of the first aspect, the forming electrode is located between adjacent two driving electrodes, and the second voltage having an opposite sign to the first voltage is applied to the forming electrode. Applying the second voltage to the forming electrode enhances directivity of the electric field between the driving electrode adjacent to the forming electrode and the sensing electrode, to upward, thereby improving sensitivity of the apparatus.

[0007] A second possible implementation form of the first aspect provides: the apparatus according to the first possible implementation form of the first aspect, where the processing circuitry is further configured to generate an image having pixel values each corresponding to the detected variation of the capacitance at a position that the driving and sensing electrodes face each other. According to the second possible implementation form of the first aspect, a clear fingerprint image may be generated by the apparatus having the improved sensitivity.

[0008] A third possible implementation form of the first aspect provides: the apparatus according to the first or second possible implementation form of the first aspect, where the processing circuitry is further configured to: swap a first group of electrodes each acting as the driving electrode for a second group of electrodes each acting as the forming electrode on a first layer on which the driving electrode is located, to change between two electrode patterns on the first layer; swap a third group of electrodes each acting as the sensing electrode for a fourth group of electrodes each acting as the forming electrode on a second layer on which the sensing electrode is located, to change between two electrode patterns on the second layer; generate an image formed by pixel values each corresponding to the detected variation of the capacitance at a position that the driving and sensing electrodes face each other, with respect to each of four electrode patterns; and combine four generated images to obtain a combined image.

[0009] In the third possible implementation form of the first aspect, driving electrodes and some forming electrodes are located on the first layer, and sensing electrodes and remaining forming electrodes are located on the second layer. Each electrode on the first layer may act as the driving electrode when applying the first voltage and act as the forming electrode when applying the second voltage. In addition, each electrode on the second layer may act as the sensing electrode when the electrode is grounded and act as the forming electrode when applying the second voltage. Accordingly, the processing circuitry may control voltages applied to each electrode to change between four electrode patterns. The processing circuitry detects variation of the capacitance at a position where the driving and sensing electrodes face each other, thus detection positions corresponding to the four electrode patterns are different from each other. Therefore, the processing circuitry generates an image with respect to each of four electrode patterns and combines the four generated images to obtain a combined image having a complete set of pixel values corresponding to all of the detection positions.

[0010] For example, the driving electrodes may be evenly spaced on the first layer, and the sensing electrodes may be evenly spaced on the second layer that is placed a predetermined distance away from the first layer. Each of the driving electrodes may stretch along one direction, and each of the sensing electrodes may stretch along another direction crossing the one direction. In addition, each forming electrode on the first layer may be located between adjacent two driving electrodes, and each forming electrode on the second layer may be located between adjacent two sensing electrodes. In this case, the processing circuitry detects variation of the capacitance at each crossing point of the driving and sensing electrodes with respect to each electrode pattern. Further, the processing circuitry may generate an image based on detected variation of the capacitance with respect to each electrode pattern and combine generated four images to obtain a full-pixels image.

[0011] A fourth possible implementation form of the first aspect provides: the apparatus according to any one of the first to third possible implementation forms of the first aspect, where a voltage signal providing the first voltage is coded in a CDM (Code Division Multiplexing) manner so that voltage signals corresponding to the driving electrodes are orthogonal to each other. According to the seventh possible implementation form of the first aspect, the CDM manner improves a signal to noise ratio (SNR) on detection signals.

[0012] A second aspect of the embodiments provides another capacitive sensing apparatus. In a first possible implementation form of the second aspect, the apparatus comprises: a plurality of sensing electrodes to which a first voltage is applied; a plurality of forming electrodes to which a second voltage having an opposite sign to the first voltage is applied, where each forming electrode is located between adjacent two sensing electrodes; and processing circuitry configured to detect variation of charge accumulated on each sensing electrode by the first voltage. In some examples, a pitch of electrodes may be within a range of 30μm to 150μm, and the apparatus may be preferably used for generating a fingerprint image. Also, the first voltage causes charge on each sensing electrode during accumulating periods, and the second voltage is applied to the forming electrode during the same periods synchronously. On the other hand, reading signals from the sensing electrodes is performed during a reading period after the accumulating period.

[0013] When approaching a finger to an overlay above the apparatus 180, capacitance of the finger causes to increase charge that is accumulated on sensing electrodes facing the finger. Accordingly, the processing circuitry may detect the finger and/or each protrusion of the finger surface based on variation of the charge. Resolution on detecting surface irregularities of the finger may relate to directivity of the electric field around the sensing electrode. Specifically, increasing the directivity may improve resolution on detection of the surface irregularities of the finger. In the first possible implementation form of the second aspect, the forming electrode is located between adjacent two sensing electrodes, and the second voltage having an opposite sign to the first voltage is applied to the forming electrode. Applying the second voltage to the forming electrode enhances directivity of the electric field around the sensing electrode to upward, thereby improving sensitivity of the apparatus.

[0014] A second possible implementation form of the second aspect provides: the apparatus according to the first possible implementation form of the second aspect, where the processing circuitry is further configured to generate an image having pixel values each corresponding to the variation of the charge on each sensing electrode. According to the second possible implementation form of the second aspect, a clear fingerprint image may be generated by the apparatus having the improved sensitivity.

[0015] A third aspect of the embodiments provides a method for generating an image by a capacitive sensing apparatus having a plurality of driving electrodes arranged side by side along a first direction and a plurality of sensing electrodes arranged side by side along a second direction crossing the first direction, a plurality of forming electrodes, and processing circuitry. In a first possible implementation form of the third aspect, the method comprises: applying, by a voltage source, a first voltage to each driving electrode; applying, by the voltage source, a second voltage having an opposite sign to the first voltage to each forming electrode, where a forming electrode among the plurality of forming electrodes is located between adjacent two driving electrodes; and generating, by the processing circuitry, an image based on variation of capacitance between the driving and sensing electrodes. In some examples, a pitch of electrodes may be within a range of 30μm to 150μm, and the apparatus may be preferably used for generating a fingerprint image. Also, the first voltage and the second voltage may be applied to the driving and forming electrodes respectively during predetermined driving periods to drive the driving and forming electrodes synchronously. On the other hand, reading signals from the sensing electrodes is performed during predetermined reading periods different from the driving periods.

[0016] When the first voltage is applied to the driving electrode, an electric field is generated between the driving and sensing electrodes, and the sensing electrode receives charge from the driving electrode. Also, when a finger is located on an overlay above the apparatus, the finger causes to change the electric field and reduce mutual capacitance between the driving and sensing electrodes. Resolution on detecting surface irregularities of the finger may relate to directivity of the electric field between the driving and sensing electrodes adjacent to each other. Specifically, increasing the directivity may improve resolution on detection of the surface irregularities of the finger. In the first possible implementation form of the third aspect, the forming electrode is located between adjacent two driving electrodes, and the second voltage having an opposite sign to the first voltage is applied to the forming electrode. Applying the second voltage to the forming electrode enhances directivity of the electric field between the driving electrode adjacent to the forming electrode and the sensing electrode, to upward, thereby improving sensitivity of the apparatus.

[0017] A second possible implementation form of the third aspect provides: the method according to the first possible implementation form of the third aspect, where the generating, by the processing circuitry, an image based on variation of the capacitance specifically comprises: generating the image having pixel values each corresponding to variation of the capacitance at a position that the driving and sensing electrodes face each other. According to the second possible implementation form of the third aspect, a clear fingerprint image may be generated by the apparatus having the improved sensitivity.

[0018] A third possible implementation form of the third aspect provides: the method according to the first or second possible implementation forms of the third aspect, further comprising: changing, by the processing circuitry, a first group of electrodes each acting as the driving electrode and a second group of electrodes each acting as the forming electrode, to make a plurality of electrode patterns, where the generating, by the processing circuitry, an image based on variation of the capacitance specifically comprises: generating the image having pixel values each corresponding to variation of the capacitance at a position that the driving and sensing electrodes face each other, with respect to each electrode pattern on the driving and second layers, and combining four images.

[0019] In the third possible implementation form of the third aspect, driving electrodes and some forming electrodes are located on the first layer, and sensing electrodes and remaining forming electrodes are located on the second layer. Each electrode on the first layer may act as the driving electrode when applying the first voltage and act as the forming electrode when applying the second voltage. In addition, each electrode on the second layer may act as the sensing electrode when the electrode is grounded and act as the forming electrode when applying the second voltage. Accordingly, the processing circuitry may control voltages applied to each electrode to change between four electrode patterns. The processing circuitry detects variation of the capacitance at a position where the driving and sensing electrodes face each other, thus detection positions corresponding to the four electrode patterns are different from each other. Therefore, the processing circuitry generates an image with respect to each of four electrode patterns and combines the four generated images to obtain a combined image having a complete set of pixel values corresponding to all of the detection positions.

[0020] A fourth possible implementation form of the third aspect provides: the method according to any one of the first to third possible implementation forms of the third aspect, further comprising: coding, by the processing circuitry, a voltage signal providing the first voltage in the CDM manner so that voltage signals corresponding to the driving electrodes are orthogonal to each other. According to the fifth possible implementation form of the third aspect, the CDM manner improves the SNR on detection signals.

[0021] A fourth aspect of the embodiments provides a method for generating an image by a capacitive sensing apparatus having a plurality of sensing electrodes, a plurality of forming electrodes, and processing circuitry. In a first possible implementation form of the fourth aspect, the method comprises: applying, by a voltage source, a first voltage to each sensing electrode; applying, by the voltage source, a second voltage having an opposite sign to the first voltage to each forming electrode, wherein each forming electrode is located between adjacent two sensing electrodes; and generating, by the processing circuitry, an image based on variation of charge accumulated on each sensing electrode by the first voltage. In some examples, a pitch of electrodes may be within a range of 30μm to 150μm, and the apparatus may be preferably used for generating a fingerprint image. Also, the first voltage causes charge on each sensing electrode during accumulating periods, and the second voltage is applied to the forming electrodes during the same periods synchronously. On the other hand, reading signals from the sensing electrodes is performed during a reading period after the accumulating period.

[0022] When approaching a finger to an overlay above the apparatus 180, capacitance of the finger causes to increase charge that is accumulated on sensing electrodes facing the finger. Accordingly, the processing circuitry may detect the finger and/or each protrusion of the finger surface based on variation of the charge. Resolution on detecting surface irregularities of the finger may relate to directivity of the electric field around the sensing electrode. Specifically, increasing the directivity may improve resolution on detection of the surface irregularities of the finger. In the first possible implementation form of the fourth aspect, the forming electrode is located between adjacent two sensing electrodes, and the second voltage having an opposite sign to the first voltage is applied to the forming electrode. Applying the second voltage to the forming electrode enhances directivity of the electric field around the sensing electrode to upward, thereby improving sensitivity of the apparatus.

[0023] A second possible implementation form of the fourth aspect provides: the method according to the first possible implementation forms of the fourth aspect, where the generating, by the processing circuitry, an image based on variation of the charge specifically comprises: generating an image having pixel values each corresponding to variation of the charge on each sensing electrode. According to the second possible implementation form of the fourth aspect, a clear fingerprint image may be generated by the apparatus having the improved sensitivity.

[0024] A fifth aspect of the embodiments provides a device such as a mobile phone, a smart phone, a tablet computer, a personal computer, a digital camera, a navigation system, or the like, where the device comprises: the apparatus according to any one of the possible implementation forms of the first aspect, an overlay covering the apparatus, and a display module located under the apparatus. In one possible implementation form of the fifth aspect, a thickness of the overlay may be approximately equal to or more than 300μm.

[0025] A sixth aspect of the embodiments provides a device such as a mobile phone, a smart phone, a tablet computer, a personal computer, a digital camera, a navigation system, or the like, where the device comprises: the apparatus according to any one of the possible implementation forms of the second aspect, an overlay covering the apparatus, and a display module located under the apparatus. In one possible implementation form of the sixth aspect, a thickness of the overlay may be approximately equal to or more than 300μm.

[0026] A seventh aspect of the embodiments provides a non-transitory computer-readable storage medium storing a program that causes a computer to perform the method according to any one of the possible implementation forms of the third aspect. A eighth aspect of the embodiments provides a non-transitory computer-readable storage medium storing a program that causes a computer to perform the method according to any one of the possible implementation forms of the fourth aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0027] FIG.1 shows an example of a device having a capacitive sensing apparatus for fingerprint sensing, according to a first embodiment of the present disclosure,

FIGs.2A to 2C show cross-sectional views of the device according to the first embodiment of the present disclosure,

FIG.3 shows an example of an electrode layout in the apparatus according to the first embodiment of the present disclosure,

FIG.4A is a schematic diagram for describing arrangement of sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure,

FIG.4B shows waveforms of voltages applied to the sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure,

FIG.5 is a schematic block diagram for describing elements of the apparatus according to the first embodiment of the present disclosure,

FIGs.6A and 6B are schematic diagrams for describing electrode patterns made from the sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure,

FIGs.7A and 7B are schematic diagrams for describing electrode patterns made from the sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure,

FIG.8 is a schematic diagram for describing a procedure to combine four images corresponding to four electrode patterns shown in FIGs.6A to 7B, according to the first embodiment of the present disclosure,

FIG.9 is a flowchart for describing a method for generating an image by the apparatus according to the first embodiment of the present disclosure,

FIG.10 shows an example of an electrode layout according to a first variation of the first embodiment of the present disclosure,

FIG.11 is a schematic diagram for describing an implementation method of the apparatus to the device according to a second variation of the first embodiment of the present disclosure,

FIG.12 is a schematic diagram for describing a coding method of voltage pulses applied to the sensing electrodes according to the first embodiment of the present disclosure,

FIG.13 shows an example of an electrode layout in the apparatus according to a second embodiment of the present disclosure,

FIGs.14A and 14B are schematic diagrams for describing arrangement of sensing and forming electrodes in the apparatus according to the second embodiment of the present disclosure,

FIGs.15A and 15B are schematic diagrams for describing electrode patterns made from the sensing and forming electrodes in the apparatus according to the second embodiment of the present disclosure,

FIGs.16A and 16B are schematic diagrams for describing improvement of sensitivity by applying forming voltages according to the second embodiment of the present disclosure,

FIGs.17A and 17B show an example of an electrode layout in the apparatus according to a variation of the second embodiment of the present disclosure,

FIG.18 is a schematic block diagram for describing elements of the apparatus according to the third embodiment of the present disclosure, and

FIG.19 is schematic diagram for describing arrangement of sensing and forming electrodes in the apparatus according to a third embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0028] The following describes technical solutions of the embodiments, referring to the accompanying drawings. It will be understood that the embodiments described below are not all but just some of embodiments relating to the present disclosure. It is to be noted that all other embodiments which may be derived by a person skilled in the art based on the embodiments described below without creative efforts shall fall within the protection scope of the present disclosure.

