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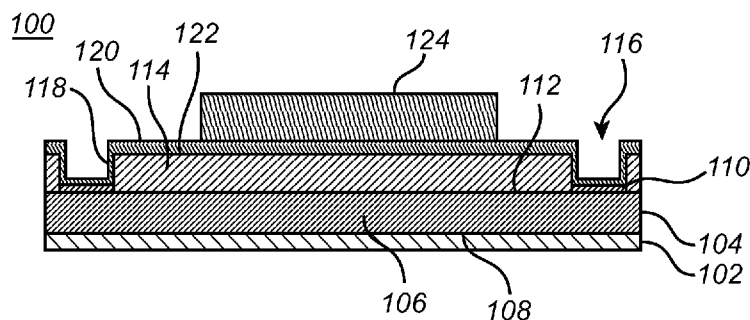


Fig. 1A

(57) Abstract: The present disclosure relates to a biometric imaging device (100, 200) comprising: a plastic film (102) forming an outer surface of the biometric imaging device; a thin-film transistor, TFT, circuit (104) comprising a capacitive fingerprint sensing device (106) having a sensing side (108) on a first side thereof, facing towards the plastic film, the capacitive fingerprint sensing device comprising electrically conductive contact pads (110) on a second side (112) thereof, facing away from the plastic film; a printed circuit board, PCB, substrate (114) attached to the second side of the TFT-circuit, the PCB-substrate comprising through-openings (116), wherein the PCB-substrate further comprises an electrical connection (118, 202) between a conductive trace (120) located on a top surface (122) of the PCB-substrate facing away from the TFT-circuit, via the through-openings of the PCB-substrate, and the conductive contact pads (110) of the capacitive fingerprint sensing device.



BIOMETRIC IMAGING DEVICE AND METHOD FOR MANUFACTURING THE BIOMETRIC IMAGING DEVICE

Field of the Invention

The present invention relates to a biometric imaging device and to a method of manufacturing the biometric imaging device. In particular, the invention relates to a fingerprint sensor module comprising a thin-film-
5 transistor (TFT) fingerprint sensor.

Background of the Invention

As the development of biometric imaging devices for identity verification, and in particular of fingerprint sensing devices, has led to devices
10 which are made smaller, cheaper and more energy efficient, the range of applications for such devices is increasing.

In particular, capacitive fingerprint sensing devices have been adopted more and more in for example consumer electronic devices due to small form factor, relatively beneficial cost/performance factor and high user acceptance.
15 There is also an increasing interest in using fingerprint sensors in smartcards to enable biometric identification in a card such as a bank card where other types of biometric systems are not applicable.

Capacitive fingerprint sensors can be manufactured in large numbers and at low cost using a thin film transistor (TFT) process. However, current
20 TFT-circuits are often very thin, having a thickness of about 5 μm , and a total thickness of about 30 μm including a carrier substrate, which requires careful handling of the TFT-circuits during manufacturing of a fingerprint sensing module to prevent wrapping, cracking or other damages.

Previous solutions have included arranging the TFT-circuit on a thick
25 substrate such as a flexible substrate or a glass substrate. However, such additional substrates increase the overall thickness of the sensing module, while in fingerprint sensing modules suitable for smartcard integration it is desirable to minimize the thickness. Moreover, in application where fingerprint

sensing takes place through the substrate, it is even more important to minimize the thickness of the substrate on which the TFT-circuit is arranged.

Accordingly, it is desirable to provide improved manufacturing methods for fingerprint sensing modules comprising a capacitive fingerprint sensing
5 device based on a TFT-process.

Summary

In view of above-mentioned and other drawbacks of the prior art, it is an object of the present invention to provide an improved biometric imaging
10 device and a method for manufacturing a biometric imaging device based on thin-film transistor technology.

According to a first aspect of the invention, it is provided a biometric imaging device comprising: a plastic film forming an outer surface of the biometric imaging device; a thin-film transistor, TFT, circuit comprising a
15 capacitive fingerprint sensing device having a sensing side on a first side thereof, facing towards the plastic film, the capacitive fingerprint sensing device comprising electrically conductive contact pads on a second side thereof, facing away from the plastic film; a printed circuit board, PCB, substrate attached to the second side of the TFT-circuit, the PCB-substrate
20 comprising through-openings, wherein the PCB-substrate further comprises an electrical connection between a conductive trace located on a top surface of the PCB-substrate facing away from the TFT-circuit, via the through-openings of the PCB-substrate, and the conductive contact pads of the capacitive fingerprint sensing device.

25 The plastic film can be a polyimide film which will be acting as an outer surface of the completed biometric imaging device. Polyimide is a preferable material since it can withstand higher temperatures compared to many other plastic materials which may be required during subsequent steps of the manufacturing process. Furthermore, a film is in the present context a thin
30 layer of material or materials which is flexible, and which can be provided as sheets or on a roll or as a liquid deposited on a surface where the liquid is

subsequently hardened to form a film. Moreover, a film may also comprise a plurality of different layers.

The present invention is based on the realization that it is preferable to provide a biometric imaging device comprising a capacitive fingerprint
5 sensing device based on TFT-technology where a finger does not have to be sensed through connection layers of the TFT-circuit. The claimed method provides biometric imaging device where only a plastic film separates the outer surface of the biometric imaging device and an active portion of the capacitive fingerprint sensing device, thereby minimizing the distance
10 between the active portion and the finger which in turn improves the performance of the biometric imaging device.

Moreover, the use of a PCB substrate provides structural stability to the very thin TFT-circuit and facilitates connection of the TFT-circuit to external circuitry since an electrical connection can easily be formed through
15 the PCB substrate.

According to one embodiment of the invention, the through openings of the PCB-substrate are located at locations corresponding to the contact pads of the fingerprint sensing device which means that an electrical connection can be formed directly through the through-opening of the PCB. However, it is
20 also possible to use a PCB with via connections and with conductive traces and contact pads on the side of the PCB-substrate facing the TFT-circuit so that the openings of the PCB-substrate do not have to be aligned with the contact pads of the fingerprint sensing device. According to one embodiment of the invention. The through openings of the PCB-substrate may also be
25 filled with an electrically conductive material.

According to one embodiment of the invention, the electrical connection comprises metal arranged on side walls of the through-opening. The metal can for example be formed on the side wall by means of metal plating by which a conductive layer can be deposited on the sidewalls of the
30 PCB through-opening, on the contact pads of the fingerprint sensing device and on a top layer of the PCB-substrate to form the electrical connection between the conductive trace located on a top surface of the PCB-substrate

and the conductive contact pads of the capacitive fingerprint sensing device. It is also possible to form the conductive traces in the conductive layer after metal plating.

According to one embodiment of the invention the electrical connection
5 comprises a bond wire reaching from the conductive trace to the contact pad via the through-opening in the PCB substrate. Accordingly, wire-bonding can be used to form the electrical connection between pre-made conductive traces on the top surface of the PCB-substrate and the conductive contact pads of the capacitive fingerprint sensing device

10 According to one embodiment of the invention, the biometric imaging device further comprises at least one component arranged on the PCB-substrate, conductive traces arranged on the top surface of the PCB-substrate configured to form an electrical connection between the at least one component and contact pads of the fingerprint sensing device. The
15 component may for example be a surface mounted discrete component and/or an integrated circuit.

According to one embodiment of the invention, the biometric imaging device is integrated in a smartcard comprising a card body in which the biometric imaging device according to any one of the aforementioned
20 embodiments is arranged; and a conductive layer electrically connected to contact pads of the biometric imaging device.

According to a second aspect of the invention, there is provided a method for manufacturing a biometric imaging device. The method comprising: providing a glass carrier; arranging a plastic film on the glass
25 carrier; forming a thin-film transistor, TFT, circuit on the plastic film, the TFT-circuit being configured to form a capacitive fingerprint sensing device having a sensing side facing towards the plastic film, the fingerprint sensing device comprising a plurality of electrically conductive contact pads, the contact pads facing away from the plastic film; arranging a printed circuit board, PCB,
30 substrate on the TFT-circuit, the PCB-substrate comprising a conductive layer on a surface facing away from the TFT-circuit; removing the glass carrier; forming openings through the PCB-substrate at locations corresponding to

the conductive contact pads of the fingerprint sensing device such that the contact pads are exposed; and forming an electrical connection between the conductive contact pads of the fingerprint sensing device and the conductive layer of the PCB-substrate.

5 In the present context, the glass substrate can be made from any type of glass suitable for use in microelectronic manufacturing and assembly, such as quartz or silica glass.

 In the described method, electrical via connections are formed by first arranging a PCB-substrate without openings on the TFT-circuit followed by
10 forming openings in the PCB-substrate.

 According to one embodiment of the invention, the conductive layer of the PCB-substrate is a continuous metal layer, and the step of forming an electrical connection further comprises depositing a metal in the openings of the PCB-substrate and forming a pattern of conductive traces in the
15 conductive layer. Metal deposition by means of metal plating can thereby be performed over the entire surface of the PCB substrate and the pattern of conductive traces on the PCB substrate is formed after the formation of the vertical via connection.

 According to one embodiment of the invention, the method further
20 comprises arranging at least one component on a top surface of the PCB-substrate and electrically connecting the at least one component to the capacitive fingerprint sensing device via the openings through the PCB-substrate.

 According to one embodiment of the invention, the method further
25 comprises arranging the biometric imaging device in a smartcard and forming an electrical connection between a conductive layer of the smartcard and the contact pads of the biometric imaging device.

