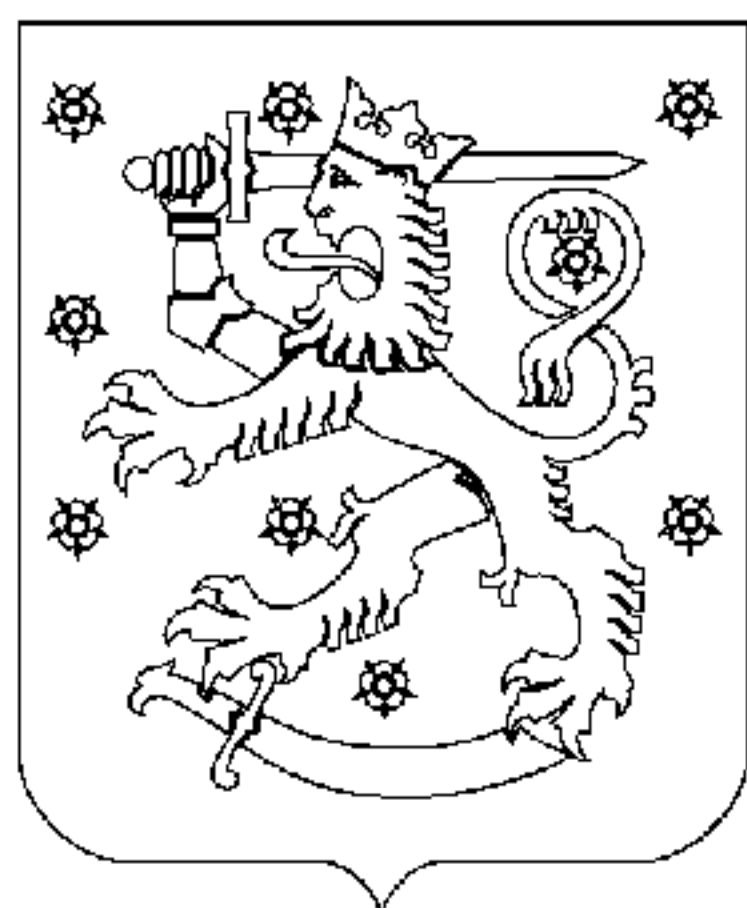


(19)



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PATENTTI- JA REKISTERIHALLITUS
PATENT- OCH REGISTERSTYRELSEN
FINNISH PATENT AND REGISTRATION OFFICE

(10) **FI 128967 B**
(12) **PATENTTIJULKAISU**
PATENTSKRIFT
PATENT SPECIFICATION

(45) Patentti myönnetty - Patent beviljats - Patent granted **15.04.2021**

(51) Kansainvälinen patenttiluokitus - Internationell patentklassifikation -
International patent classification
A61B 5/0408 (2006.01)
A61B 5/0478 (2006.01)
H01M 4/04 (2006.01)
C23C 16/22 (2006.01)

(21) Patenttihakemus - Patentansökning - Patent application 20205059

(22) Tekemispäivä - Ingivningsdag - Filing date **21.01.2020**

(23) Saapumispäivä - Ankomstdag - Reception date **21.01.2020**

(43) Tullut julkiseksi - Blivit offentlig - Available to the public **15.04.2021**