[0029] (First embodiment) Following describes a first embodiment of the present disclosure. The first embodiment of the present disclosure relates to a device having a capacitive sensing apparatus such as a capacitive FPS. For example, the device may be a mobile phone, a smart phone, a tablet computer, a personal computer, a digital camera, a navigation system, or the like.

[0030] FIG.1 shows an example of a device having a capacitive sensing apparatus for fingerprint sensing, according to a first embodiment of the present disclosure. A device 10 shown in FIG.1 is a full-display type device that a display panel 11 covers almost all of a front surface of the device 10. As shown in FIG.1, there exists a sensing area 11a on the display panel 11 for detecting a fingerprint. When a finger FG is located on the sensing area 11a, the device 10 may perform detection of the fingerprint and fingerprint authorization based on identification information.

[0031] Following describes a layer structure of the device 10 around the sensing area 11a, with reference to FIGs.2A to 2C. FIGs.2A to 2C show cross-sectional views of the device 10 along II-II line shown in FIG.1. In an example of FIG.2A, the device 10 has an overlay 21, a FPS/Touch sensor 22 and a display module 23. The overlay 21 is a transparent glass or film and covers the FPS/touch sensor layer 22. The FPS/touch sensor layer 22 may include at least one sensor used as a FPS and/or a touch sensor. A capacitive sensing apparatus described below is included in the FPS/touch sensor layer 22. The display module 23 may be an organic light emitting diode (OLED), a liquid crystal display (LCD), or the like, and is located under the FPS/touch sensor layer 22.

The device 10 may further comprise a polarizer 24 as shown in FIGs. 2B and 2C, and these variations may be within a scope of the first embodiment of the present disclosure.

[0032] Following describes the capacitive sensing apparatus for generating a fingerprint image, according to the first embodiment of the present disclosure, with reference to FIGs.3 to 8.

[0033] FIG.3 shows an example of an electrode layout in the apparatus according to the first embodiment of the present disclosure. As shown in FIG.3, the apparatus comprises electrodes evenly spaced on a first layer L1 and electrodes evenly spaced on a second layer L2 that is placed a predetermined distance away from the first layer L1. Each electrode on the first layer L1 stretches along one direction, and each electrode on the second layer L2 stretches along another direction crossing the first direction. In this example, voltage pulses may be applied to at least a part of the electrodes on the first layer L1, and at least a part of the electrodes on the second layer L2 may receive electric charge from the electrodes on the first layer L1.

[0034] In the first embodiment of the present disclosure, a first group of the electrodes on the first layer L1 acts as a driving electrode (TX) to which a first voltage is applied, and a second group of the electrodes on the first layer L1 acts as a forming electrode (FX) to which a second voltage is applied. In addition, a third group of the electrodes on the second layer L2 acts as a sensing electrode (RX) to receive the electric charge from the driving electrode, and a fourth group of the electrodes on the second layer L2 acts as a forming electrode (FX) to which a second voltage is applied. Each forming electrode (FX) on the first layer L1 is located between adjacent two driving electrodes (TX), and each forming electrode (FX) on the second layer L2 is located between adjacent two sensing electrodes (RX).

[0035] FIG.4A shows arrangement of sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure. In an example of FIG.4A, the driving electrodes (TX) and the forming electrodes (FX) are alternately arranged on a substrate and are covered by an overlay such as a transparent glass or film. Optionally, the overlay may also cover the electrodes on the second layer (L2).

[0036] FIG.4B shows waveforms of voltages applied to the sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure. In FIG.4B, a first voltage V1 indicates an amplitude of the first voltage pulse (TX voltage pulse) applied to the driving electrodes (TX), and a second voltage V2 indicates an amplitude of the second voltage pulse (FX voltage pulse) applied to the forming electrodes (FX). The second voltage V2 has an opposite sign to the first voltage V1 in each time period. The first voltage V1 and the second voltage V2 are applied to the driving and forming electrodes respectively during predetermined driving periods to drive the driving and forming electrodes synchronously. On the other hand, reading signals from the sensing electrodes is performed during predetermined reading periods different from the driving periods.

[0037] If the first voltage V1 is applied to the driving electrode (TX), an electric field is generated between the driving electrode (TX) and the sensing electrode (RX), and the sensing electrode (RX) receives charge from the driving electrode (TX). When a finger FG is located on the overlay 21, the finger FG causes to change the electric field and reduce mutual capacitance between the driving electrode (TX) and the sensing electrode (RX).

[0038] Resolution on detecting surface irregularities of the finger FG relates to directivity of the electric field generated between the driving electrode (TX) and the sensing electrode (RX) facing each other. Specifically, increasing the directivity may improve resolution on detection of the surface irregularities of the finger FG. Applying the second voltage V2 to the forming electrode (FX) enhances directivity of the electric field between the driving electrode (TX) and the sensing electrode (RX) facing each other, to upward. This may improve sensitivity of the apparatus.

[0039] Following describes elements included in the apparatus according to the first embodiment of the present disclosure with reference to FIG.5. FIG.5 is a schematic block diagram for describing elements of the apparatus according to the first embodiment of the present disclosure. A capacitive sensing apparatus 50 is an example of the apparatus according to the first embodiment of the present disclosure.

[0040] As shown in FIG.5, the apparatus 50 comprises a plurality of driving electrodes 51a, 51b, 51c ..., a plurality of sensing electrodes 52a, 52b, 52c ..., a plurality of forming electrodes 53a, 53b, 53c ..., a voltage source 54, processing circuitry 55, a detector 56, and a storage 57.

[0041] The processing circuitry 55 controls the voltage source 54 to apply the first voltage V1 to each driving electrode and to apply the second voltage V2 to each forming electrode. The processing circuitry 55 may be an integrated circuit (IC) so called Touch IC implemented in a touch panel, or a processor such as a central processing unit (CPU), a field-programmable gate array (FPGA) or an application specific integrated circuit (ASIC). The processing circuitry 55 is connected to the storage 57 such as a read-only memory (ROM), a random access memory (RAM), a flash memory, a solid state drive (SSD), a hard disk drive (HDD), or the like. The storage 57 may store a program to cause the processing circuitry 55 to control operation of the apparatus 50.

[0042] In addition, the processing circuitry 55 controls the detector 56 to detect variation of capacitance between the driving and sensing electrodes based on received electric charge from the driving electrodes by the sensing electrodes. Further, the processing circuitry 55 generates an image having pixel values each corresponding to the detected variation of the capacitance at each crossing point of the driving and sensing electrodes. Optionally, the processing circuitry 55 may control the voltage source 54 to change the electrode pattern on the first layer L1 and the second layer L2, and generates another image based on the detected variation of the capacitance at each crossing point of the driving and sensing electrodes.

[0043] Specifically, the processing circuitry 55 may swap the first group of electrodes each acting as the driving electrode (TX) for the second group of electrodes each acting as the forming electrode (FX) on the first layer L1. Further, the processing circuitry 55 may swap the third group of electrodes each acting as the sensing electrode (RX) for the fourth group of electrodes each acting as the forming electrode (FX) on the second layer L2.

[0044] Swapping on the first layer L1 provides changes between a first pattern shown in FIG.6A and a second pattern shown in FIG.6B. FIGs.6A and 6B are schematic diagrams for describing electrode patterns made from the sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure. Likewise, swapping on the second layer L2 provides changes between a third pattern shown in FIG.7A and a fourth pattern shown in FIG.7B. FIGs.7A and 7B are schematic diagrams for describing electrode patterns made from the sensing and forming electrodes in the apparatus according to the first embodiment of the present disclosure. Accordingly, the processing circuitry 55 may switch between the first to fourth patterns mentioned above.

[0045] The processing circuitry 55 may generate an image based on the detected variation of the capacitance at the crossing point of the driving and sensing electrodes with respect to each of the first to fourth patterns, and store first to fourth images corresponding to the first to fourth patterns respectively in the storage 57. Since pixels forming the image may be obtained only at the crossing points of the driving and sensing electrodes (see dashed rectangles in FIGs.6A to 7B), the first to fourth images look like those shown in FIG.8. FIG.8 is a schematic diagram for describing a procedure to combine four images corresponding to four electrode patterns shown in FIGs.6A to 7B, according to the first embodiment of the present disclosure. In order to complete an image of the fingerprint, the processing circuitry 55 combines the first to fourth images to generate a full-pixels image of the fingerprint as shown in FIG.8.

[0046] (Method for generating the full-pixels image) Following describes one example of a method for generating the fingerprint image according to the first embodiment of the present disclosure with reference to FIG.9. FIG.9 is a flowchart for describing one example of a method for generating an image by the apparatus according to the first embodiment of the present disclosure.

[0047] At a step S11, the processing circuitry 55 captures a first image based on outputs from the sensing electrodes (RX lines) in the first pattern (see FIG.6A). For example, the processing circuitry 55 controls the voltage source 54 to apply the first voltage V1 to each driving electrode and to apply the second voltage V2 to each forming electrode, so that the electrodes in the apparatus 50 forms the first pattern. Also, the processing circuitry 55 controls the detector 56 to detect variation of capacitance between the driving and sensing electrodes based on outputs from the sensing electrodes, and generates an image having pixel values each corresponding to variation of the capacitance at a crossing point of the driving and sensing electrodes.

[0048] At a step S12, the processing circuitry 55 controls the voltage source 54 to swap the driving electrodes (TX lines) for the forming electrodes (FX lines) on the first layer L1 to change from the first pattern to the second pattern (see FIG.6B). Further, the processing circuitry 55 captures a second image based on outputs from the sensing electrodes (RX lines) in the second pattern.

[0049] At a step S13, the processing circuitry 55 controls the voltage source 54 to swap the driving electrodes (TX lines) for the forming electrodes (FX lines) on the first layer L1 and the second layer L2 to change from the second pattern to the third pattern (see FIG.7A). Further, the processing circuitry 55 captures a third image based on outputs from the sensing electrodes (RX lines) in the third pattern.

[0050] At a step S14, the processing circuitry 55 controls the voltage source 54 to swap the driving electrodes (TX lines) for the forming electrodes (FX lines) on the second layer L2 to change from the third pattern to the fourth pattern (see FIG.7B).

Further, the processing circuitry 55 captures a fourth image based on outputs from the sensing electrodes (RX lines) in the fourth pattern.

[0051] At a step S15, the processing circuitry 55 combines the first to fourth images to generate a full-pixels image. When a process of the step S15 is completed, the series of processes shown in FIG.9 ends.

[0052] (First variation of the first embodiment) Following describes a first variation of the first embodiment of the present disclosure with reference to FIG.10. FIG.10 shows an example of an electrode layout according to a first variation of the first embodiment of the present disclosure. As shown in FIG.10, the sensing electrodes (RX lines) and/or the driving electrodes may be composed of metal mesh. In this case, it is preferable to arrange dummy mesh between the adjacent two sensing electrodes in order to make each sensing electrode inconspicuous. Using the metal mesh may reduce resistance of the electrode.

[0053] (Second variation of the first embodiment) Following describes a second variation of the first embodiment of the present disclosure with reference to FIG.11. FIG.11 is a schematic diagram for describing an implementation method of the apparatus to the device according to a second variation of the first embodiment of the present disclosure.

[0054] As described above with reference to FIGs.2A to 2C, the apparatus according to the first embodiment of the present disclosure may be installed in the FPS/touch sensor layer 22 on the display module 23 (Out-cell case). On the other hand, the apparatus according to the first embodiment of the present disclosure may be implemented in a display such as OLED directly as shown in FIG.11 (On-cell case). In this case, electrodes used for TX lines and/or FX lines may be arranged on a thin film encapsulation (TFE) structure. Also, electrodes used for RX lines and/or FX lines may be arranged on an insulator layer on the TX lines and be covered by an overcoat layer.

[0055] (Coding method) Following describes a coding method of voltage pulses applied to the driving electrodes with reference to FIG.12. FIG.12 is a schematic diagram for describing a coding method of voltage pulses applied to the sensing electrodes according to the first embodiment of the present disclosure.

[0056] As shown in FIG.12, a voltage signal providing the first voltage V1 may be coded in a CDM (Code Division Multiplexing) manner so that voltage signals applied to the different driving electrodes are orthogonal to each other. In an example of FIG.12, four RX outputs 3.8, 0.2, -0.2, 0.2 are obtained when TX1 to TX4 pulses are applied to TX1 to TX 4 lines respectively. In this case, the processing circuitry 55 performs decoding processing based on the following equation (1) and obtains an output signal 0.8 (0.8=4-3.2). Using the CDM manner improves a signal to noise ratio (SNR) on detection signals.

$$\begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{pmatrix} \begin{pmatrix} 3.8 \\ 0.2 \\ -0.2 \\ 0.2 \end{pmatrix} = \begin{pmatrix} 4 \\ 3.2 \\ 4 \\ 4 \end{pmatrix} \quad \ldots (1)$$

[0057] (Second embodiment) Following describes a second embodiment of the present disclosure with reference to FIGs.13 to 16.

[0058] FIG.13 shows an example of an electrode layout in the apparatus according to a second embodiment of the present disclosure. In the second embodiment of the present disclosure, electrodes on the first layer L1 have a rectangular shape and are arranged in tiles. Cross-sectional view taken along a A-A line in FIG.13 is as shown in FIG.14A, and a transparent view from above of electrodes on the first layer L1 and the second layer L2 is as shown in FIG.14B. FIGs.14A and 14B are schematic diagrams for describing arrangement of sensing and forming electrodes in the apparatus according to the second embodiment of the present disclosure.

[0059] In an example of FIG.14A, the driving electrodes (TX) and the forming electrodes (FX) are alternately arranged on a substrate and are covered by an overlay such as a transparent glass or film. In addition, the driving electrodes (TX) adjacent to each other are connected via an bridge line (TX bridge). Therefore, the driving electrodes connected with each other are arranged side by side along a first direction crossing a second direction in which the sensing electrodes (RX) extend. Likewise, the forming electrodes (FX) adjacent to each other are connected via an bridge line (FX bridge), and the forming electrodes connected with each other are arranged side by side along the first direction.

[0060] As shown in FIG.14B, the driving electrodes connected with each other form a TX line along the first direction (X-direction in FIG.13). Likewise, the forming electrodes connected with each other form a FX line along the first direction. The first voltage V1 (see FIG.4B) is applied to the TX line, and the second voltage V2 (see FIG.4B) is applied to the FX line. Optionally, a part of electrodes on the second layer L2 may be configured to act as the forming electrodes as with the first embodiment of the present disclosure.