 A smartcard can be considered to be any card comprising functionality such as biometric sensing, and smartcards may be used as payment cards,
30 identification cards, access cards and in other applications where a card with built-in functionality is desirable. In the present context, the smartcard comprises a biometric imaging device.

Further effects and features of the second aspect of the invention are largely analogous to those described above in connection with the first aspect of the invention.

According to a third aspect of the invention, it is provided a method for
5 manufacturing a biometric imaging device. The method comprises: providing a glass carrier; arranging a plastic film on the glass carrier; forming a thin-film transistor, TFT, circuit on the plastic film, the TFT-circuit being configured to form a capacitive fingerprint sensing device having a sensing side facing towards the plastic film, the fingerprint sensing device comprising a plurality of
10 electrically conductive contact pads, the contact pads facing away from the plastic film; providing a printed circuit board, PCB, substrate, the PCB-substrate comprising a conductive pattern on a top surface of the PCB-substrate and openings through the PCB-substrate at locations corresponding to the conductive contact pads of the fingerprint sensing device; arranging the
15 PCB-substrate on the TFT-circuit, with the conductive pattern facing away from the TFT-circuit, wherein the openings of the PCB-substrate are aligned with the contact pads of the TFT-circuit such that the contact pads are exposed; removing the glass carrier; and forming an electrical connection between the conductive contact pads of the fingerprint sensing device and the
20 conductive pattern of the PCB-substrate.

In the described method, a PCB-substrate with pre-formed openings and with a pre-formed pattern of conductive traces is arranged on the TFT-circuit, which can be advantageous when it is desirable to reduce the number of process steps to be performed when the PCB substrate is attached to the
25 TFT circuit.

According to one embodiment of the invention, forming an electrical connection comprises wire bonding to form bond wires between the conductive pattern of the PCB-substrate and the conductive contact pads of the fingerprint sensing device. The bond wires are preferably protected by
30 forming an encapsulation covering the bond wires.

According to one embodiment of the invention, forming an electrical connection comprises depositing a metal layer in the openings of the PCB-

substrate such that the metal layer forms an electrical connection between the conductive contact pads of the fingerprint sensing device and a top surface of the PCB-substrate. It is thus possible to form an electrical connection through the PCB substrate using either wire bonding or metal plating. However, if a PCB substrate with pre-formed conductive traces is used the conductive traces would need to either be protected during metal deposition or new conductive traces would need to be patterned after metal deposition.

Further effects and features of the third aspect of the invention are largely analogous to those described above in connection with the first and second aspects of the invention.

Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

Brief Description of the Drawings

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing an example embodiment of the invention, wherein:

Figs. 1A-C schematically illustrate biometric imaging devices according to embodiments of the invention;

Figs. 2A-B schematically illustrate a biometric imaging device according to an embodiment of the invention;

Fig. 3 is a flow chart describing steps of a method of manufacturing a biometric imaging device according to an embodiment of the invention;

Figs. 4A-J schematically illustrate steps of a method of manufacturing a biometric imaging device according to an embodiment of the invention;

Fig. 5 is a flow chart describing steps of a method of manufacturing a biometric imaging device according to an embodiment of the invention;

Figs. 6A-G schematically illustrate steps of a method of manufacturing a biometric imaging device according to an embodiment of the invention;

Fig. 7 schematically illustrates details of capacitive fingerprint sensing device in a biometric imaging device according to an embodiment of the invention;

Figs. 8A-C schematically illustrate details of a smartcard comprising a biometric imaging device according to an embodiment of the invention; and

Fig. 9 schematically illustrates a biometric imaging device according to an embodiment of the invention.

Detailed Description of Example Embodiments

In the present detailed description, various embodiments of a biometric imaging device and a method of manufacturing the biometric imaging device according to the present invention are mainly discussed with reference to a biometric imaging device comprising a capacitive fingerprint sensing device.

Fig. 1A is a schematic cross section view of a biometric imaging device 100 according to an example embodiment. The biometric imaging device 100 comprises a plastic film 102 forming an outer surface of the biometric imaging device 100. The plastic film 102 is preferably a polyimide film 102 which is formed by depositing a liquid coating on a glass substrate followed by heat treatment to solidify the polyimide film 102.

The biometric imaging device 100 further comprises a thin-film transistor, TFT, circuit 104 comprising a capacitive fingerprint sensing device 106 having a sensing side 108 on a first side thereof, facing towards the plastic film 102. The sensing surface of the illustrated biometric imaging device 100 is thus the outer surface of the plastic film 102. Here, conventional TFT manufacturing processes are used and the steps of manufacturing a TFT-based capacitive fingerprint sensing device 106 are generally known and will not be described in further detail herein. That the sensing side 108 of the fingerprint sensing device 106 is arranged to face the plastic film 102 means that connection layers of the TFT-circuit 104 are arranged above an active sensing portion of the sensing transistors in the TFT-circuit 104 and that a

distance between an active sensing portion of the fingerprint sensing device 106 and a finger placed on the exposed surface of the plastic film 102 is minimized.

The capacitive fingerprint sensing device 106 comprises an array of electrically conductive sensing elements connected to thin-film transistors. A capacitive fingerprint sensing device 106 should be understood to further comprise sensing circuitry connected to the sensing elements for reading a signal from the sensing elements. The sensing circuitry may in turn comprise internal readout circuitry or be connected to external readout circuitry for providing a result of the sensing elements to an external device for further processing, which in the present case may be included in the biometric imaging device.

The capacitive fingerprint sensing device 106 further comprises a plurality of electrically conductive contact pads 110 for electrically connecting the fingerprint sensing device 106 to external circuitry. External circuitry here refers to circuitry outside of the fingerprint sensing device 106 and may thus include both components and circuits arranged on the PCB-substrate which provide functionality of the biometric imaging device as well as components and circuitry outside of the biometric imaging device. Moreover, the contact pads 110 are not necessarily arranged to be directly connected to such circuitry, an electrical connection may instead be formed via additional conductive elements. The contact pads 110 are arranged on a second side 112 of the TFT-circuit 104 facing away from the plastic film 102 and are exposed on an upper surface of the TFT-circuit 104 as illustrated in Fig. 1D. A base metal layer of the contact pads 110 can be formed together with a connection layer which is a part of the TFT-circuit 104. Depending on the application, further surface metallization of the contact pads 110 such as electro-plating of Ni and Au may be required to prevent oxidation and to facilitate interconnection.

A printed circuit board, PCB, substrate 114 is attached to the second side 112 of the TFT-circuit, the PCB-substrate 114 comprising through-openings 116 at locations corresponding to the contact pads 110 of the

fingerprint sensing device 106. The PCB-substrate 114 further comprises an electrical connection 118 between a conductive trace 120 located on a top surface 122 of the PCB-substrate facing away from the TFT-circuit 106, via the through-openings 116 of the PCB-substrate 114, and to the conductive
5 contact pads 110 of the capacitive fingerprint sensing device 106. The electrical connection 118 is formed by a metal which is plated on a sidewall of the through opening in the PCB-substrate 114.

The biometric imaging device further comprises a component 124 arranged on the PCB-substrate 114 as illustrated in Figs. 1A-B. The
10 component 124 arranged on the PCB-substrate 114 can be a surface mounted discrete component 124 such as a decoupling capacitor or the component may be an integrated circuit such as a readout circuit for the fingerprint sensing device, a secure element (SE) or micro control unit (MCU). Direct soldering of extra components onto the PCB-substrate 114 provides a
15 short connection length between the component and the fingerprint sensing device 106 and good electrical performance. Moreover, the integration of components and circuits in the biometric imaging device 100 limits the total number of separate devices which need to be integrated together with the biometric imaging device, which is advantageous for example in a smartcard
20 implementation where manufacturing and assembly can be simplified by reducing the number of separate components.

Fig. 1B is a schematic top view of the biometric imaging device 100 illustrating the conductive traces 120 of the PCB-substrate 114 and a centrally arranged components 112 which may comprise both one or more integrated
25 circuits and one or more discrete components. The exposed side in Fig. 1B is thus the side opposite the sensing side of the biometric imaging device 100.

Fig. 1C schematically illustrate a biometric imaging device 150 according to an example embodiment where the through openings of the PCB-substrate 114 are filled with an electrically conducting material 130 to
30 form an electrically conductive via connection 130. The PCB-substrate 114 further comprises electrically conductive contact pads 132 and possibly also

electrically conductive traces (not shown) located on the side of the PCB-substrate facing the TFT-circuit 104.

The conductive contact pads 132 of the PCB-substrate 114 are thereby arranged to form a mechanical and electrical contact with the contact pads
5 110 of the TFT-circuit 104 where an anisotropic conductive film (ACF) can be used to form the electrical connection between the PCB-substrate 114 and the TFT-circuit 104. However, other means of forming an electrical connection such as soldering are also possible. By means of via connections 130 through the PCB-substrate 114, conductive traces and conductive pads 132 of the
10 PCB-substrate 114, it is not required that the through-openings of the PCB-substrate 114 are aligned with the contact pads 110 of the TFT-circuit 104, thereby providing additional freedom of design of both the TFT-circuit 104 and the PCB-substrate 114.

Figs. 2A-B schematically illustrate a biometric imaging device 200
15 which in most respects is similar to the biometric imaging device 100 of Figs. 1A-B. The key difference is that in Figs. 2A-B, the electrical connection is formed by a bond wire 202 reaching from the top surface 122 of the PCB-substrate 114, via the through opening 116 in the PCB-substrate 114 and to the connection pad 110 of the capacitive fingerprint sensing device 106. The
20 bond wire is protected by an encapsulating material 204. Moreover, the PCB-substrate 114 can also be a flexible substrate.