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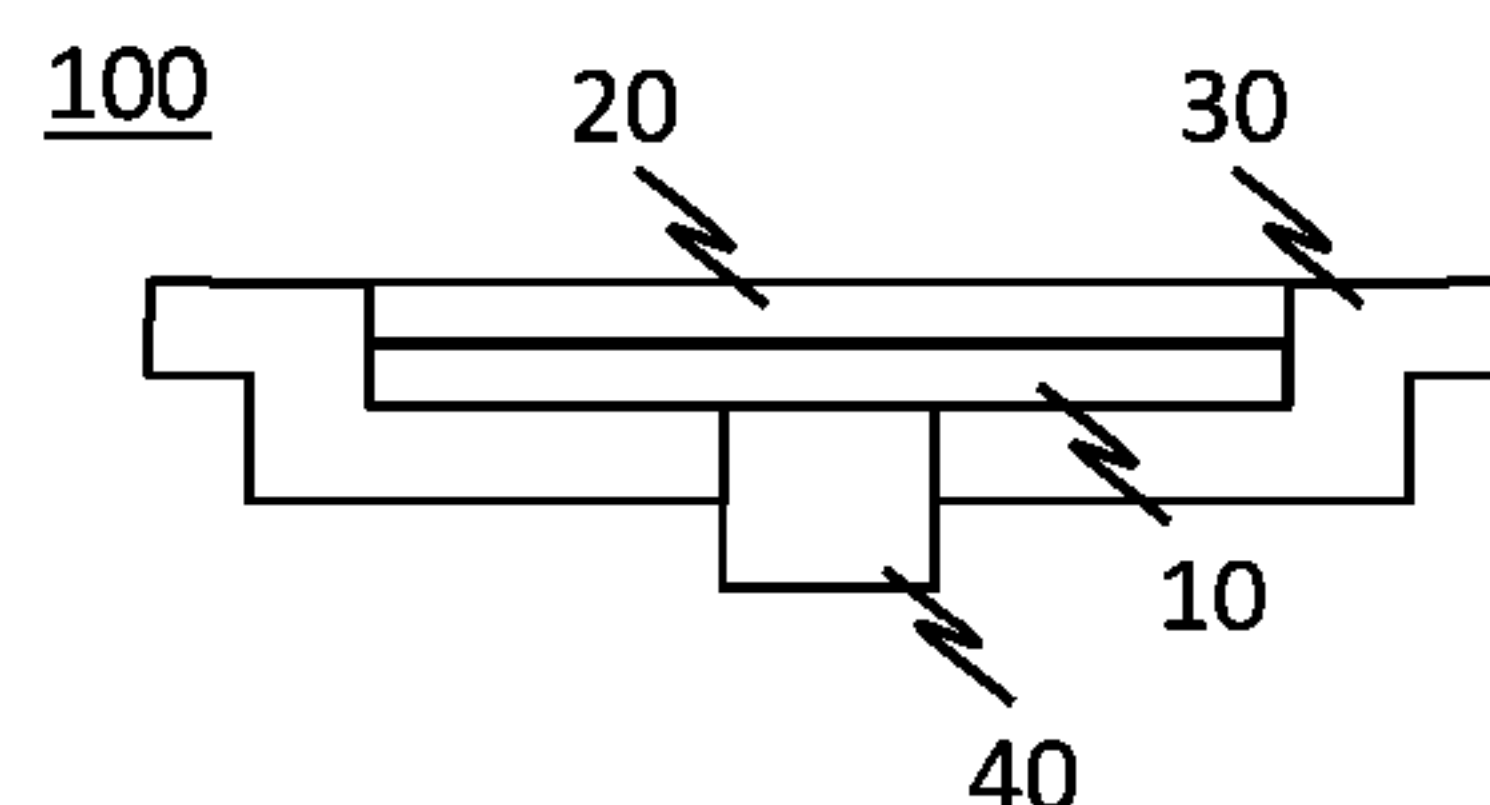
(54) Keksinnön nimitys - Uppfinningens benämning - Title of the invention
Kuivaelektrodi ihon biometristä mittausta varten ja sen valmistusmenetelmä
Torrelektrod för biometrisk mätning på hud och förfarande för dess framställning
Dry electrode for biometric measurement on a skin and a method of manufacturing same

(56) Viitejulkaisut - Anförda publikationer - References cited
JP 2016147814 A, WO 2019162518 A1, CN 106435518 A, CN 209236137 U, CN 110507316 A, CN 106667451 A

(57) Tiivistelmä - Sammandrag - Abstract

Kuiva elektrodi ihon biometristä mittausta varten, käsittäen substraatin (10), joka muodostaa elektrodin pohjan, substraatin käsittäessä metalli- tai puolijohdemateriaalia; sähköä johtavan kalvon (20) substraatin ensimmäisellä pinnalla (10); ja kiinnityselementin (30) elektrodin kiinnittämiseksi ihoon. Sähköä johtava kalvo (20) on suoraan kasvatettu substraatin ensimmäiselle pinnalle (10) ja sisältää grafeenikalvon.

A dry electrode for biometric measurement, comprising a substrate (10) forming the scaffold of the electrode, the substrate comprising metal or semiconductor material; an electrically conductive film (20) on a first surface of the substrate (10); and an attaching element (30) for attaching the electrode; wherein the electrically conductive film (20) is directly deposited on the first surface of the substrate (10).



DRY ELECTRODE FOR BIOMETRIC MEASUREMENT ON A SKIN AND A METHOD OF MANUFACTURING SAME

TECHNICAL FIELD

The present application generally relates to a dry electrode for biometric measurement on a skin and to method of manufacturing same. In particular, but not exclusively, the present application relates to dry electrodes for measuring biopotential signals such as ECG, EEG, EMG and EOG signals in addition to bioimpedance measurements.

BACKGROUND

This section illustrates useful background information without admission of any technique described herein being representative of the state of the art.