[0061] Optionally, the processing circuitry 55 may swap a first group of electrodes each acting as the driving electrode (TX line) for a second group of electrodes each acting as the forming electrode (FX line) on the first layer L1. Swapping between the TX line for the FX line provides changes between two electrode patterns shown in FIGs.15A and 15B. FIGs.15A and 15B are schematic diagrams for describing electrode patterns made from the sensing and forming electrodes in the apparatus according to the second embodiment of the present disclosure. Since those two electrode patterns have different crossing points of the TX and RX lines, the processing circuitry 55 controls the voltage source 54 to perform changes between the two electrode patterns, and generates two images corresponding to the two electrode patterns respectively based on variation of the capacitance at each crossing point of the TX and RX lines. Further, the processing circuitry 55 combines the two images to generate a full-pixels image.

[0062] Following describes improvement of sensitivity by applying forming voltages with reference to FIGs.16A and 16B. FIGs.16A and 16B are schematic diagrams for describing improvement of sensitivity by applying forming voltages according to the second embodiment of the present disclosure.

[0063] In an example of FIG.16A, a distance H between a surface of electrodes on the first layer L1 and a metal sample on the overlay is 700μm, a pitch of the electrodes on the first layer L1 may be within a range of 30μm to 150μm, and the metal sample has a width of 100μm. Under these conditions, detected capacitance distribution becomes as shown in FIG.16B. In FIG.16B, a solid line indicates the capacitance distribution under a first condition that V2 is equal to -0.9 times V1, a dotted line indicates the capacitance distribution under a second condition that V2 is equal to -0.5 times V1, and a dash-dotted line indicates the capacitance distribution under a third condition that V2 is equal to V1. The third condition corresponds to a condition of an existing FPS. As clearly shown in FIG.16B, a width W1 of the solid line is narrower than a width W0 of the dash-dotted line. This indicates that applying the second voltage V2 having an opposite sign to the first voltage to the FX lines improves resolution on detection of surface irregularities of an object located on the overlay. Also, comparison between the solid line and the dotted line represents that the resolution increases as the magnitude of V1 approaches that of V2. This tendency does not depend on a shape of the electrodes and is the same in the first embodiment of the present disclosure.

[0064] (Variation of the second embodiment) Following describes a variation of the second embodiment of the present disclosure with reference to FIGs.17A and 17B. FIGs.17A and 17B show an example of an electrode layout in the apparatus according to a variation of the second embodiment of the present disclosure. As shown in FIG.17A, the driving and sensing electrodes as well as the forming electrodes are arranged on one layer. The driving electrodes are connected with each other via the TX bridge as shown in FIG.17B and form a TX line along a horizontal direction. Likewise, the forming electrodes connected with each other form a FX line along the horizontal direction. On the other hand, the forming electrodes connected with each other form a RX line along a vertical direction. The first voltage V1 (see FIG.4B) is applied to the TX line, and the second voltage V2 (see FIG.4B) is applied to the FX line as with the first and second embodiments of the present disclosure. The electrodes layout described above may be within a scope of the second embodiment of the present disclosure.

[0065] (Third embodiment) Following describes a third embodiment of the present disclosure with reference to FIGs.18 and 19. The third embodiment of the present disclosure relates to a self-capacitance type FPS.

[0066] FIG.18 is a schematic block diagram for describing elements of the apparatus according to the third embodiment of the present disclosure. As shown in FIG.18, the apparatus 180 comprises a plurality of sensing electrodes 181a, 181b, 181c ..., a plurality of forming electrodes 182a, 182b, 182c ..., a voltage source 183, processing circuitry 184, a detector 185, and a storage 186.

[0067] The processing circuitry 184 controls the voltage source 183 to accumulate charge on each sensing electrode by applying the first voltage V1, and to apply the second voltage V2 to each forming electrode. The processing circuitry 184 may be an IC so called Touch IC implemented in a touch panel, or a processor such as a CPU, a FPGA or an ASIC. The processing circuitry 184 is connected to the storage 186 such as a ROM, a RAM, a flash memory, a SSD, a HDD, or the like. The storage 186 may store a program to cause the processing circuitry 184 to control operation of the apparatus 180.

[0068] In addition, the processing circuitry 184 controls the detector 185 to read charge that is accumulated on each sensing electrode. When approaching a finger to an overlay above the apparatus 180, capacitance of the finger causes to increase charge that is accumulated on sensing electrodes facing the finger. Accordingly, the processing circuitry 184 may detect the finger and/or each protrusion of the finger surface based on variation of the charge. Further, the processing circuitry 184 generates an image having pixel values each corresponding to the variation of the accumulated charge at a position of each forming electrode.

[0069] The forming electrodes may be arranged as shown in FIG.19. FIG.19 is schematic diagram for describing arrangement of sensing and forming electrodes in the apparatus according to a third embodiment of the present disclosure. In an example of FIG.19, each branch of the forming electrode is located between adjacent two sensing electrodes. The branches of the forming electrode may be connected via bridge lines although FIG.19 shows the forming electrode formed integrally.

[0070] The foregoing disclosure merely discloses exemplary embodiments, and is not intended to limit the protection scope of the present invention. It will be appreciated by those skilled in the art that the foregoing embodiments and all or some of other embodiments and modifications which may be derived based on the scope of claims of the present invention will of course fall within the scope of the present invention.

CLAIMS

1. A capacitive sensing apparatus comprising:

a plurality of driving electrodes to which a first voltage is applied, wherein the plurality of driving electrodes are arranged side by side along a first direction;

a plurality of sensing electrodes arranged side by side along a second direction crossing the first direction;

a plurality of forming electrodes to which a second voltage having an opposite sign to the first voltage is applied, wherein a forming electrode among the plurality of forming electrodes is located between adjacent two driving electrodes; and

processing circuitry configured to detect variation of capacitance between the driving and sensing electrodes.

2. The apparatus according to claim 1, wherein the processing circuitry is further configured to generate an image having pixel values each corresponding to the detected variation of the capacitance at a position that the driving and sensing electrodes face each other.

3. The apparatus according to claim 1 or 2, wherein the processing circuitry is further configured to:

swap a first group of electrodes each acting as the driving electrode for a second group of electrodes each acting as the forming electrode on a first layer on which the driving electrode is located, to change between two electrode patterns on the first layer;

swap a third group of electrodes each acting as the sensing electrode for a fourth group of electrodes each acting as the forming electrode on a second layer on which the sensing electrode is located, to change between two electrode patterns on the second layer;

generate an image formed by pixel values each corresponding to the detected variation of the capacitance at a position that the driving and sensing electrodes face each other, with respect to each of four electrode patterns; and

combine four generated images to obtain a combined image.

4. The apparatus according to any one of claims 1 to 3, wherein

a voltage signal providing the first voltage is coded in a CDM (Code Division Multiplexing) manner so that voltage signals corresponding to the driving electrodes are orthogonal to each other.

5. A capacitive sensing apparatus comprising:

a plurality of sensing electrodes to which a first voltage is applied;

a plurality of forming electrodes to which a second voltage having an opposite sign to the first voltage is applied, wherein each forming electrode is located between adjacent two sensing electrodes; and

processing circuitry configured to detect variation of charge accumulated on each sensing electrode by the first voltage.

6. The apparatus according to claim 5, wherein

the processing circuitry is further configured to generate an image having pixel values each corresponding to the variation of the charge read from each sensing electrode.

7. A method for generating an image by a capacitive sensing apparatus having a plurality of driving electrodes arranged side by side along a first direction, a plurality of sensing electrodes arranged side by side along a second direction crossing the first direction, a plurality of forming electrodes, and processing circuitry, the method comprising:

applying, by a voltage source, a first voltage to each driving electrode;

applying, by the voltage source, a second voltage having an opposite sign to the first voltage to each forming electrode, wherein a forming electrode among the plurality of forming electrodes is located between adjacent two driving electrodes; and

generating, by the processing circuitry, an image based on variation of capacitance between the driving and sensing electrodes.

8. The method according to claim 7, further comprising:

changing, by the processing circuitry, a first group of electrodes each acting as the driving electrode and a second group of electrodes each acting as the forming electrode, to make a plurality of electrode patterns,

wherein the generating, by the processing circuitry, an image based on variation of the capacitance specifically comprises:

generating the image having pixel values each corresponding to variation of the capacitance at a position that the driving and sensing electrodes face each other, with respect to each electrode pattern on the first and second layers, and combining all generated images.

9. The method according to claim 8, wherein the generating, by the processing circuitry, an image specifically comprises generating the image having pixel values each corresponding to the variation of the capacitance at a position of each sensing electrode.

10. The method according to claim 8 or 9, further comprising:

coding, by the processing circuitry, a voltage signal providing the first voltage in a CDM (Code Division Multiplexing) manner so that voltage signals corresponding to the driving electrodes are orthogonal to each other.

11. A method for generating an image by a capacitive sensing apparatus having a plurality of sensing electrodes, a plurality of forming electrodes, and processing circuitry, the method comprising:

applying, by a voltage source, a first voltage to each sensing electrode;

applying, by the voltage source, a second voltage having an opposite sign to the first voltage to each forming electrode, wherein each forming electrode is located between adjacent two sensing electrodes; and

generating, by the processing circuitry, an image based on variation of charge accumulated on each sensing electrode.

12. the method according to claim 11, wherein the generating, by the processing circuitry, an image specifically comprises generating the image having pixel values each corresponding to the variation of the charge read from each sensing electrode.

13. The method according to claim 11 or 12, further comprising:

coding, by the processing circuitry, a voltage signal providing the first voltage in a CDM (Code Division Multiplexing) manner so that voltage signals corresponding to the driving electrodes are orthogonal to each other.

14. A non-transitory computer-readable storage medium storing a program that causes a computer to perform the method according to any one of claims 7 to 10.

15. A non-transitory computer-readable storage medium storing a program that causes a computer to perform the method according to any one of claims 11 to 13.