Fig. 3 is a flowchart outlining the steps of a method for manufacturing a biometric imaging device 100 according to an embodiment of the invention, which will be described with reference to Figs. 4A-J schematically illustrating
25 steps of the method.

The method comprises providing 300 a glass carrier 101 as illustrated in Fig. 4A and arranging 302 a plastic film 102 on the glass carrier 101, illustrated in Fig. 4B. The plastic film 102 is preferably a polyimide film 102 which is deposited as a liquid coating on the glass substrate 101 followed by
30 heat treatment to solidify the polyimide film 102.

Next, illustrated in Fig. 4C, a thin-film transistor, TFT, circuit 104 is formed 304 on the plastic film 102, the TFT-circuit 104 being configured to

form a capacitive fingerprint sensing device 106 having a sensing side 108 facing towards the plastic film 102. The fingerprint sensing device 106 further comprises a plurality of electrically conductive contact pads 110 as illustrated in Fig. 4D, and the contact pads 110 can be formed during the process of
5 forming a topmost connection layer of the TFT-circuit. The contact pads 110 are facing away from the plastic film and are subsequently used for connecting the fingerprint sensing device 106 to external circuitry

In the following step illustrated in Fig. 4E, a printed circuit board, PCB, substrate 114 comprising a conductive layer 402 on a surface facing away
10 from the TFT-circuit is arranged 306 on the TFT-circuit 104.

The next step illustrated in Fig. 4F comprises removing 308 the glass carrier which can be done by means of a laser lift-off debonding process where a UV-wavelength laser illuminates the interface between the polyimide film 102 and the glass carrier 101 through the glass carrier 101 to release the
15 adhesion between the polyimide film 102 and the glass carrier 101.

In order to access the contact pads 110 of the fingerprint sensing device 106, openings 116 are formed 310 through the PCB-substrate at locations corresponding to the conductive contact pads 110 of the fingerprint sensing device such that the contact pads are exposed as illustrated in Fig.
20 4H.

To form 312 an electrical connection 118 between the conductive contact pads 110 of the fingerprint sensing device and the conductive traces 120 of the PCB-substrate 114, a metal layer 402 is plated over the top surface 122 of the PCB-substrate 114, in the openings 116 and on the
25 contact pads 110 to form the electrical connection 118 as illustrated in Fig. 4I. Metal plating can be performed by first using electroless plating is to plate a thin layer of Cu on the dielectric surface of the PCB-substrate 114 followed by electrolytic plating to form a Cu layer having the required thickness. After metal plating, the desired pattern of conductive traces is formed in the metal
30 layer on the top surface of the PCB-substrate 114.

Fig. 4J further illustrates a component 124 arranged on a top surface of the PCB-substrate 114. The component 124 which may comprise control

circuitry for the fingerprint sensing device is connected to the contact pads 110 via the openings 116 through the PCB-substrate 114.

It should be noted that even though some of the described steps are by necessity performed in a specific order, other manufacturing steps may be performed in a different order than what is described above. For example, the removal of the glass carrier 101 can be performed as the last step, after forming openings 116 and electrical connections 118 through the PCB-substrate 114.

Fig. 5 is a flowchart outlining the steps of a method for manufacturing a biometric imaging device 200 according to an embodiment of the invention, which will be described with reference to Figs. 6A-G schematically illustrating steps of the method.

The steps illustrated in Figs. 6A-D are the same as the steps illustrated in Figs. 4A-D and will therefore not be discussed in detail. In short, the first four steps comprise providing 500 a glass carrier 101, arranging 502 a plastic film 102 on the glass carrier, forming 504 a thin-film transistor, TFT, circuit 104 on the plastic film 102, the TFT-circuit 104 being configured to form a capacitive fingerprint sensing device 106 having a sensing side 108 facing towards the plastic film 102, and forming a plurality of electrically conductive contact pads 110 for connecting the fingerprint sensing device 106 to external circuitry.

Next, the method comprises providing 506 a printed circuit board, PCB, substrate 114 comprising a conductive pattern 120 on a top surface 122 of the PCB-substrate 114 and openings 116 through the PCB-substrate 114 at locations corresponding to the conductive contact pads 110 of the fingerprint sensing device 106 as illustrated by the top-view of the PCB-substrate in Fig. 6E.

The PCB-substrate 114 is then arranged 508 on the TFT-circuit 104, illustrated in Fig. 6F, with the conductive pattern 120 facing away from the TFT-circuit 104, wherein the openings 116 of the PCB-substrate 114 are aligned with the contact pads 110 of the TFT-circuit 104 such that the contact pads 110 are exposed. In Fig 6F, the glass carrier 101 has been removed

510. Accordingly, the PCB-substrate 114 is pre-formed with the required conductive pattern 120 and through openings 116 before being attached to the TFT-circuit 104.

Fig. 6G illustrates the final step of forming 512 an electrical connection
5 202 between the conductive contact pads 110 of the fingerprint sensing device 106 and the conductive pattern 120 of the PCB-substrate. In the described method, forming 512 an electrical connection comprises wire bonding to form bond wires 202 between the conductive pattern 120 of the PCB-substrate 114 and the conductive contact pads 110 of the fingerprint
10 sensing device 106. The conductive pattern 120 further comprises PCB contact pads 602 located at or near the edge of the biometric imaging device 200 to connect the biometric imaging device 200 to external circuitry, for example in a smartcard as will be illustrated in the following.

It would in principle be possible to form an electrical connection by
15 metal plating the side walls of the openings 116 also when using a PCB-substrate with pre-formed openings and conductive traces. This would require that any existing conductive traces are protected during metal plating, or that the desired pattern of conductive traces is formed after metal plating.

Fig. 7 is a schematic view of different layers of the TFT-circuit 104
20 which is arranged on the polyimide film 102. The lower layer 702 arranged closest to the polyimide film 102 is here described as an active layer 702 where the transistors are formed, illustrated by the active sensing portion 708 of the TFT-circuit. In practice the active layer 702 consist of a plurality of conducting and insulating layers to form the desired transistor and capacitive
25 sensing functionality. On top of the active layer 702 in Fig. 7 follows first and second connection layers 704, 706 where electrical connections to the active layer 702 are formed. It should be noted that the number of connection layers can be selected based on the requirements of a given application, and that the two connection layers in the presently described TFT-circuit should be
30 seen as an illustrative example. The contact pads 110 are not shown in Fig. 7 but they may be formed in the second connection layer 706. The sensing side 108 of the capacitive fingerprint sensing device formed by the TFT-circuit is

thus defined as the side of the TFT-circuit where the active region 708 is closest to the surface of the circuit. In a biometric imaging device according to various embodiments of the invention, the finger 710 to be imaged is placed on the outer surface of the polyimide film 102 to thereby minimize the distance between the finger 710 and the active region 708.

The total thickness of the TFT-circuit 104 can be approximately 5 μm or below and it therefore requires structural support in the form of the polyimide film 102 and the PCB-substrate 114 in order to be manageable in an assembly process.

Figs. 8A-B and Fig. 9 schematically illustrates a biometric imaging device 120 integrated in the body 800 of a smartcard 900. Here it can be seen that only an outer layer of the smartcard 900 separates the finger 710 from the biometric imaging device 100, 200. Electrical connections are formed between the biometric imaging device 100, 200 and a conductive layer 802 of the smartcard 900. As illustrated in Fig. 8A, the electrical connection can be formed by forming a vertical connection 118 between the conductive layer 802 and a contact pad 602 of the PCB which in turn connects to the contact pad 110 of the fingerprint sensing device 106, thereby enabling an electrical connection between the fingerprint sensing device 106 and circuitry of the smartcard. However, it is also possible to use a connecting element arranged on the contact pad 110 to facilitate an electrical connection. The connecting element can be a solder ball, a conductive plate, a conductive pillar, a PCB plate, a via connection or a similar conductive structure. The connecting element is primarily intended to reduce the height difference between the contact pad and the top surface of the PCB-substrate in order to facilitate an electric connection between the biometric imaging device and external circuitry. The connecting element may also be configured to protrude above the PCB-substrate. Accordingly, different configurations of the electrical connection are possible depending on if a connecting element is used or not, and if so, which type of connecting element.

In Fig. 8B it is illustrated that an electrical connection between the biometric imaging device 200 and the conductive layer 802 of the smartcard

900 is formed via the contact pad 602 located at an edge of the PCB-substrate 114. The contact pad 602 of the PCB-substrate 114 is in turn electrically connected to the bond wire so that an electrical connection between the fingerprint sensing device 106 and circuitry of the smartcard can
5 be formed.

A method of arranging the biometric imaging device in a smartcard 900 would thus comprise forming a physical connection between a conductive layer 802 of the smartcard and a contact pad 602 of the PCB-substrate 114.

Fig. 8C is a schematic top view of a biometric imaging device
10 comprising contact pads 602 on the PCB-substrate 114 where the contact pads are used to connect the biometric imaging device to circuitry of the smartcard. Since a PCB is less costly per area unit than a TFT-circuit it may be preferable to form contact pads on the PCB-substrate, when possible, to save TFT-area. Moreover, possibility to use larger contact pads on the PCB-
15 substrate allows for a lower bonding accuracy in smartcard manufacturing which simplifies the manufacturing process.

The biometric imaging device can be connected to functionality in the smartcard such as a secure element, SE, used in fingerprint authentication and/or to a contact plate 904 of the type commonly used in credit cards and
20 as illustrated in Fig. 9.