Biometric measurements, such as ECG and EEG are widely used in medicine and health monitoring. Electrodes used in these measurements need be cost effective, easy to use and compatible with human skin, i.e. not irritating.

Currently, pre-gelled Ag/AgCl electrodes dominate the market in electrodes used in clinical biopotential recorders as they are a close approximation of nonpolarizable electrodes and their half-cell potential is compatible with body composition. However, such pre-gelled Ag/AgCl electrodes present some challenges, such as rigidity causing discomfort during long-term use, skin irritation and rash, a delay of several minutes before electrodes start to operate and gain proper biometric signals, performance degradation over time as the gel dries or reacts with sweat. Moreover, silver is rather an expensive and toxic material.

Furthermore, solutions for dry electrodes have been introduced to tackle the issues arisen in wet electrodes. For example, electrodes with a graphene paste or solution-based coating processes have been presented as well as processes in which chemical vapour deposition, CVD, grown graphene is transferred from the growth substrate onto an electrode.

It is the object of the invention to mitigate the challenges of the prior art.

SUMMARY

Various aspects of examples of the invention are set out in the claims.

According to a first example aspect of the present invention, there is provided a dry electrode for biometric measurement on a skin as defined by claim 1.

The graphene film may comprise a nanolayer of graphene, comprising a monolayer of graphene, or multiple layers of graphene.

- 5 The electrically conductive film may cover substantially the entire first surface of the substrate.

The attaching element may comprise an adhesive element for attaching the electrode to skin.

- 10 The attaching element may comprise an element for attaching the electrode to a further entity, such as clothing or a further item being in contact with skin.

The dry electrode may be flexible.

- 15 The metal or semiconductor material may comprise copper, nickel, iron, aluminium, zinc, titan, platinum, germanium, gallium, arsenic, indium, cobalt, palladium, tungsten, chromium, golds, silver, iridium, ruthenium, rhenium, rhodium, tin, steel, alloys of the foregoing, Si, SiO₂, SiC, Al₂O₃, Si₃N₄, SrTiO₃, or hexagonal boron nitride.

The electrically conductive film may be deposited directly on the first surface of the substrate using chemical vapour deposition, CVD, or atomic layer deposition, ALD.

The dry electrode may further comprise a connector element on a second surface of the substrate.

- 20 According to a second example aspect of the present invention, there is provided a method of manufacturing the dry electrode of the first example aspect of the present invention comprising depositing an electrically conductive film directly on a first surface of a metal substrate using chemical vapour deposition, CVD, or atomic layer deposition, ALD.

- 25 Different non-binding example aspects and embodiments of the present invention have been illustrated in the foregoing. The embodiments in the foregoing are used merely to explain selected aspects or steps that may be utilized in implementations of the present invention. Some embodiments may be presented only with reference to certain example aspects of the invention. It should be appreciated that corresponding
30 embodiments may apply to other example aspects as well.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of example embodiments of the present invention, reference is now made to the following descriptions taken in connection with the accompanying drawings in which:

- 5 Fig. 1 shows a schematic side view of a dry electrode for biometric measurement according to an embodiment of the invention;
- Fig. 2 shows a schematic front view of a dry electrode for biometric measurement according to an embodiment of the invention; and
- Fig. 3 shows a flow diagram of a manufacturing method of a dry electrode for biometric measurement according to an embodiment of the invention.
- 10

DETAILED DESCRIPTION OF THE DRAWINGS

The present invention and its potential advantages are understood by referring to Figs. 1 through 3 of the drawings. In this document, like reference signs denote like parts or steps.

- 15 Figs. 1 and 2 show a schematic side and front view of a dry electrode for biometric measurement according to an embodiment of the invention. The dry electrode 100 comprises a substrate 10 forming the scaffold, or base, of the electrode. The substrate 10 comprises an electrically conductive material, such as metal or semiconductor material. In an embodiment, the substrate 10 comprises copper, nickel, iron,
- 20 aluminium, zinc, titan, platinum, germanium, gallium, arsenic, indium, cobalt, palladium, tungsten, chromium, gold, silver, iridium, ruthenium, rhenium, rhodium, tin, steel, or alloys of the foregoing, Si, SiO₂, SiC, Al₂O₃, Si₃N₄, SrTiO₃, or hexagonal boron nitride.