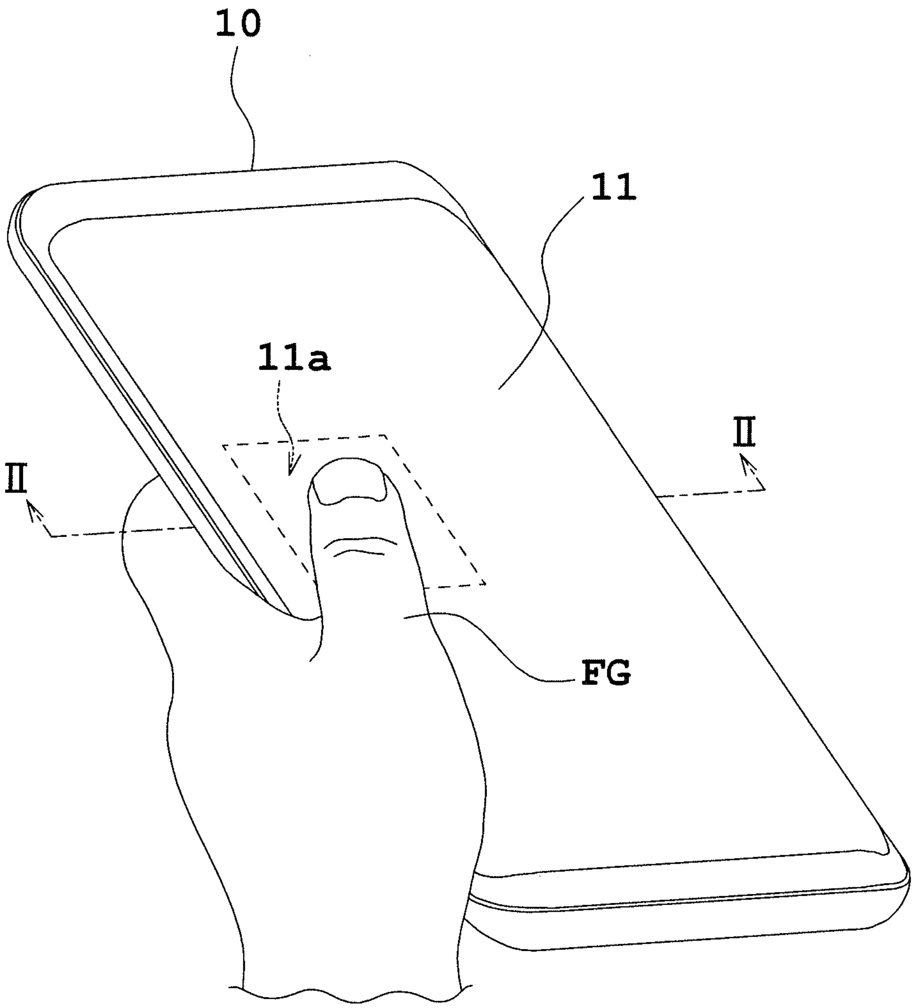

FIG.1

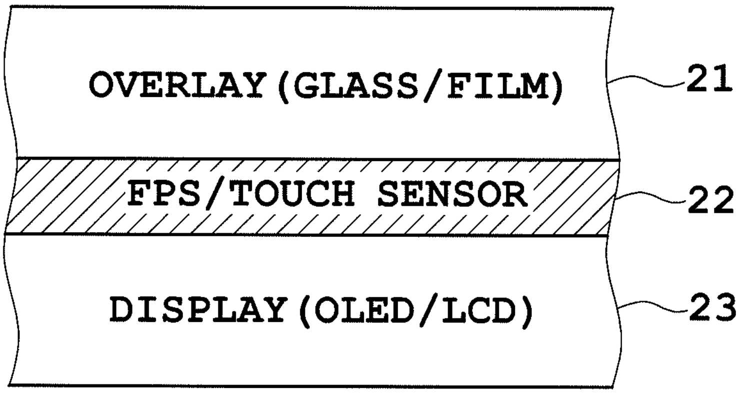

FIG.2A

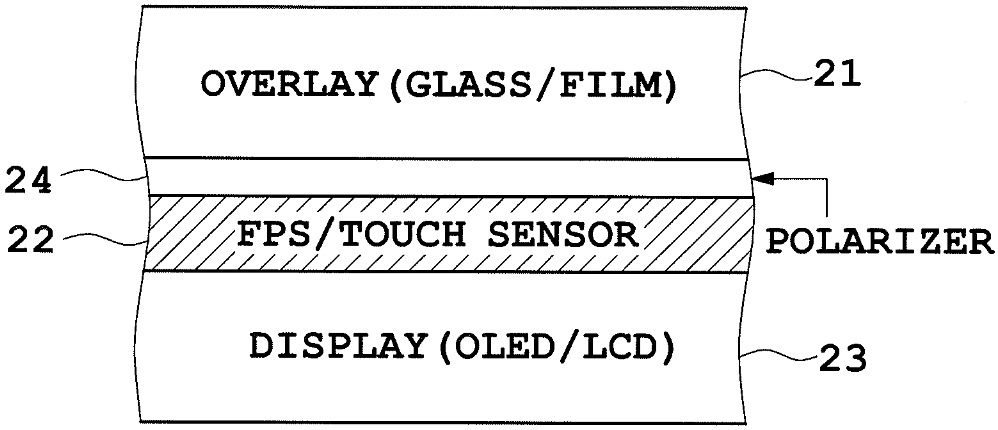

FIG.2B

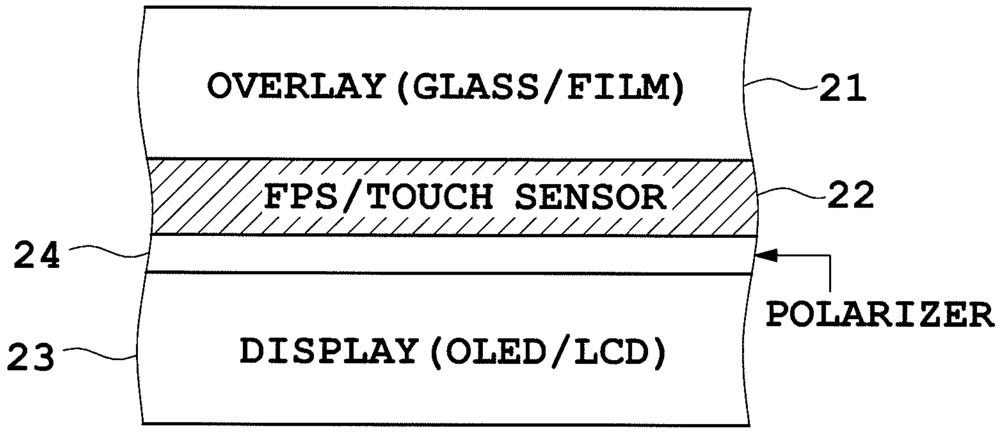

FIG.2C

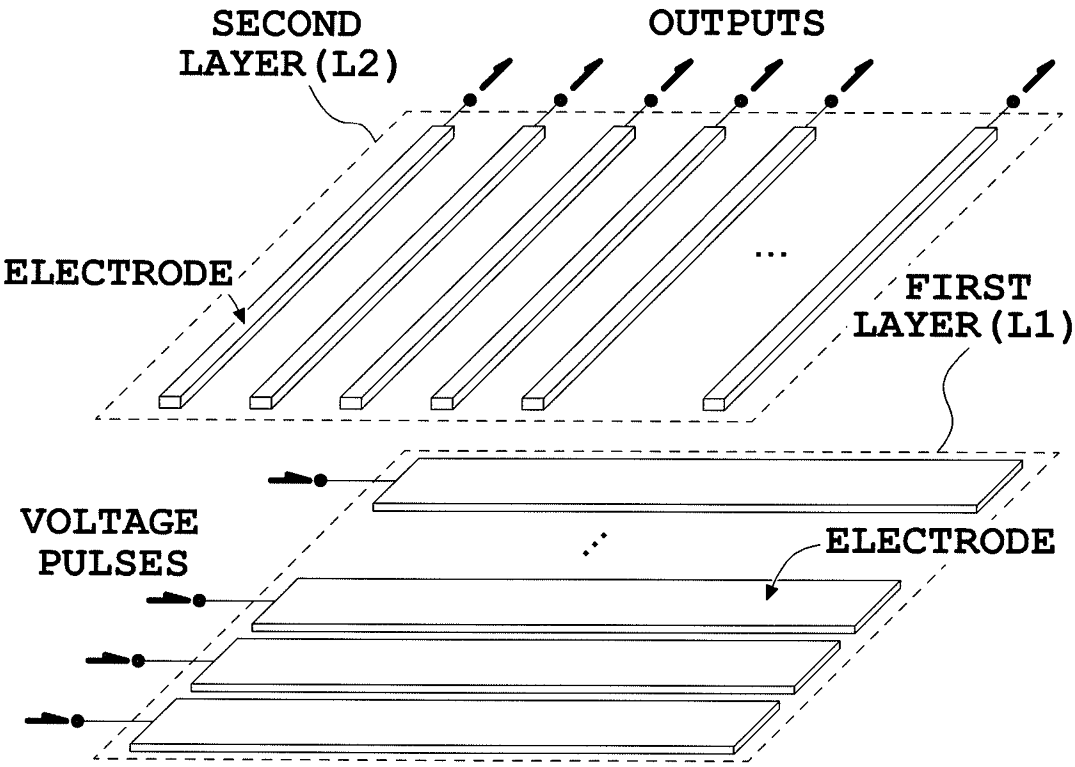
SECOND
LAYER(L2)
OUTPUTS
ELECTRODE
...
FIRST
LAYER(L1)
VOLTAGE
PULSES
ELECTRODE

FIG.3

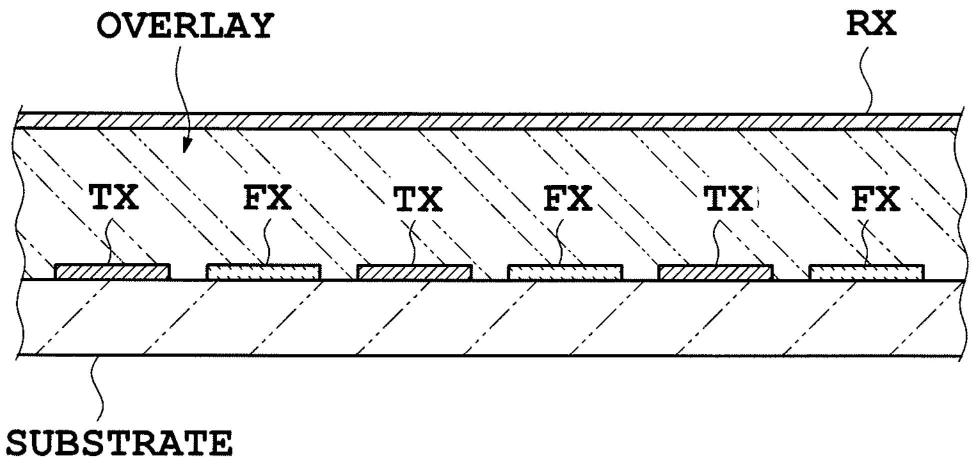
OVERLAY
RX
TX
FX
TX
FX
TX
FX
SUBSTRATE

FIG. 4A

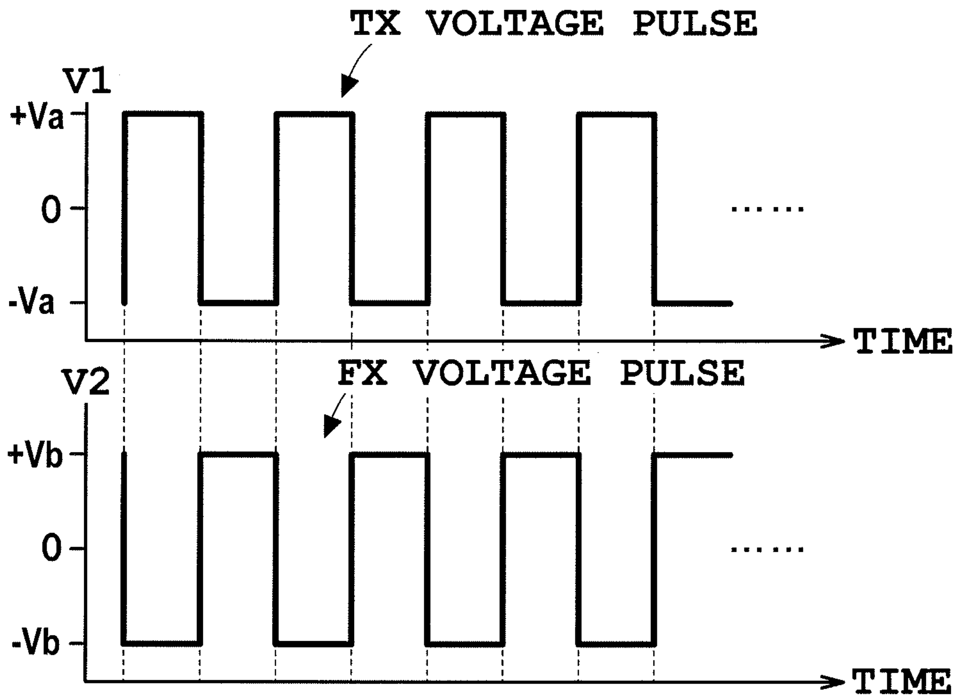
TX VOLTAGE PULSE
V1
+Va
0
-Va
TIME
V2
FX VOLTAGE PULSE
+Vb
0
-Vb
TIME

FIG. 4B

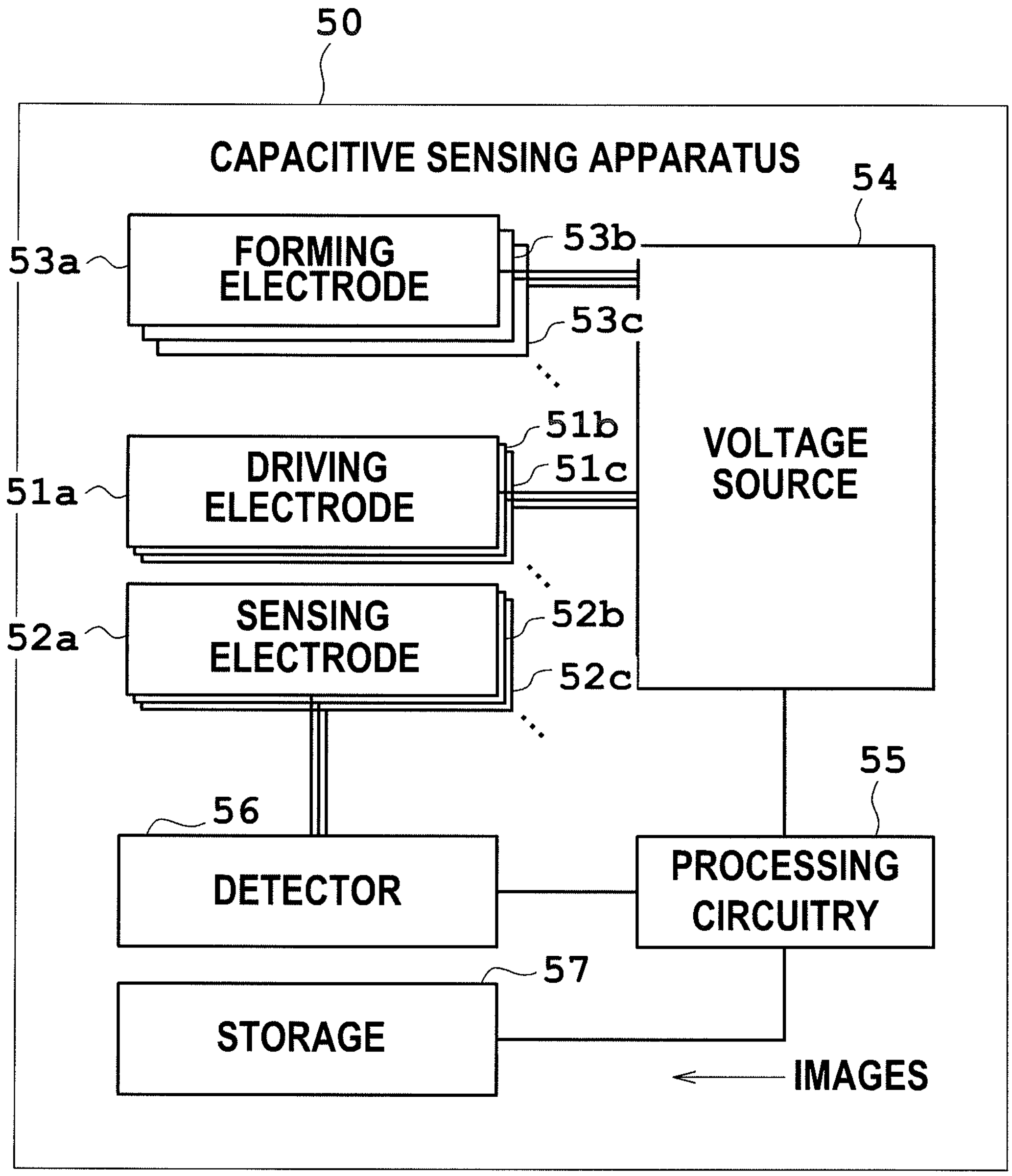
50
CAPACITIVE SENSING APPARATUS
54
53a
FORMING ELECTRODE
53b
53c
51b
51a
DRIVING ELECTRODE
51c
VOLTAGE SOURCE
52a
SENSING ELECTRODE
52b
52c
55
56
DETECTOR
PROCESSING CIRCUITRY
57
STORAGE
IMAGES

FIG.5

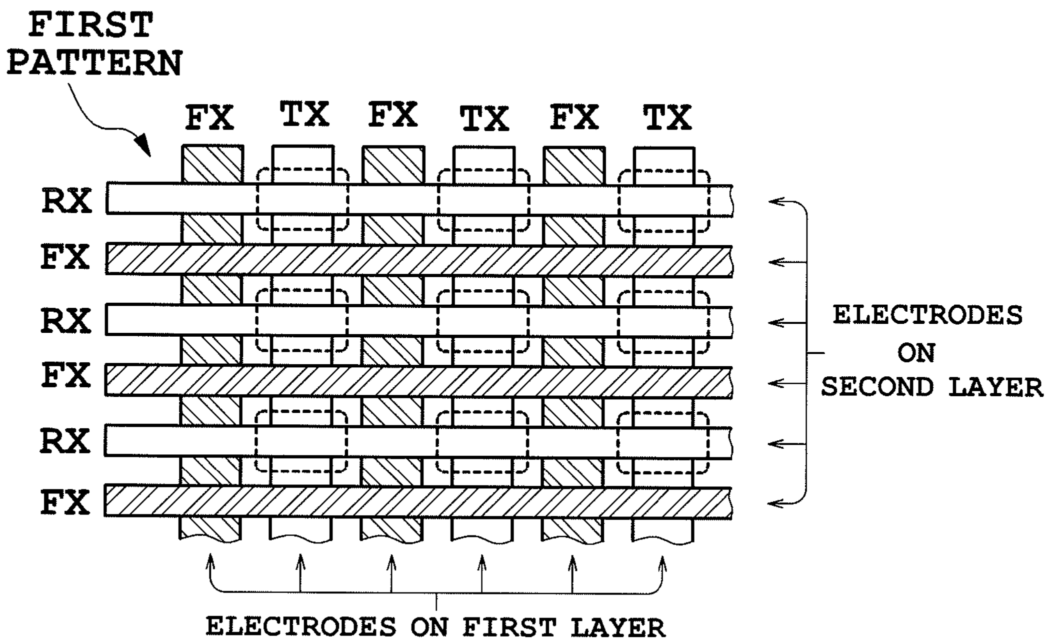
FIRST
PATTERN
FX
TX
FX
TX
FX
TX
RX
FX
RX
FX
RX
FX
ELECTRODES
ON
SECOND LAYER
ELECTRODES ON FIRST LAYER