Fig. 9 schematically illustrates a smartcard 900 comprising a biometric imaging device 100, 200 according to embodiments of the invention. The smartcard 900 is provided with means for wireless communication with a smartcard reader such as a point-of-sale (POS) terminal 906 and with a
25 contact plate 904 for communication via physical contact with the terminal 906.

Even though the invention has been described with reference to specific exemplifying embodiments thereof, many different alterations, modifications and the like will become apparent for those skilled in the art.
30 Also, it should be noted that parts of the biometric imaging device may be omitted, interchanged or arranged in various ways, the biometric imaging device yet being able to perform the functionality of the present invention.

Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements
5 or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS

1. A biometric imaging device (100, 150, 200) comprising:
5 a plastic film (102) forming an outer surface of the biometric imaging device;
a thin-film transistor, TFT, circuit (104) comprising a capacitive fingerprint sensing device (106) having a sensing side (108) on a first side thereof, facing towards the plastic film, the capacitive fingerprint sensing
10 device comprising electrically conductive contact pads (110) on a second side (112) thereof, facing away from the plastic film;
a printed circuit board, PCB, substrate (114) attached to the second side of the TFT-circuit, the PCB-substrate comprising through-openings (116), wherein the PCB-substrate further comprises an electrical connection (118,
15 202) between a conductive trace (120) located on a top surface (122) of the PCB-substrate facing away from the TFT-circuit, via the through-openings of the PCB-substrate, and the conductive contact pads (110) of the capacitive fingerprint sensing device.
- 20 2. The biometric imaging device according to claim 1, wherein the through openings of the PCB-substrate are located at locations corresponding to the contact pads of the fingerprint sensing device.
3. The biometric imaging device according to claim 1 or 2, wherein
25 the through openings of the PCB-substrate are filled with an electrically conductive material.
4. The biometric imaging device according to claim 1 or 2, wherein
the electrical connection comprises metal (118) arranged on side walls of the
30 through-opening.

5. The biometric imaging device according to claim 2, wherein the electrical connection comprises a bond wire reaching from the conductive trace (120) to the contact pad (110).

5 6. The biometric imaging device according to any one of claims 1 to 5, further comprising at least one component (124) arranged on the PCB-substrate and conductive traces arranged on the top surface of the PCB-substrate configured to form an electrical connection between the at least one component and contact pads of the fingerprint sensing device.

10

7. The biometric imaging device according to claim 6, wherein the at least one component arranged on the PCB-substrate is a surface mounted discrete component or an integrated circuit.

15

8. A smartcard (900) comprising:
a card body (800) comprising a biometric imaging device (100, 200) according to any one of claims 1 to 7 arranged in the card body; and
a conductive layer (802) electrically connected to contact pads (110) of the biometric imaging device.

20

9. Method for manufacturing a biometric imaging device (100) comprising:

providing (300) a glass carrier (101);
arranging (302) a plastic film (102) on the glass carrier;
25 forming (304) a thin-film transistor, TFT, circuit (104) on the plastic film, the TFT-circuit being configured to form a capacitive fingerprint sensing device (106) having a sensing side (108) facing towards the plastic film (102), the fingerprint sensing device comprising a plurality of electrically conductive contact pads (110), the contact pads facing away from the plastic film;
30 arranging (306) a printed circuit board, PCB, substrate (114) on the TFT-circuit, the PCB-substrate comprising a conductive layer (402) on a surface facing away from the TFT-circuit;

removing (308) the glass carrier;
forming (310) openings (116) through the PCB-substrate at locations corresponding to the conductive contact pads of the fingerprint sensing device such that the contact pads are exposed; and
5 forming (312) an electrical connection (118) between the conductive contact pads of the fingerprint sensing device and the conductive layer of the PCB-substrate.

10 10. The method according to claim 9, wherein the conductive layer of the PCB-substrate is a continuous metal layer, and wherein the step of forming an electrical connection further comprises depositing a metal in the openings of the PCB-substrate and forming a pattern of conductive traces in the conductive layer.

15 11. The method according to claim 10, wherein depositing a metal in the openings of the PCB-substrate comprises metal plating.

20 12. The method according to any one of claims 9 to 11, further comprising arranging at least one component (124) on a top surface of the PCB-substrate (114) and electrically connecting the at least one component to the capacitive fingerprint sensing device (106) via the openings (116) through the PCB-substrate.

25 13. The method according to any one of claims 9 to 12, further comprising:
arranging the biometric imaging device in a smartcard (800); and
forming an electrical connection (802) between a conductive layer of the smartcard and the contact pads (110) of the biometric imaging device.

30 14. Method for manufacturing a biometric imaging device (200) comprising:
providing (500) a glass carrier (101);

arranging (502) a plastic film (102) on the glass carrier;
forming (504) a thin-film transistor, TFT, circuit (104) on the plastic film,
the TFT-circuit being configured to form a capacitive fingerprint sensing
device (106) having a sensing side (108) facing towards the plastic film (102),
5 the fingerprint sensing device comprising a plurality of electrically conductive
contact pads (110), the contact pads facing away from the plastic film;
providing (506) a printed circuit board, PCB, substrate, the PCB-
substrate comprising conductive traces (120) on a top surface of the PCB-
substrate and openings (116) through the PCB-substrate at locations
10 corresponding to the conductive contact pads of the fingerprint sensing
device;
arranging (508) the PCB-substrate (114) on the TFT-circuit, with the
conductive pattern facing away from the TFT-circuit, wherein the openings of
the PCB-substrate are aligned with the contact pads of the TFT-circuit such
15 that the contact pads are exposed;
removing (510) the glass carrier; and
forming (512) an electrical connection (118, 202) between the
conductive contact pads of the fingerprint sensing device and the conductive
traces of the PCB-substrate.

20

15. The method according to claim 14, wherein forming an electrical
connection comprises wire bonding to form bond wires (202) between the
conductive pattern of the PCB-substrate and the conductive contact pads of
the fingerprint sensing device.

25

16. The method according to claim 15, further comprising providing
encapsulation covering the bond wires.

17. The method according to claim 14, wherein forming an electrical
30 connection comprises depositing (212) a metal layer (118) in the openings of
the PCB-substrate such that the metal layer forms an electrical connection

between the conductive contact pads of the fingerprint sensing device and a top surface of the PCB-substrate.

18. The method according to any one of claims 14 to 17, further
5 comprising arranging at least one component (124) on a top surface of the PCB-substrate (114) and electrically connecting the at least one component to the capacitive fingerprint sensing device (106) via the openings (118) through the PCB-substrate.
- 10 19. The method according to any one of claims 14 to 18, further comprising:
arranging the biometric imaging device in a smartcard (900); and
forming a connection between a conductive layer (802) of the smartcard and a contact pad (602) of the PCB-substrate.

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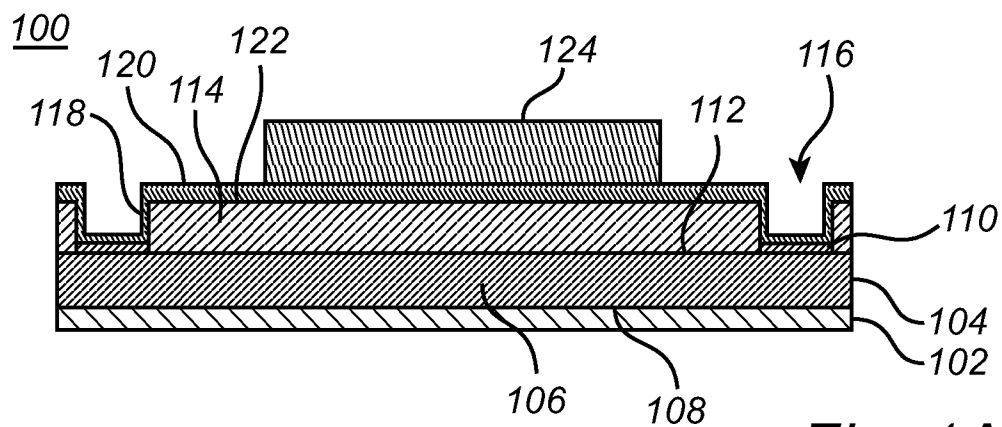