FIG. 6A

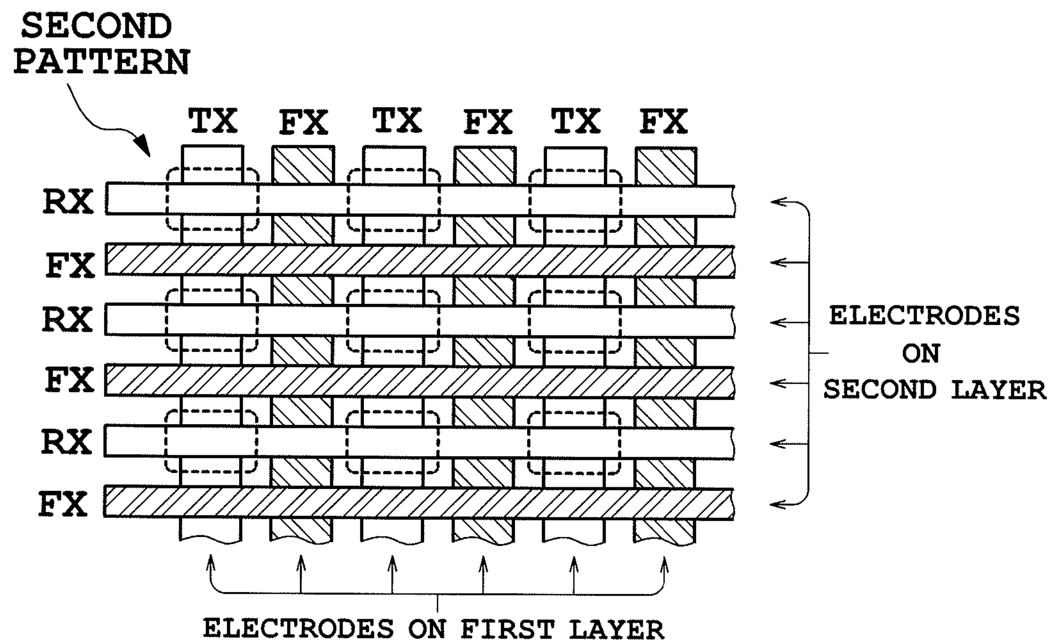
SECOND
PATTERN
TX
FX
TX
FX
TX
FX
RX
FX
RX
FX
RX
FX
ELECTRODES
ON
SECOND LAYER
ELECTRODES ON FIRST LAYER

FIG. 6B

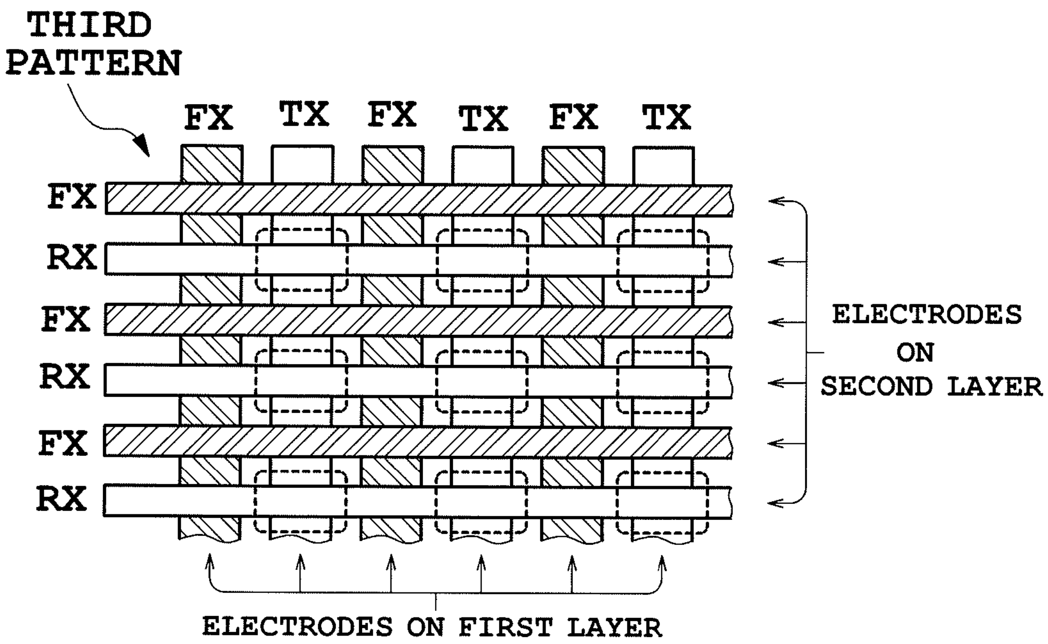
THIRD
PATTERN
FX
TX
FX
TX
FX
TX
FX
RX
FX
RX
FX
RX
ELECTRODES
ON
SECOND LAYER
ELECTRODES ON FIRST LAYER

FIG.7A

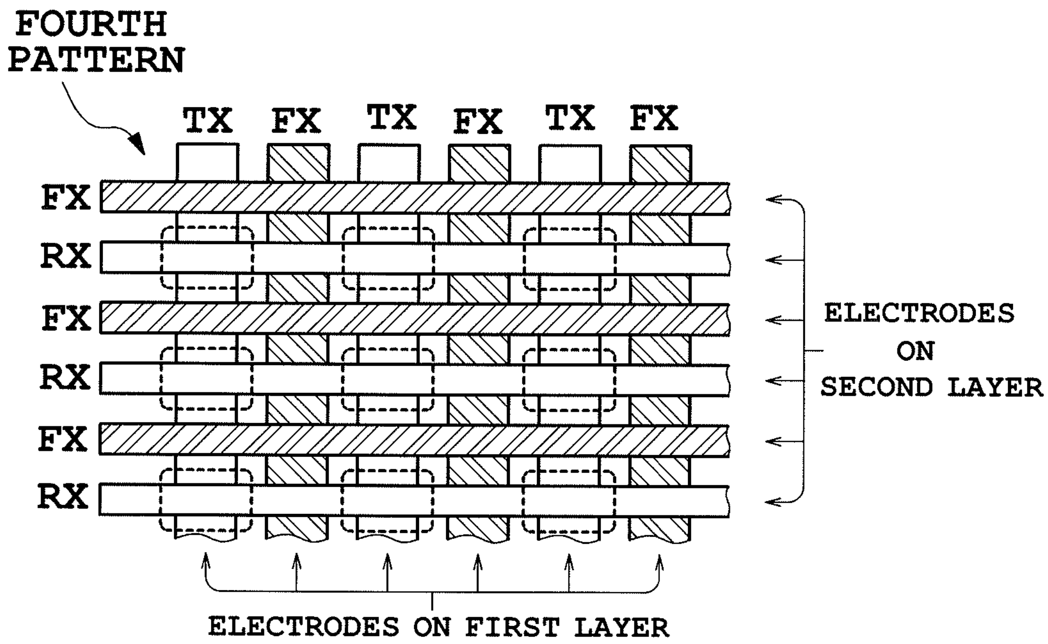
FOURTH
PATTERN
TX
FX
TX
FX
TX
FX
FX
RX
FX
RX
FX
RX
ELECTRODES
ON
SECOND LAYER
ELECTRODES ON FIRST LAYER

FIG.7B

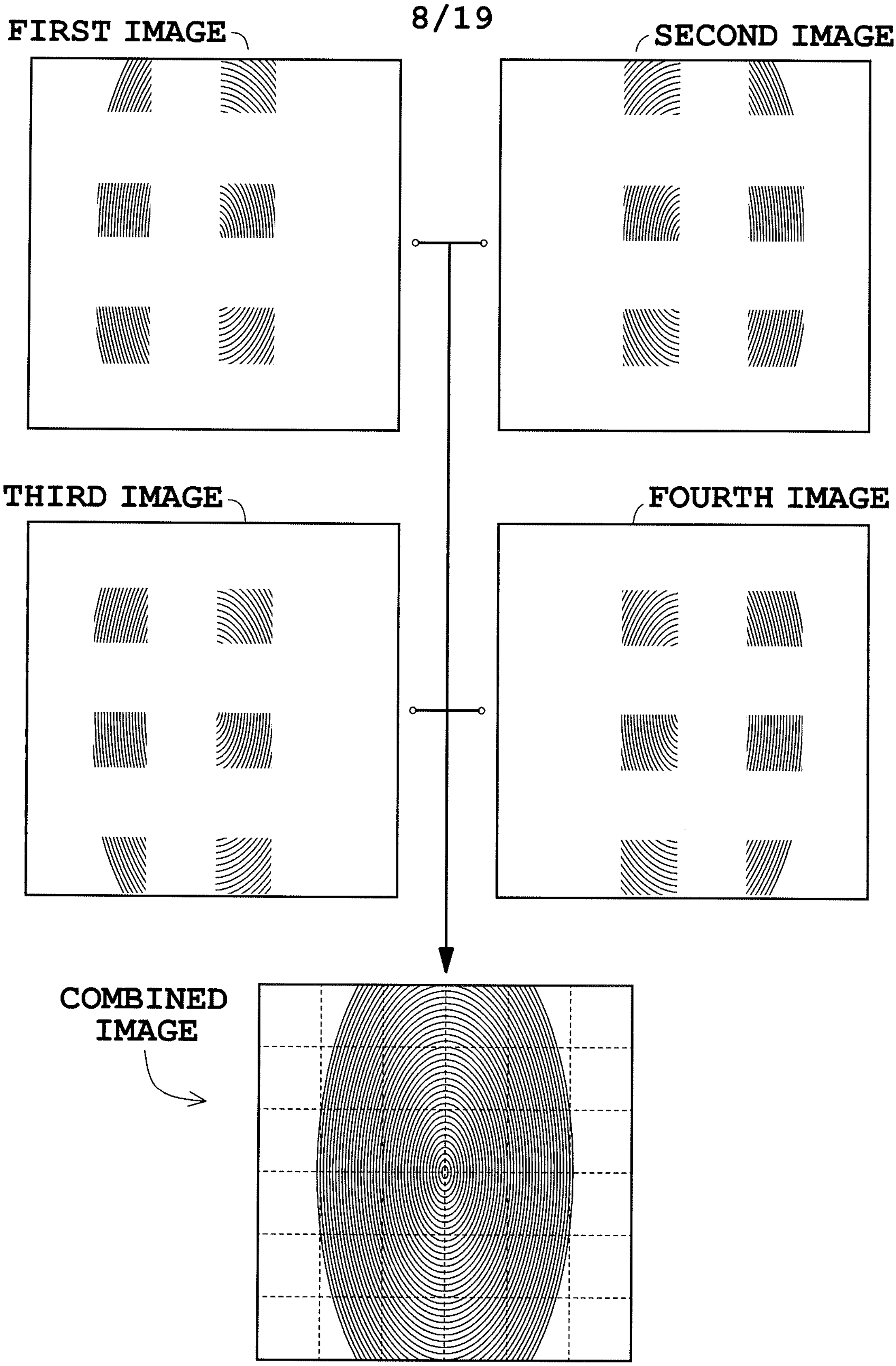
FIRST IMAGE
SECOND IMAGE
THIRD IMAGE
FOURTH IMAGE
COMBINED IMAGE

FIG.8

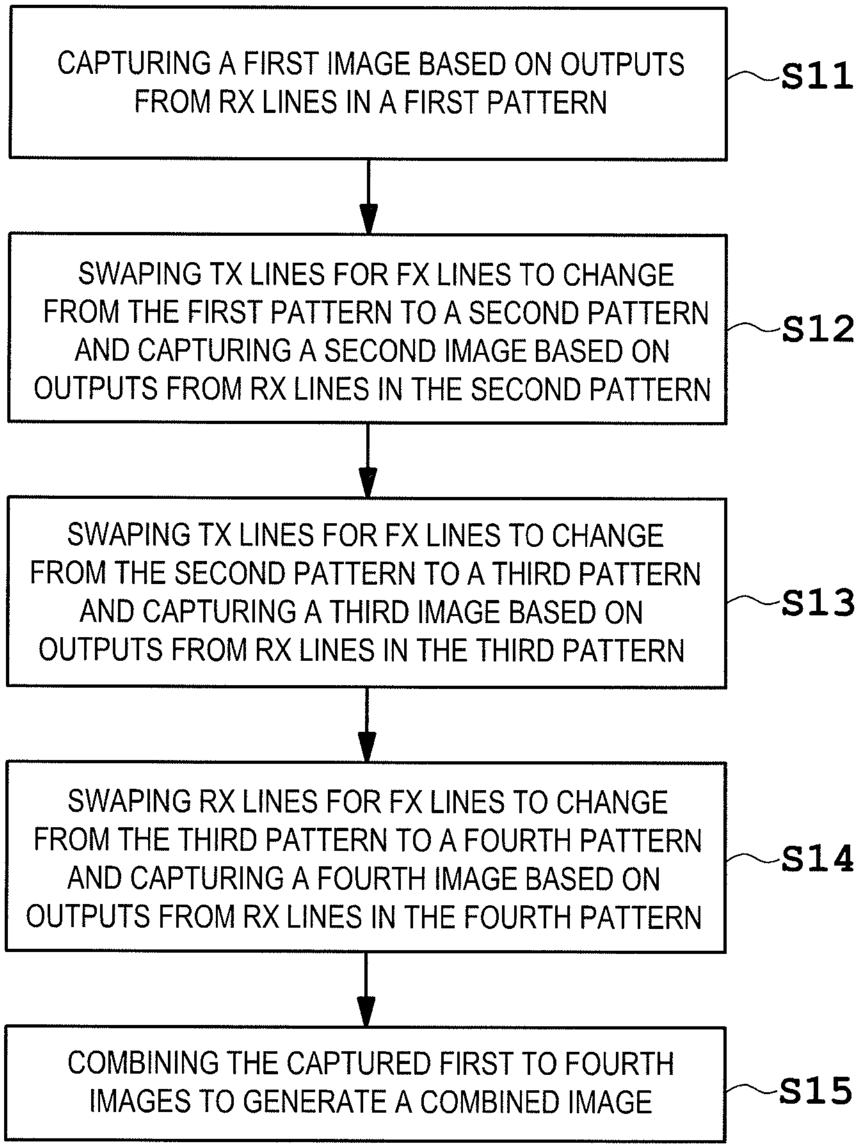
CAPTURING A FIRST IMAGE BASED ON OUTPUTS FROM RX LINES IN A FIRST PATTERN
S11
SWAPING TX LINES FOR FX LINES TO CHANGE FROM THE FIRST PATTERN TO A SECOND PATTERN AND CAPTURING A SECOND IMAGE BASED ON OUTPUTS FROM RX LINES IN THE SECOND PATTERN
S12
SWAPING TX LINES FOR FX LINES TO CHANGE FROM THE SECOND PATTERN TO A THIRD PATTERN AND CAPTURING A THIRD IMAGE BASED ON OUTPUTS FROM RX LINES IN THE THIRD PATTERN
S13
SWAPING RX LINES FOR FX LINES TO CHANGE FROM THE THIRD PATTERN TO A FOURTH PATTERN AND CAPTURING A FOURTH IMAGE BASED ON OUTPUTS FROM RX LINES IN THE FOURTH PATTERN
S14
COMBINING THE CAPTURED FIRST TO FOURTH IMAGES TO GENERATE A COMBINED IMAGE
S15

FIG. 9

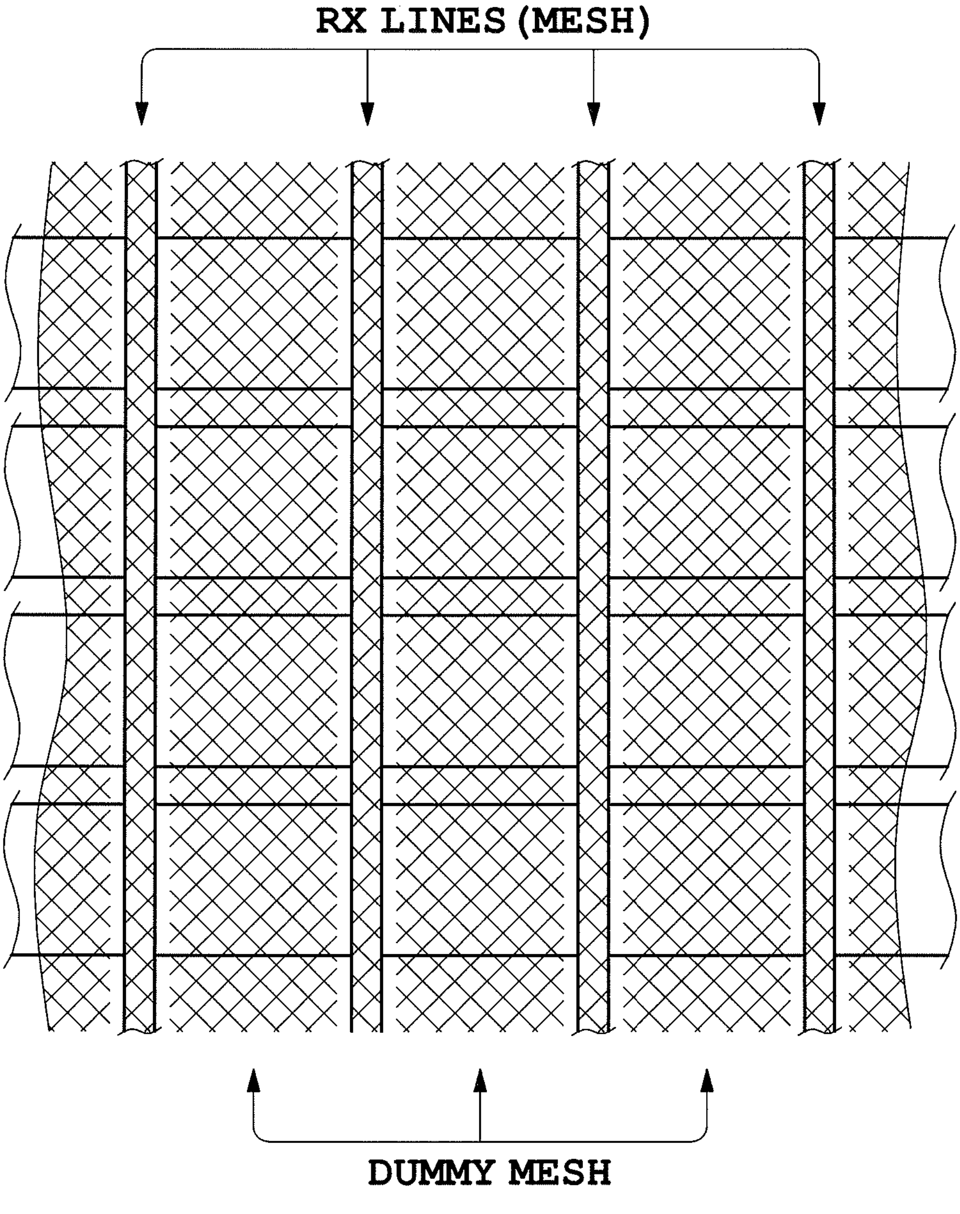

FIG.10

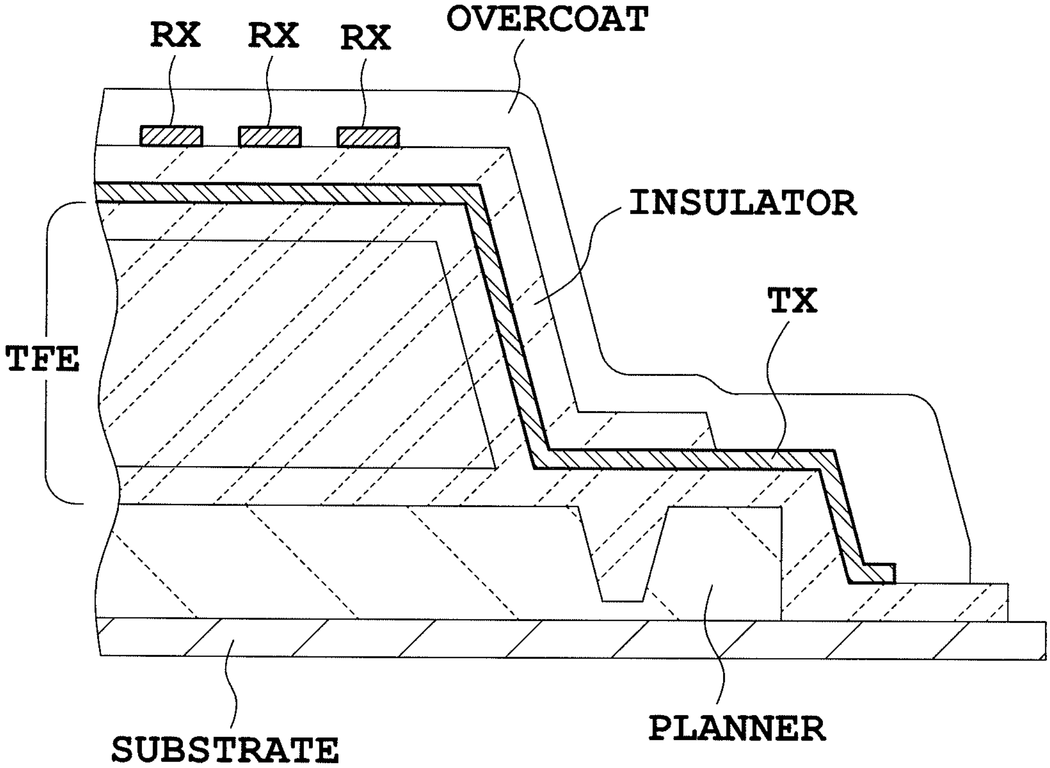

FIG.11

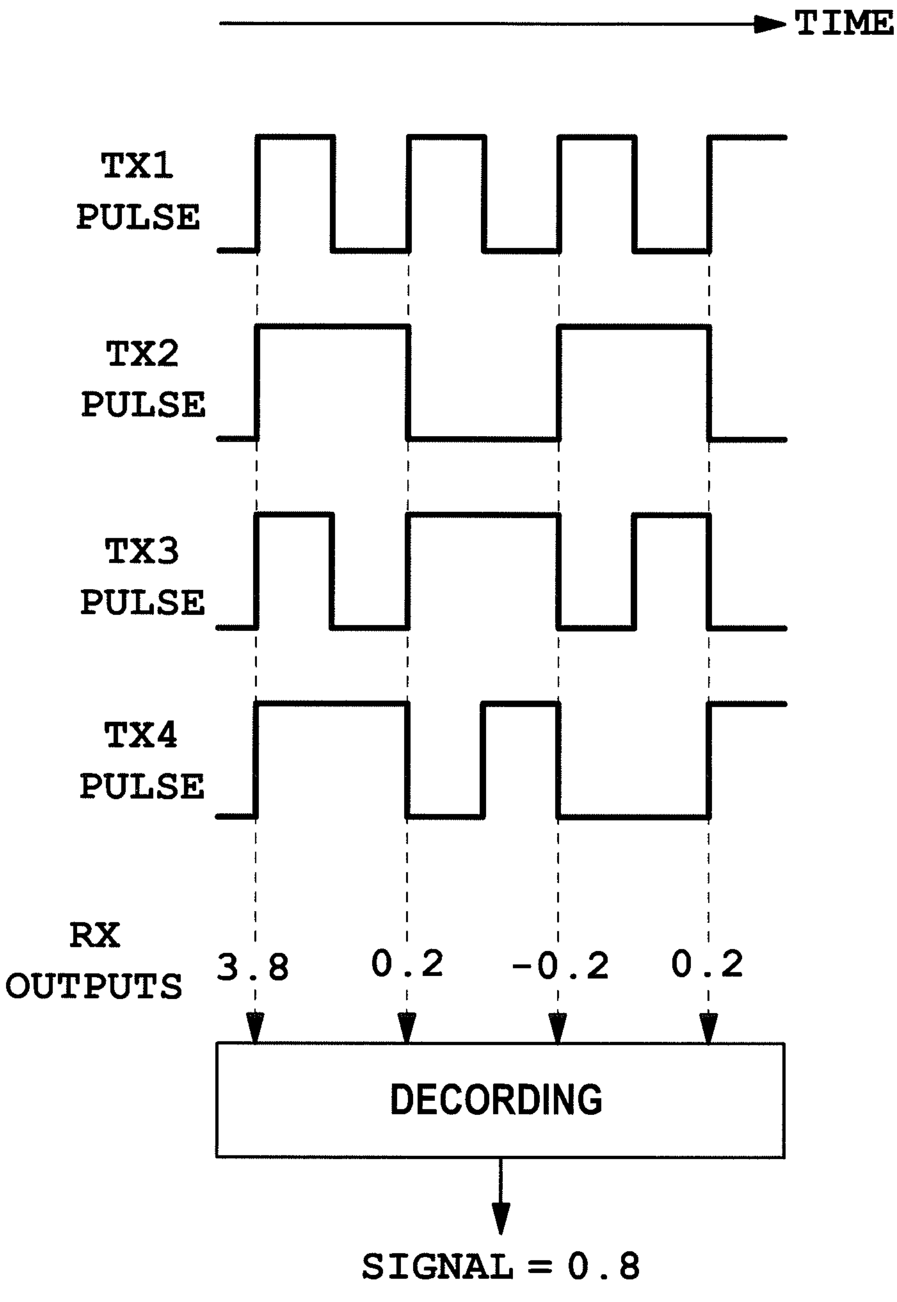
TIME
TX1 PULSE
TX2 PULSE
TX3 PULSE
TX4 PULSE
RX OUTPUTS
3.8
0.2
-0.2
0.2
DECORDING
SIGNAL = 0.8