Fig. 1A

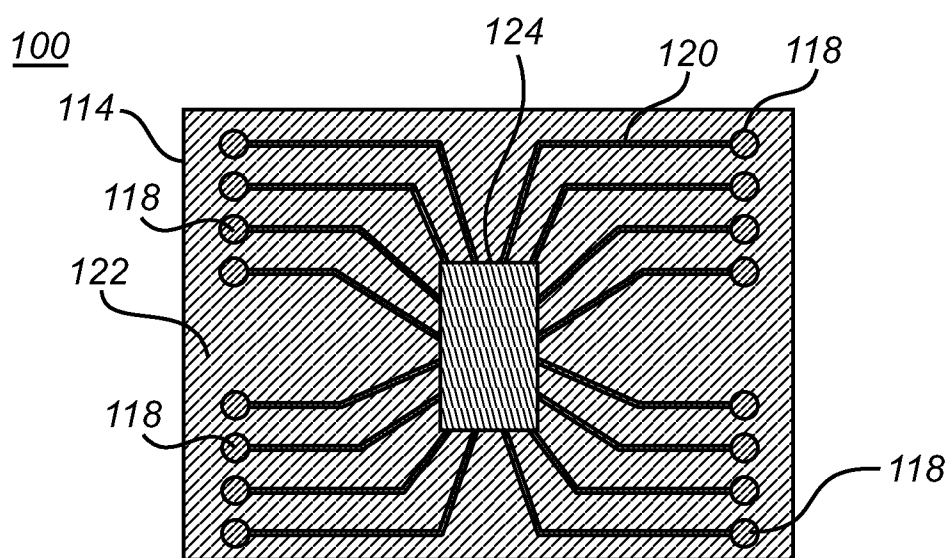


Fig. 1B

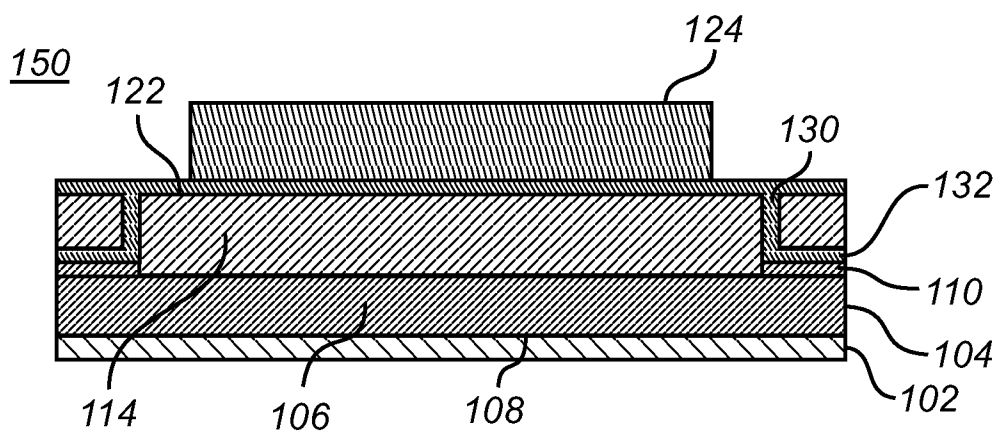


Fig. 1C

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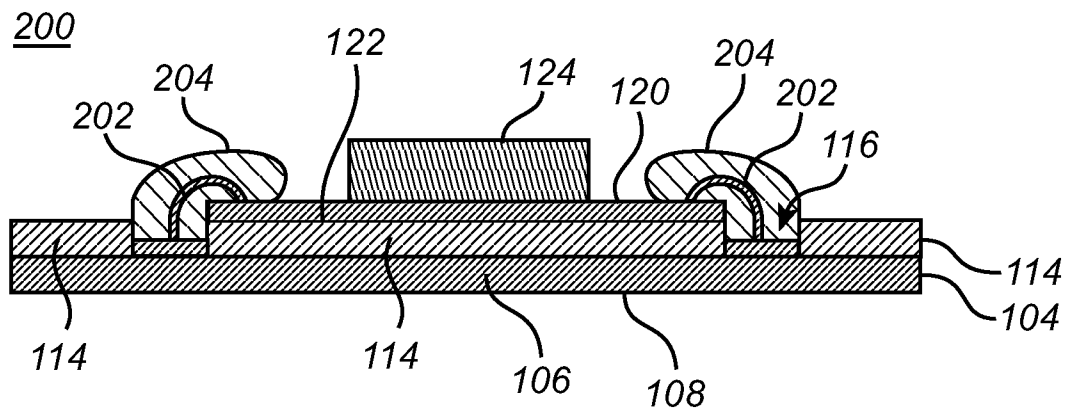


Fig. 2A

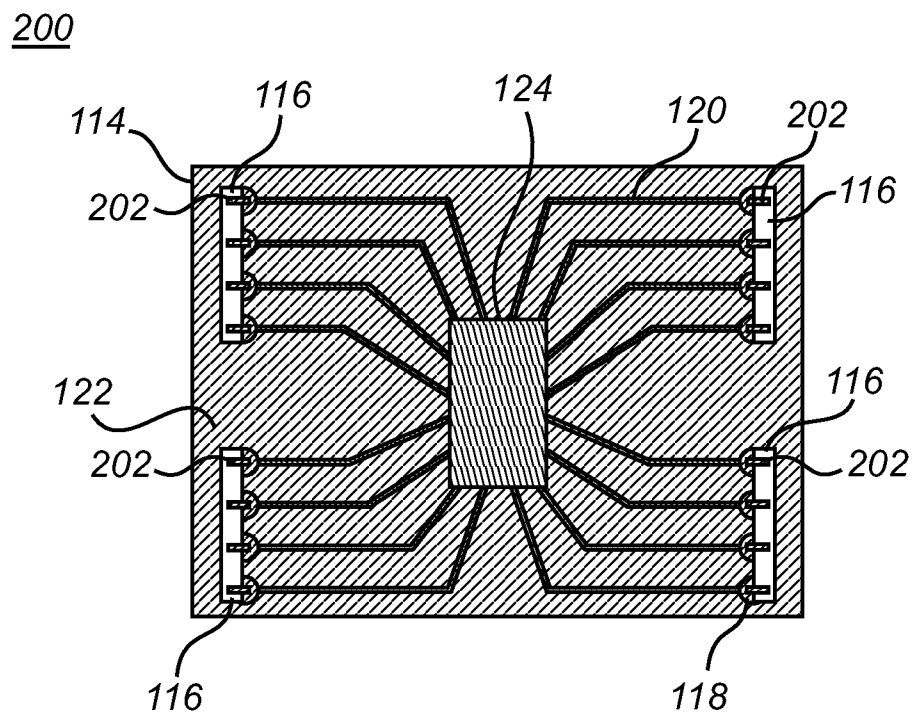
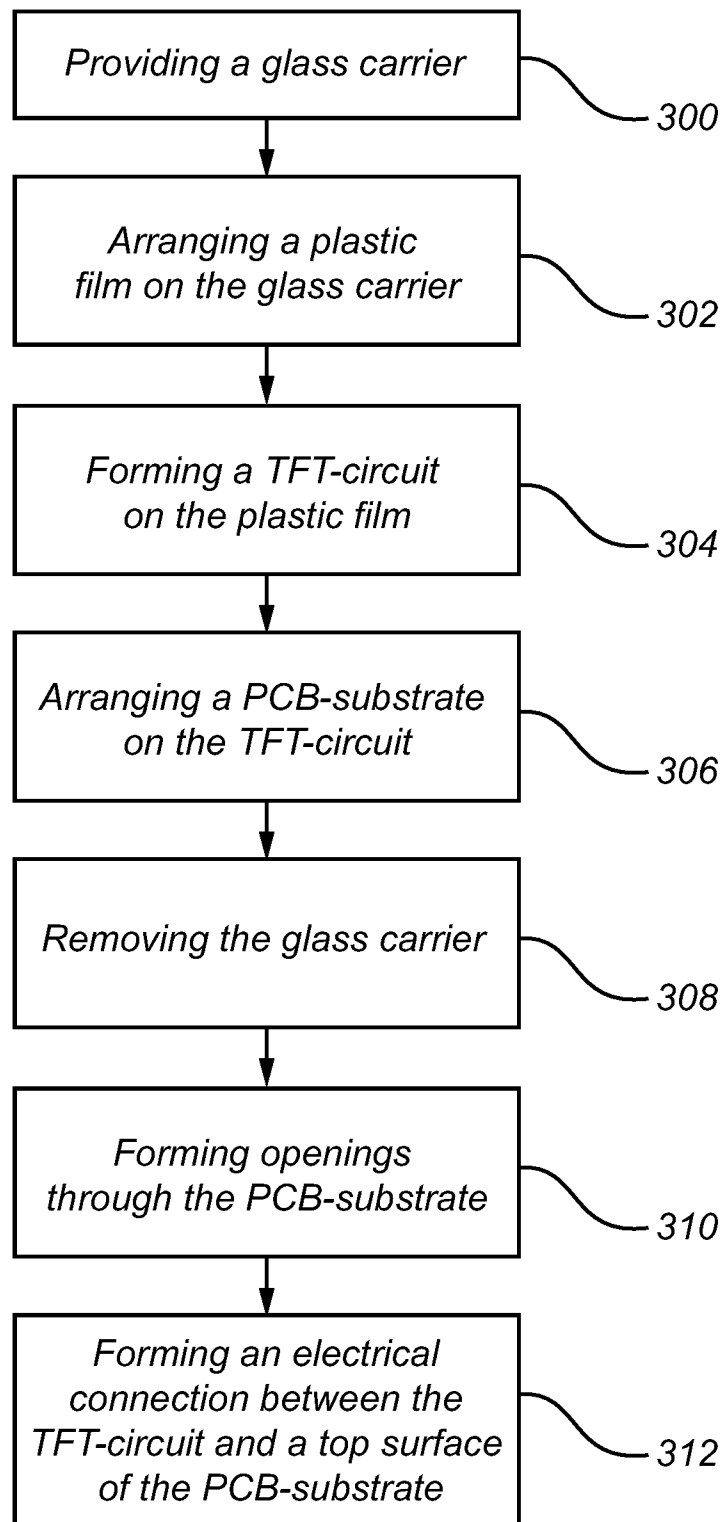


Fig. 2B

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*Fig. 3*

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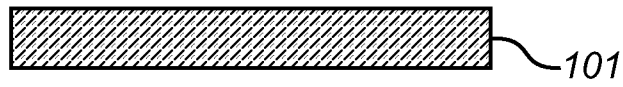