FIG.12

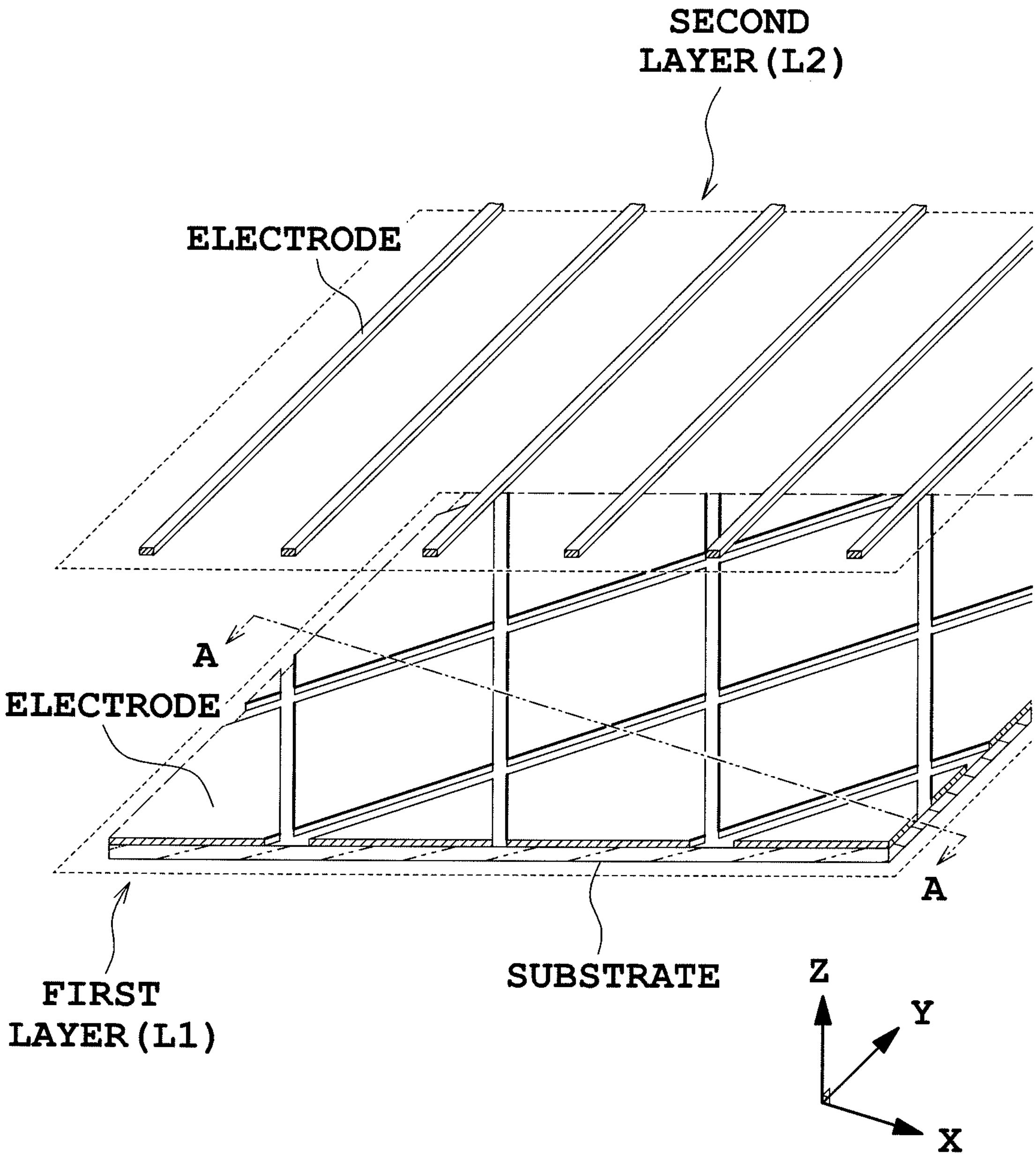
SECOND
LAYER(L2)
ELECTRODE
A
ELECTRODE
A
FIRST
LAYER(L1)
SUBSTRATE
Z
Y
X

FIG.13

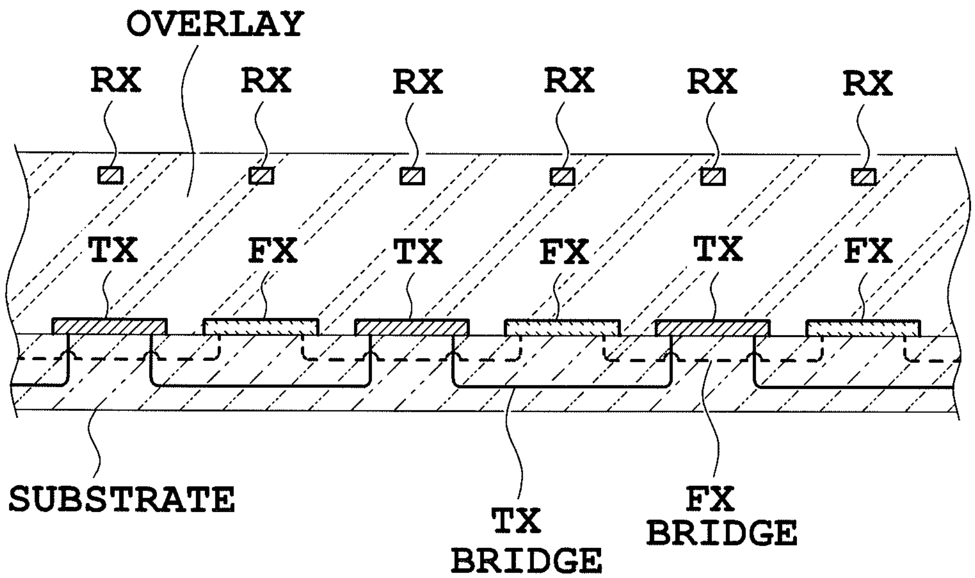

FIG.14A

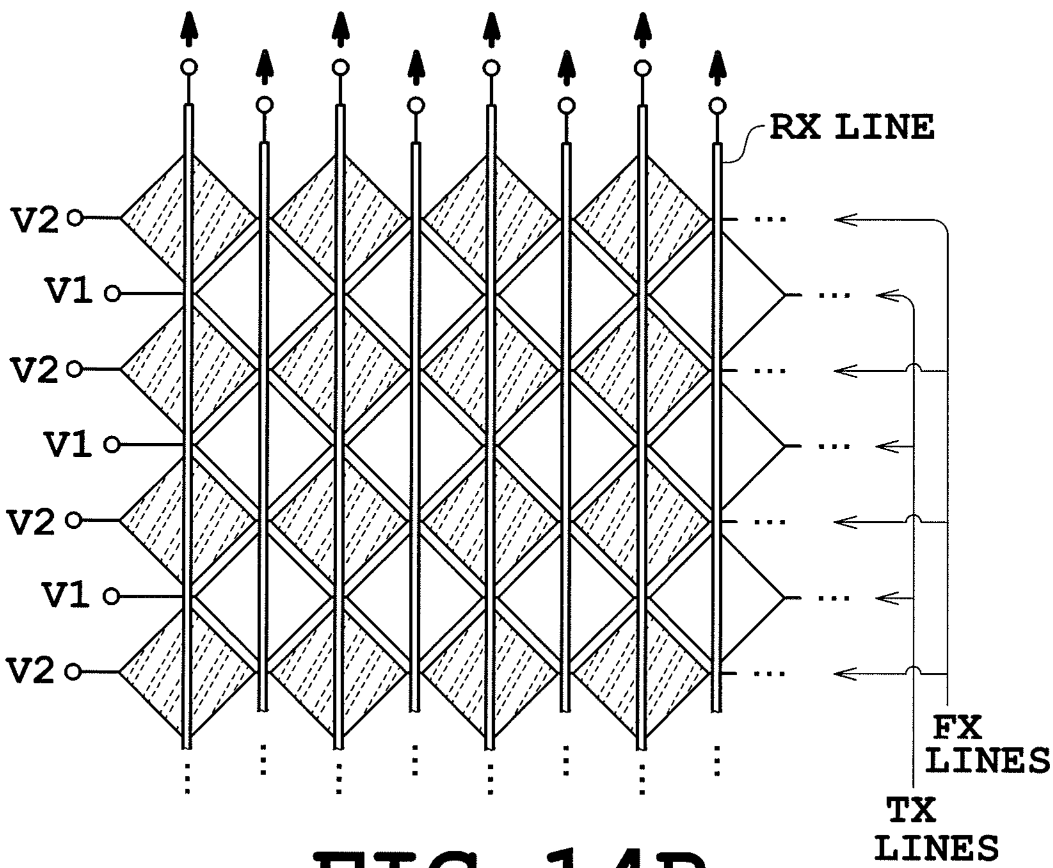

FIG.14B

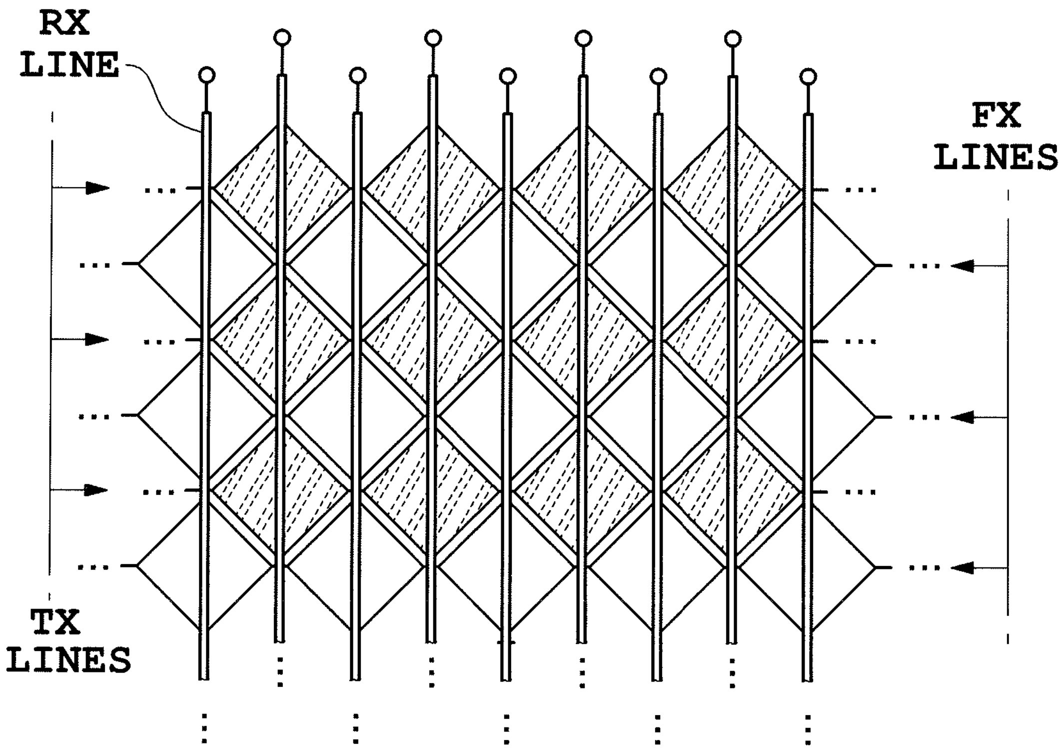

FIG.15A

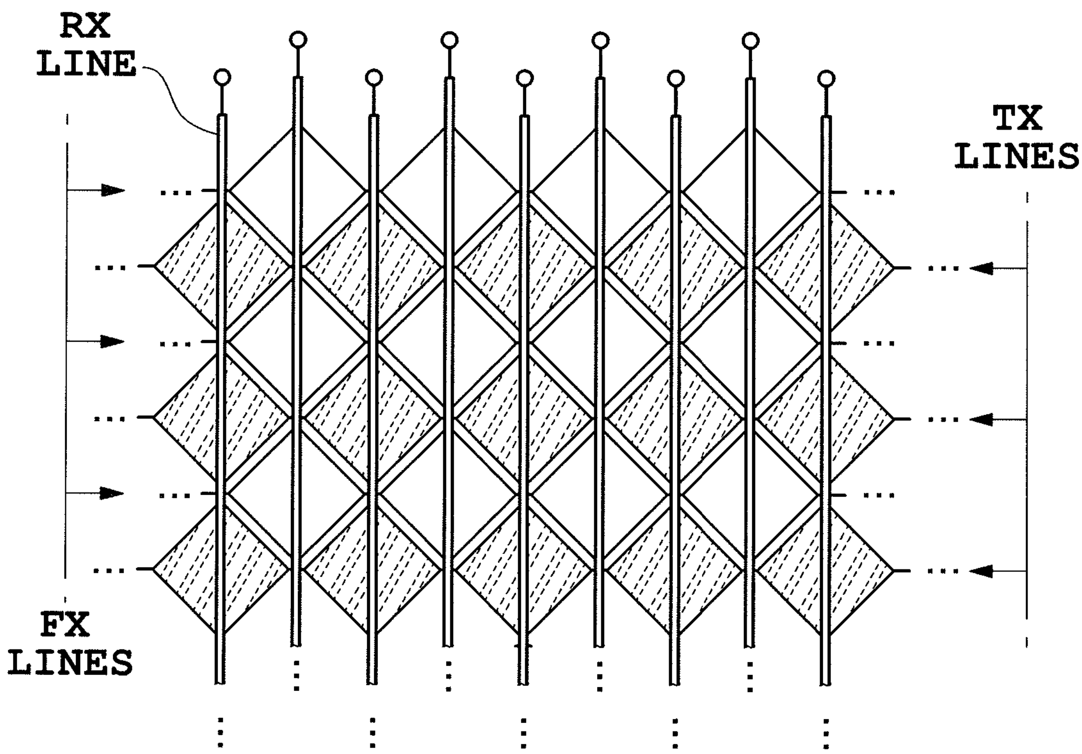

FIG.15B

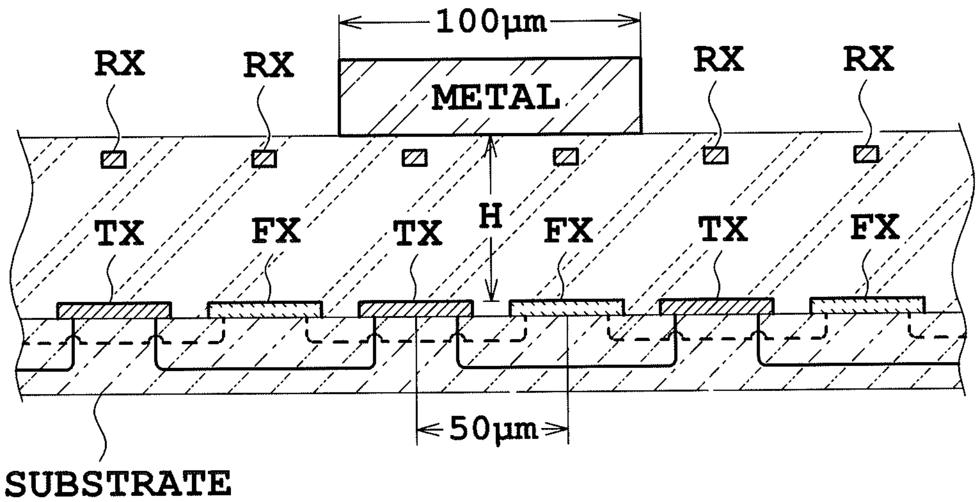

FIG. 16A

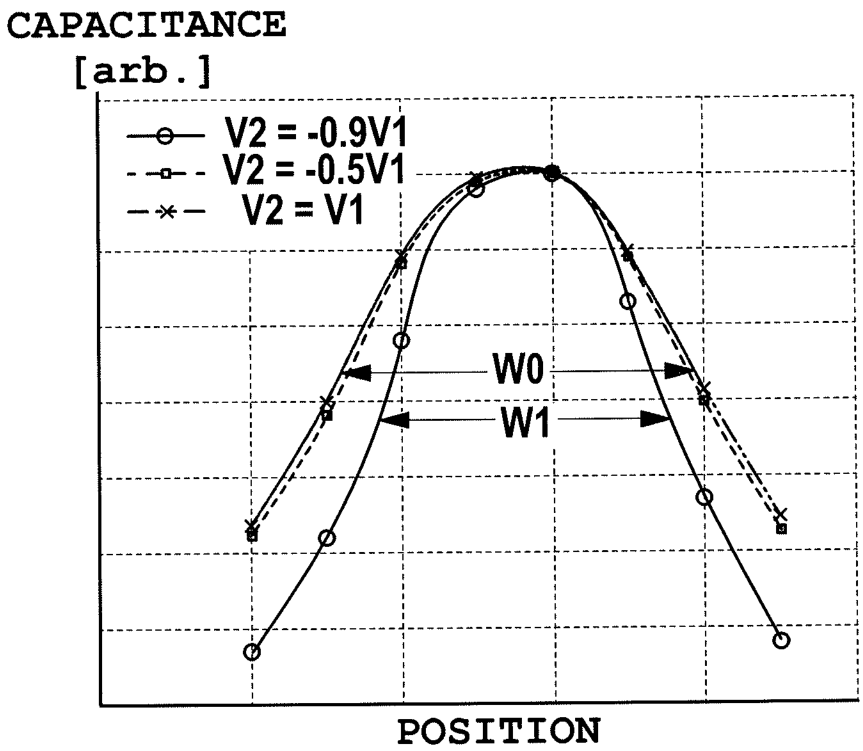

FIG. 16B

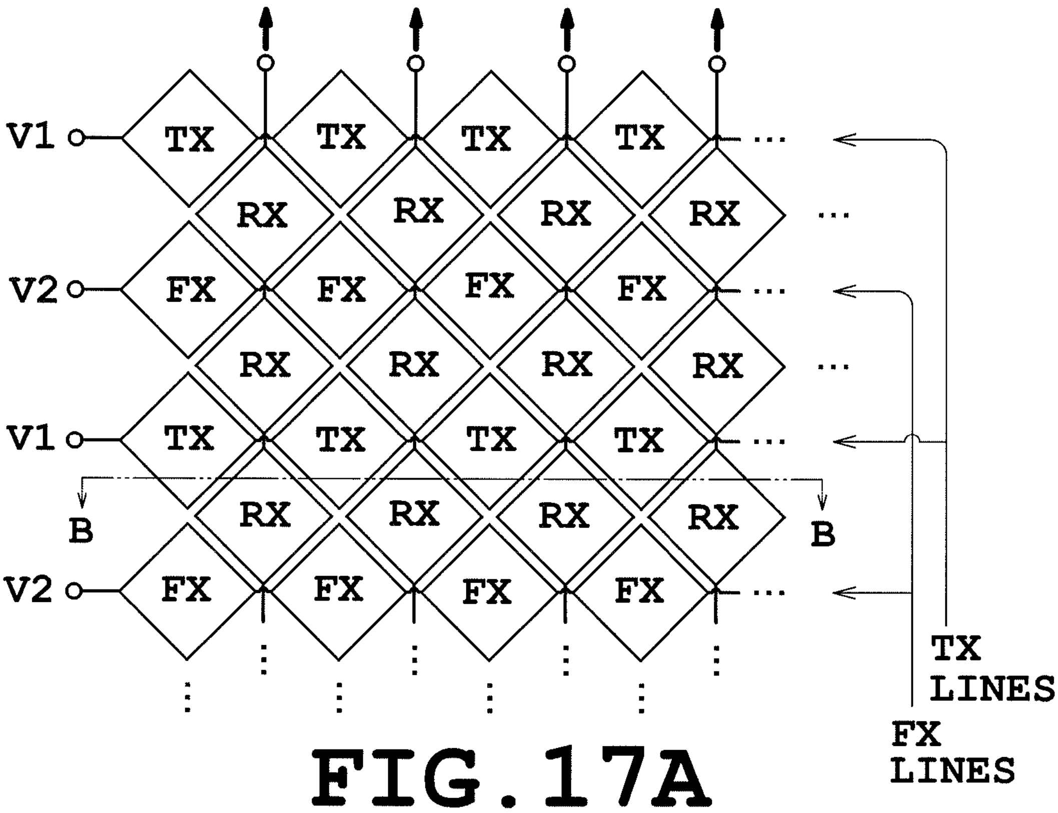

FIG.17A

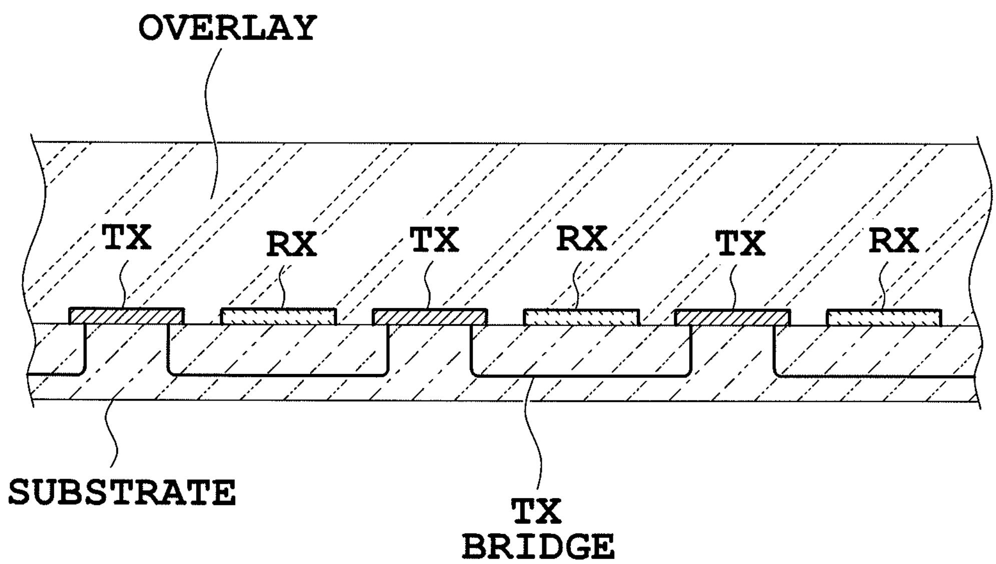

FIG.17B

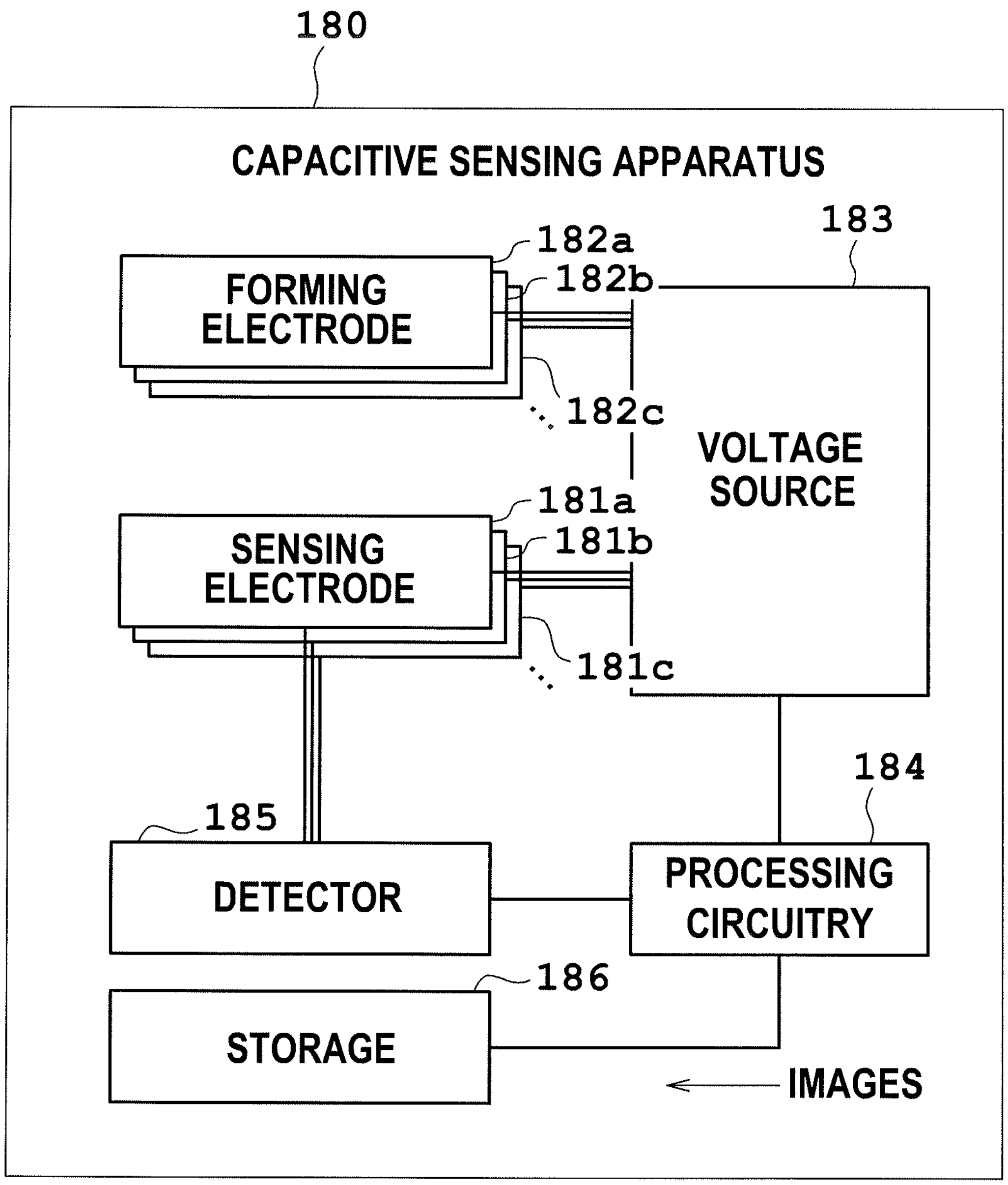
180
CAPACITIVE SENSING APPARATUS
182a
182b
183
FORMING ELECTRODE
182c
VOLTAGE SOURCE
181a
181b
SENSING ELECTRODE
181c
184
185
DETECTOR
PROCESSING CIRCUITRY
186
STORAGE
IMAGES

FIG.18

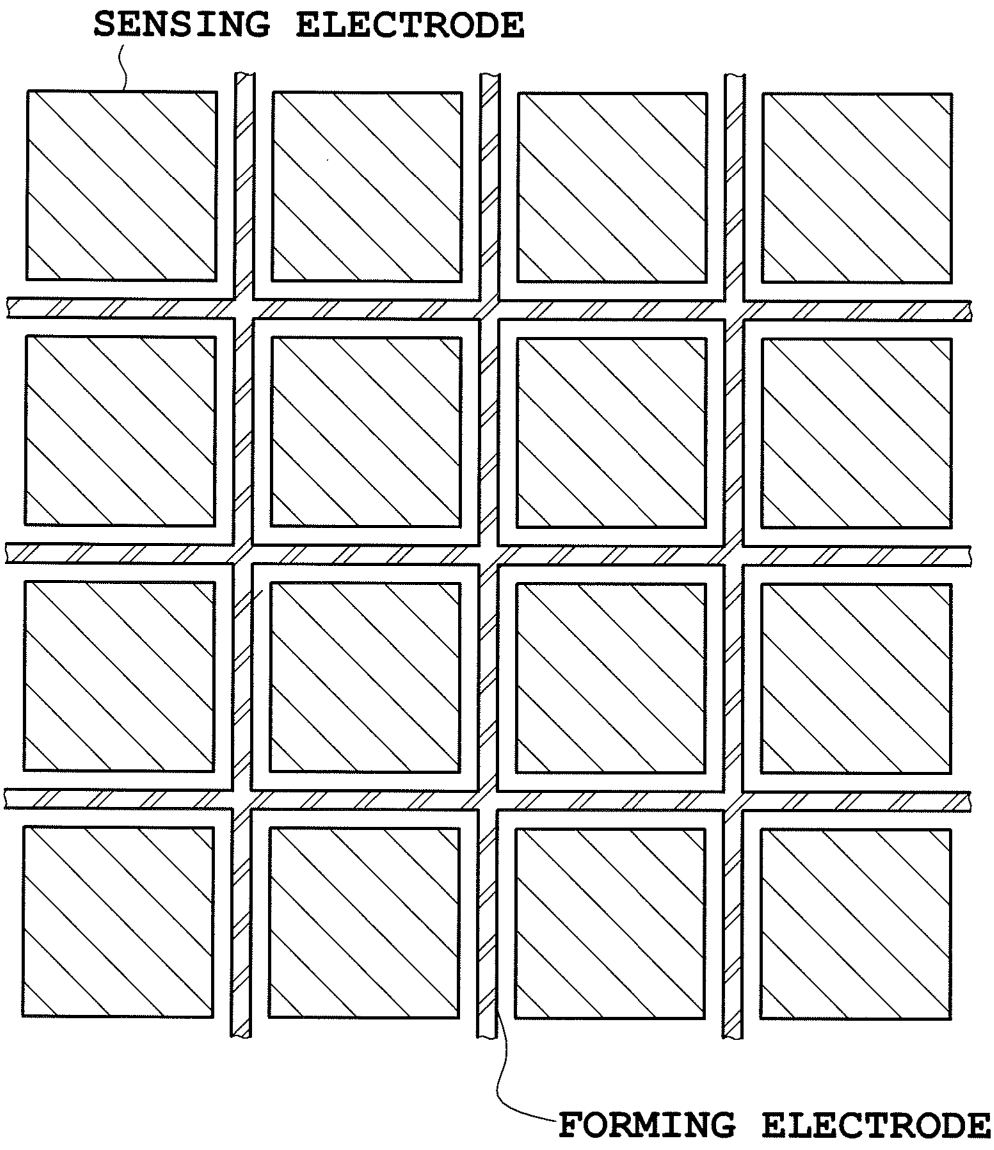

FIG.19

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/106480

A. CLASSIFICATION OF SUBJECT MATTER

G06F 3/044(2006.01)i； G06F 3/041(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNKI, WPI, EPODOC, CNPAT, IEEE: fingerprint, touch, panel, driving, sensing, forming, electrode, voltage, level, opposite, complementary

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104133590 A (AU OPTRONICS CORPORATION) 05 November 2014 (2014-11-05) description, paragraph [0040], figure 1	1-15
A	CN 107015707 A (BOE TECHNOLOGY GROUP CO., LTD. et al.) 04 August 2017 (2017-08-04) the whole document	1-15
A	CN 105786246 A (XIAMEN TIANMA MICRO-ELECTRONICS CO., LTD. et al.) 20 July 2016 (2016-07-20) the whole document	1-15
A	US 2018275791 A1 (BOE TECHNOLOGY GROUP CO., LTD.) 27 September 2018 (2018-09-27) the whole document	1-15

☐ Further documents are listed in the continuation of Box C.   ☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 April 2021	**29 April 2021**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**DONG,Gang**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961348**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/106480

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	104133590	A	05 November 2014	None			
CN	107015707	A	04 August 2017	WO	2018228284	A1	20 December 2018
CN	105786246	A	20 July 2016	None			
US	2018275791	A1	27 September 2018	CN	107632727	A	26 January 2018
				WO	2018014707	A1	25 January 2018
				EP	3486756	A1	22 May 2019