Fig. 4A

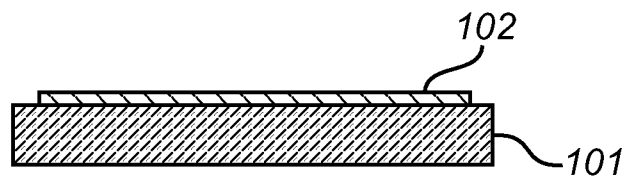


Fig. 4B

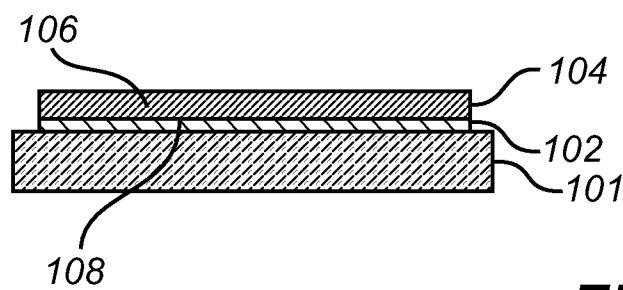


Fig. 4C

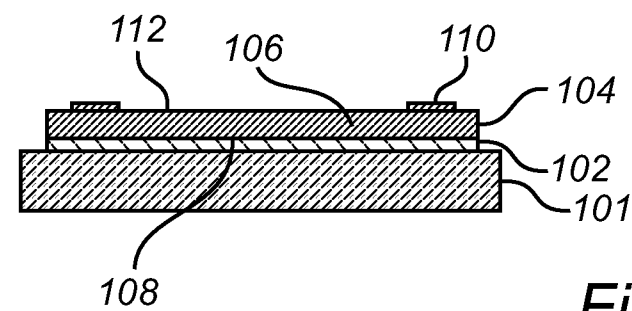


Fig. 4D

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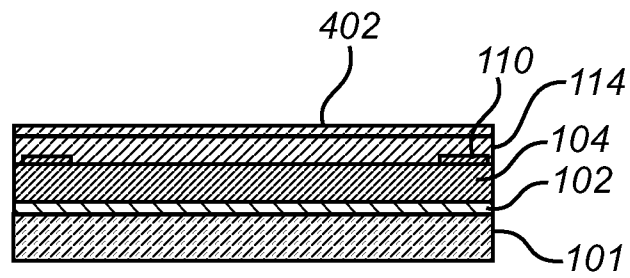


Fig. 4E

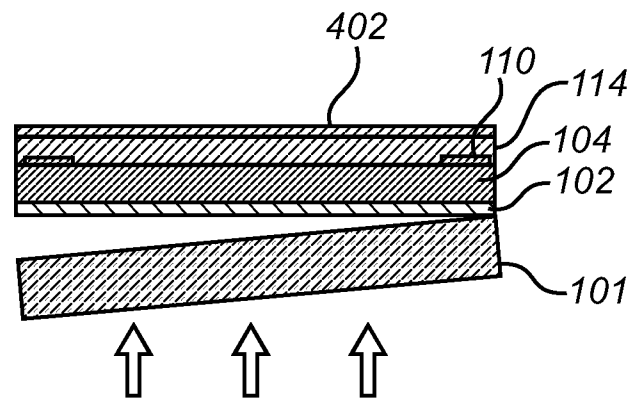


Fig. 4F

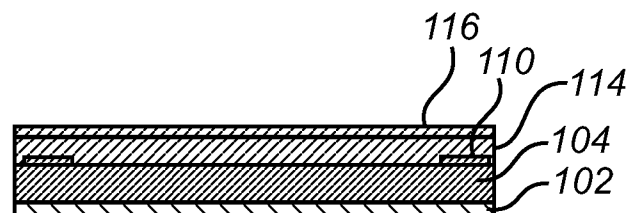
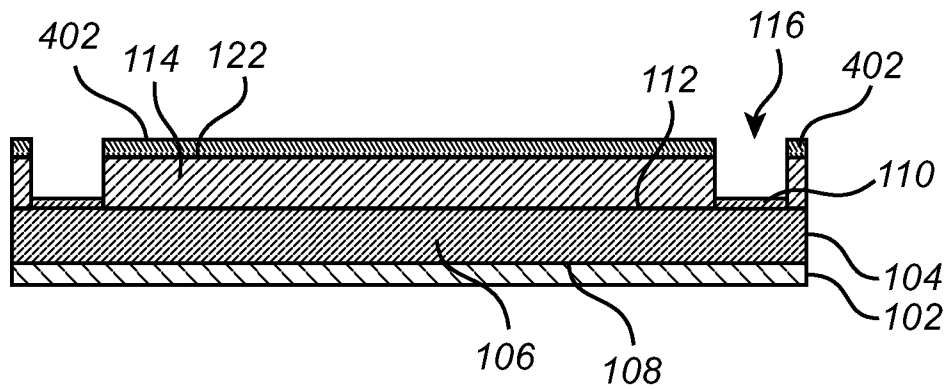
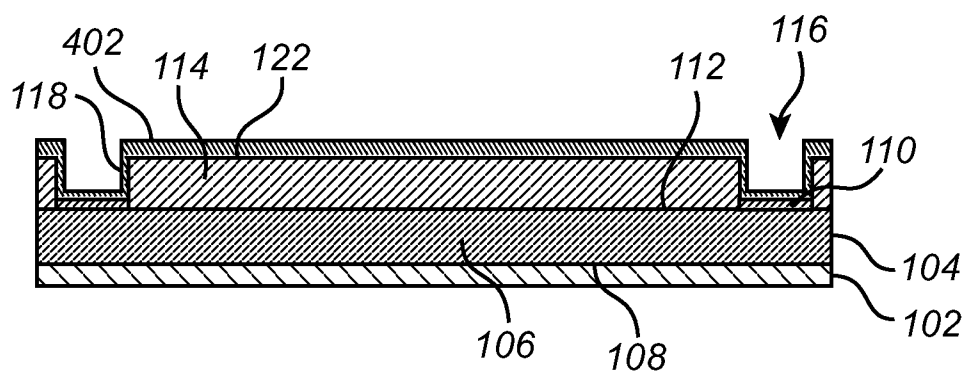
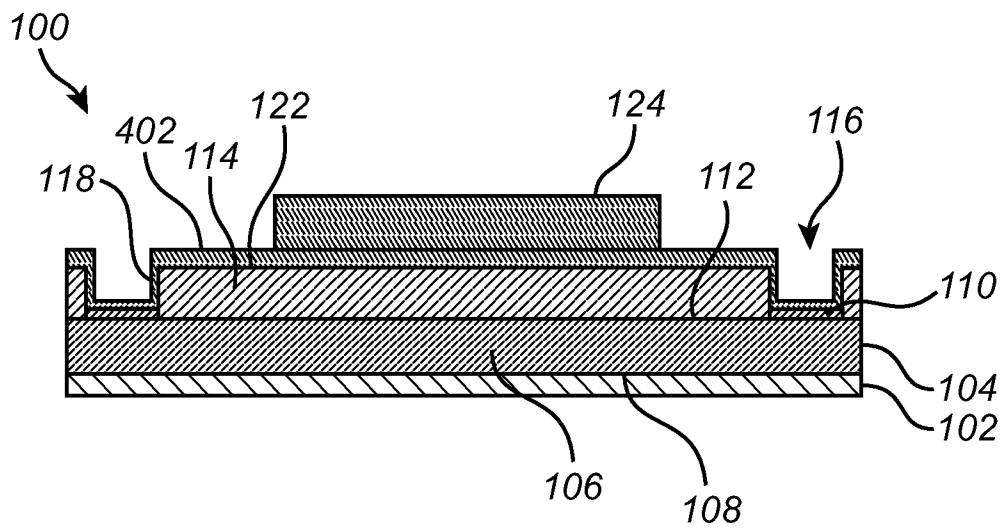
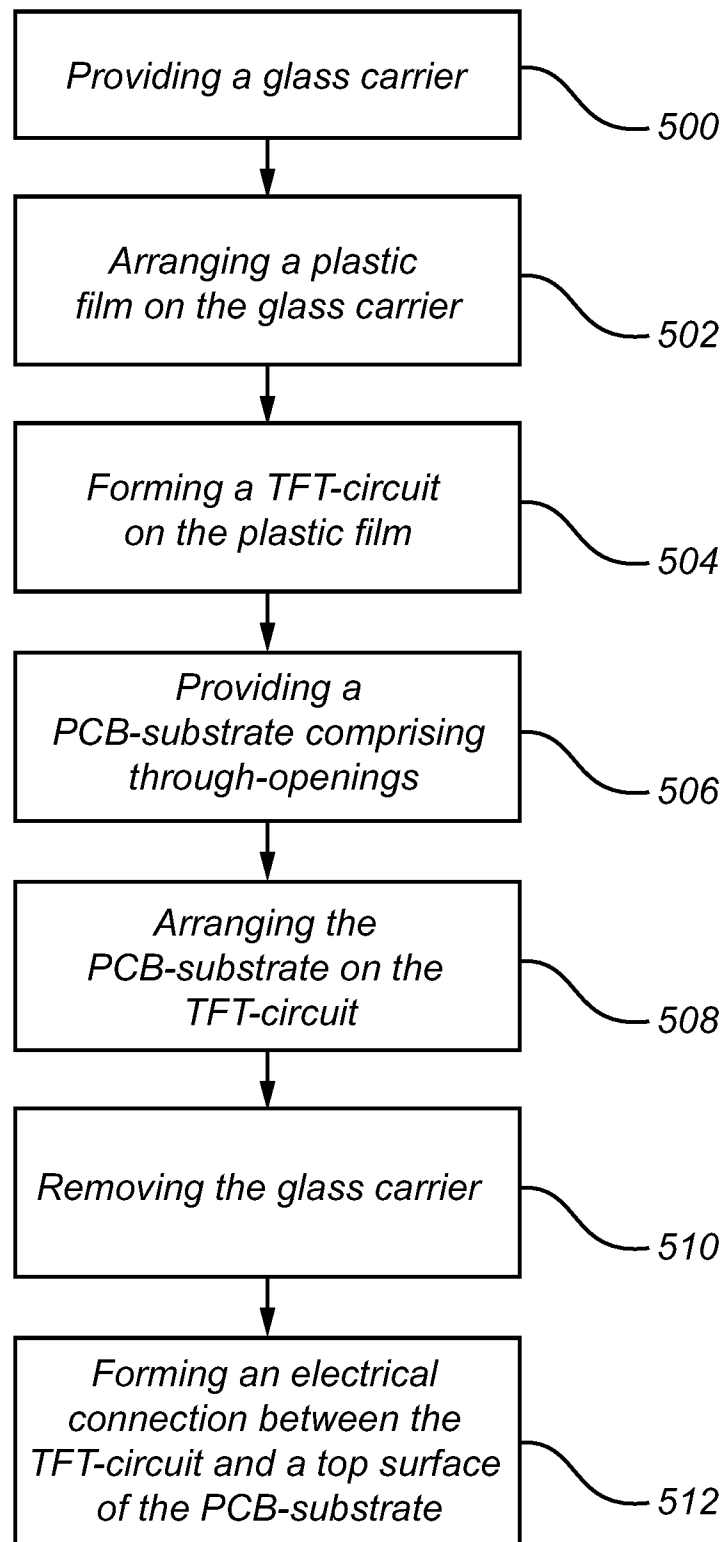


Fig. 4G

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*Fig. 4H**Fig. 4I**Fig. 4J*

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*Fig. 5*

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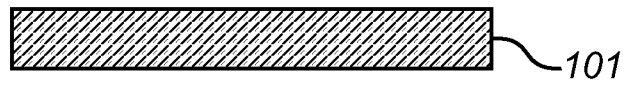


Fig. 6A

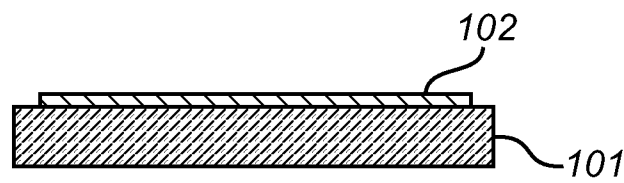


Fig. 6B

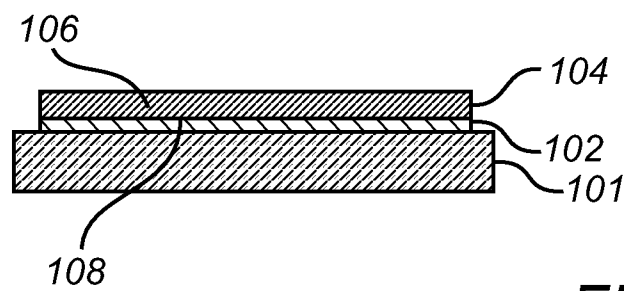


Fig. 6C

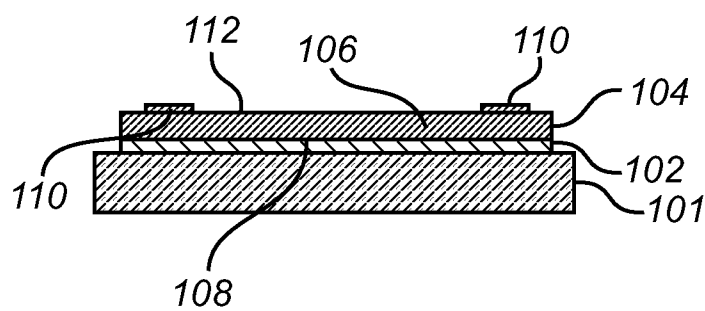


Fig. 6D

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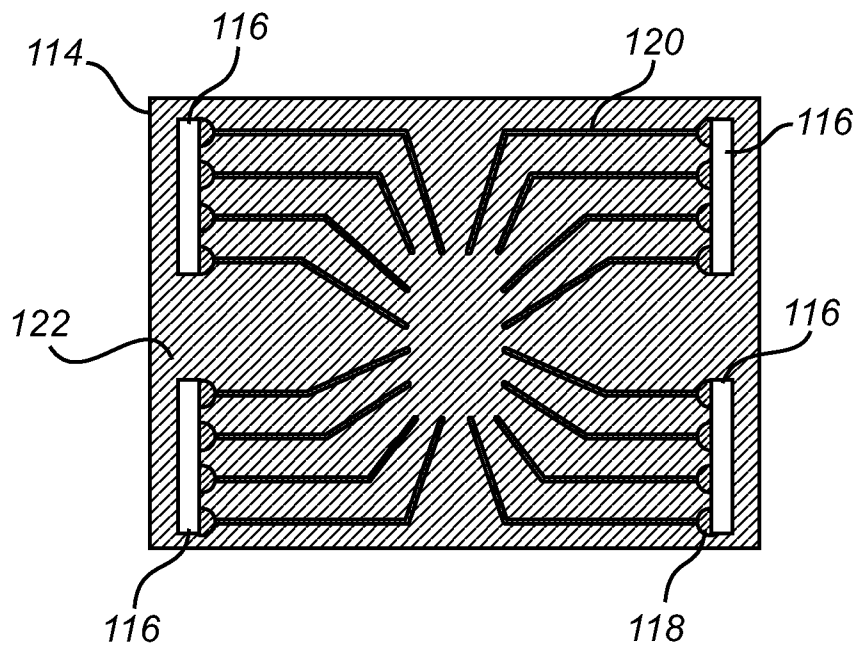


Fig. 6E

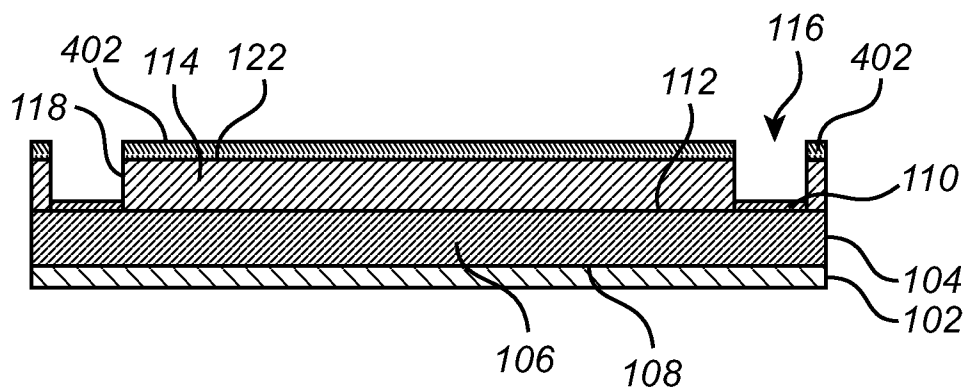


Fig. 6F

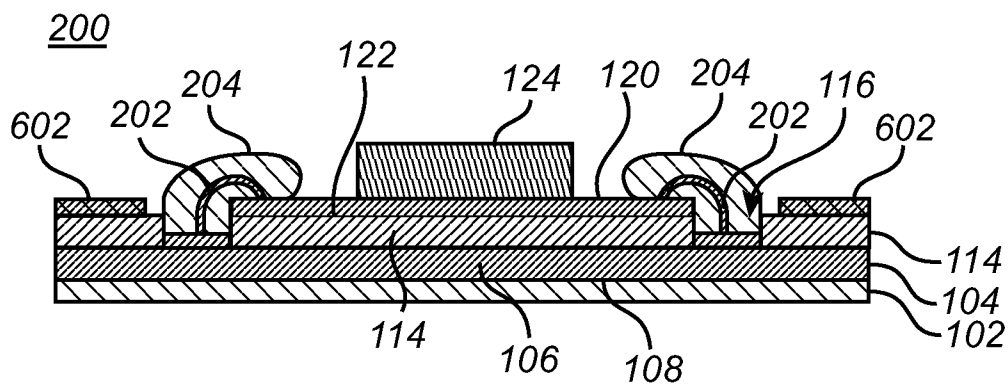


Fig. 6G

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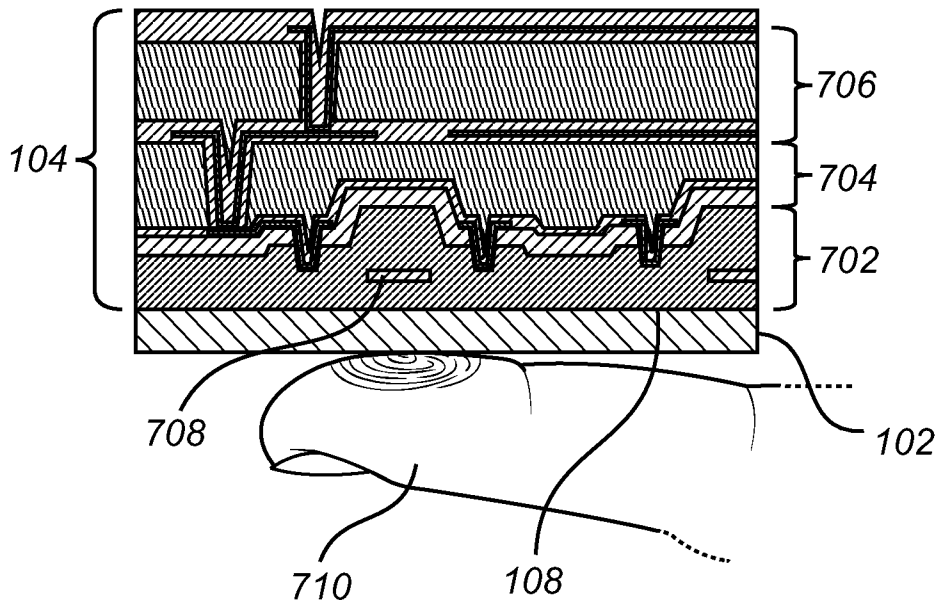


Fig. 7

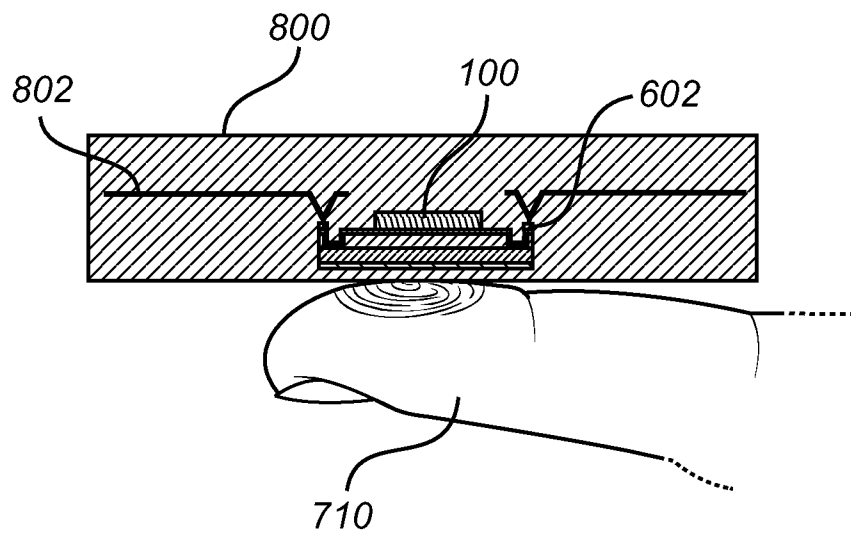


Fig. 8A

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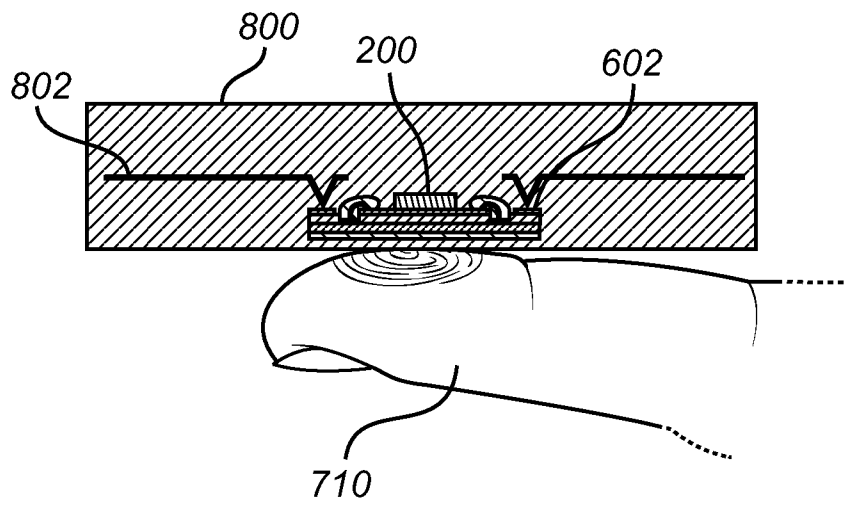


Fig. 8B

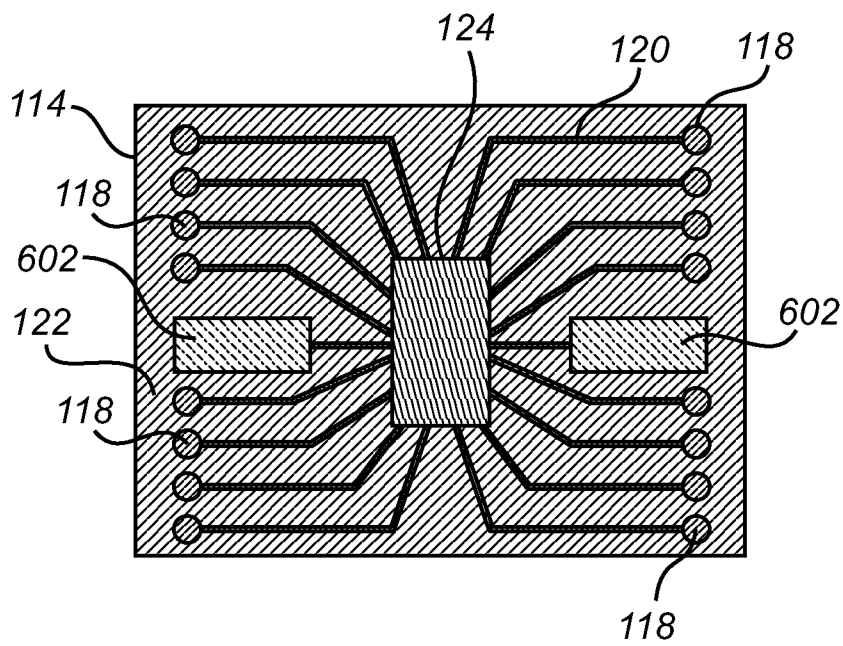


Fig. 8C

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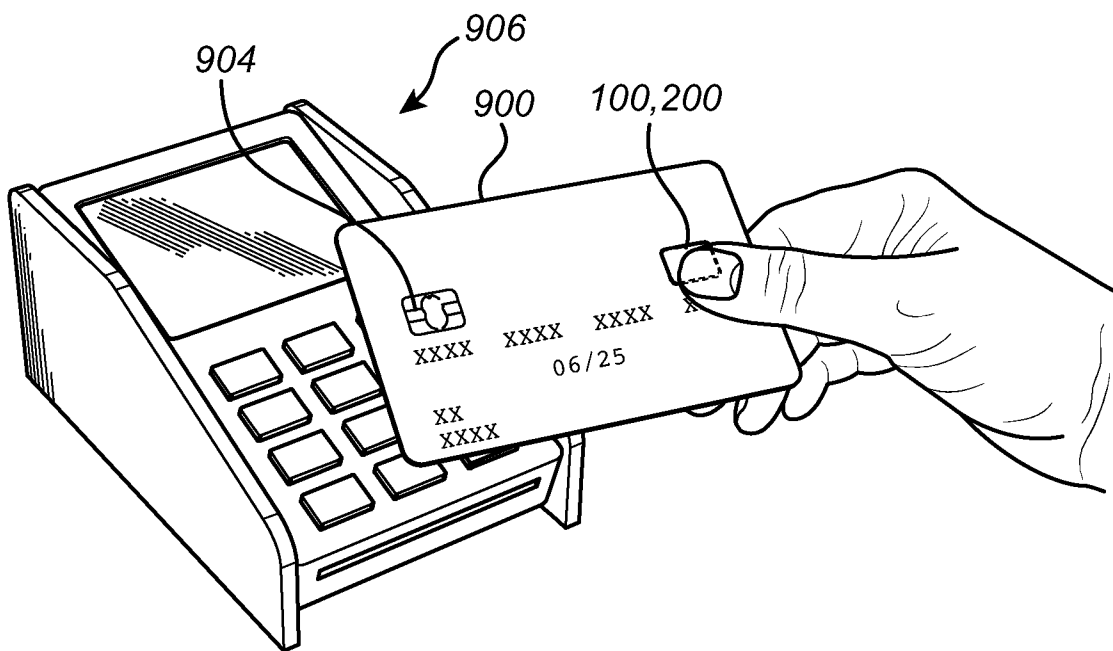


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2023/050609

A. CLASSIFICATION OF SUBJECT MATTER IPC: see extra sheet 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) IPC: G06F, G06K, G06V Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched SE, DK, FI, NO classes as above Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC, IBM-TDB		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20150030217 A1 (WICKBOLDT PAUL ET AL), 29 January 2015 (2015-01-29); paragraphs [0024]-[0025], [0067]-[0072], [0080]-[0083], [0101]-[0111], [0126], [0172]-[0176], [0179]; claims 1-20 --	1-19
Y	US 20200160024 A1 (JIN JONG WOO ET AL), 21 May 2020 (2020-05-21); paragraphs [0006]-[0007], [0045]-[0053], [0058]-[0070]; figures 1,2,3B,4B,5B; claims 1-15 --	1-19
Y	US 20210019018 A1 (GUO YUZHEN ET AL), 21 January 2021 (2021-01-21); paragraphs [0071], [0094]-[0097]; claims 11-15 --	1-19
☒ 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 "D" document cited by the applicant in the international application "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 18-08-2023	Date of mailing of the international search report 21-08-2023	
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Henrik Andersson Telephone No. + 46 8 782 28 00	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2023/050609

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y	US 20200218869 A1 (HAN SANG-HYUN), 9 July 2020 (2020-07-09); abstract; paragraphs [0191]-[0203]; claims 1-28 --	1-19
A	US 20180373913 A1 (PANCHAWAGH HRISHIKESH VIJAYKUMAR ET AL), 27 December 2018 (2018-12-27); whole document --	1-19
A	US 20140333328 A1 (NELSON RICHARD B ET AL), 13 November 2014 (2014-11-13); whole document --	1-19
A	US 20170364726 A1 (BUCHAN NICHOLAS IAN ET AL), 21 December 2017 (2017-12-21); whole document -- -----	1-19

Continuation of: second sheet

International Patent Classification (IPC)

G06V 40/13 (2022.01)

G06F 3/044 (2006.01)

G06F 3/043 (2006.01)

G06K 19/07 (2006.01)

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