- The dry electrode 100 further comprises an electrically conductive film 20 on a first surface of the substrate 10. In an embodiment, the electrically conductive film 20 comprises a graphene film. It is to be noted that although a graphene film 20 is referred to hereinafter, in further embodiments, the electrically conductive film comprises material selected from the group of ZnO, Ru, Pt, TiN, TiC, ZrC, VC, HfC, Cr₇C₃, Cr₂C₃, Co₂C, MgTe, AlSb, Si₃N₄, SiC, TiS₂, Cu_xSe, GaN, GaAs, GaSb, Rh₂O₃, CdSe, InP,
- 30 In₂Se₃, InAs, InSb, Lu₂O₃, W_xC, WN_xCy, or any combination thereof.

The graphene film 20 is directly deposited, or grown, on the first surface of the

substrate using a suitable deposition method. The skilled person appreciates that the substrate 10 in an embodiment, is removed, for example by cutting, from a larger substrate on which a graphene film has been deposited, i.e. direct deposition does not require that the substrate 10 was in its final shape and/or size during deposition. In a further embodiment, the substrate 10 comprises a three-dimensional structures, such as indentations and/or protrusions. In a further embodiment, the substrate is 10 in the form of spring-like elements, has a structure akin to fibrous material such as wool, or a porous structure akin to a mesh or a honeycomb

The technical effects of direct deposition of the graphene film comprise a substantial simplification of the process of manufacturing the dry electrode, an improved adhesion of the graphene film to the substrate, and a uniform covering of the substrate surface with the graphene film as opposed to prior art systems in which the graphene film is first deposited on a separate substrate and then transferred with complicated multi step processes on an electrode.

In an embodiment, the graphene film 20 comprises a nanolayer of graphene, for example a monolayer of graphene grown on the surface of the substrate 10. In a further embodiment, the nanolayer of graphene comprises a multilayer growth.

In an embodiment, the graphene film 20 is directly deposited using a chemical vapor deposition, CVD, method or atomic layer deposition, ALD, method, or sputtering.

Further suitable deposition methods may be used in an embodiment, as long as uniformity of the film and adhesion to the substrate are comparable with the deposition methods mentioned hereinbefore.

The graphene film 20 provides for, as also previously known, for a low impedance between the electrode and the skin. With the graphene film being deposited directly on the substrate, with good adhesion and film uniformity, the dry electrode provides for excellent signal quality and protection against corrosion, as the graphene film protects the substrate as well. Furthermore, the graphene film provides for non-toxicity and minimizes any chemical reaction between the skin and the electrode.

In an embodiment, the substrate 10 and the graphene film 20 and consequently the dry electrode 100 are flexible providing the technical effect that the dry electrode is easily attached to skin in various positions as well as to a further entity such as to clothing without compromising ease of use and comfort of the user.

The dry electrode 100, in an embodiment, further comprises an attaching element 30. In an embodiment, the attaching element 30 comprises an adhesive element configured for attaching the dry electrode 100 to the skin of the subject of the measurement. As the dry electrode 100 is light and thin due to the directly deposited graphene nanolayer, the adhesive element need not provide strong adhesion and accordingly more skin friendly and less irritating adhesives can be used. In an embodiment, the adhesive element surrounds the substrate 10 and/or the graphene film 20. In a further element, the adhesive element resides on the graphene film 20, partially overlapping it while leaving a contact surface to the skin available, as shown in Fig. 2.

In a further embodiment, the attaching element 30 comprises an element for attaching the electrode 100 to a further entity, such as clothing. Such an element in an embodiment comprises for example elements such as Velcro, buttons or magnetic elements.

The dry electrode 100, in an embodiment, further comprises a connector element 40 for connecting the electrode to a measurement instrument. In an embodiment, the connector element is positioned on a second surface of the substrate 10. In an embodiment, the connector element comprises a connector for connecting the leads or wires of a measurement instrument, such as a snap fastener, conductive Velcro, or magnetic connectors.

In the following an example of the dimensions of the dry electrode 100 is given. In an example embodiment, the radius of the electrode including the adhesive element 30 is 40 mm, whereas the radius of the electrode element, i.e. the graphene film 20 and the substrate 10 is 20mm. The thickness of single layer graphene of the graphene film 20 is 0,335 nm whereas the thickness of the substrate 10, comprising copper, is 50 μm . A skin friendly adhesive, such as an adhesive similar to kinesio tape, with thickness of 150 μm is used as the adhesive layer 30.

Fig. 3 shows a flow chart of a method for manufacturing a dry electrode according to an embodiment of the invention. At 310 a substrate 10 configured to function as the scaffold of the electrode is provided, for example a copper substrate. At 320 a deposition process is carried out, for example a CVD or ALD deposition process for growing a graphene film 20 on the substrate 10. The parameters of the deposition

depend on the desired thickness of the graphene film 20, which is in an embodiment a monolayer or has multiple graphene layers. At 330 the graphene film has been deposited uniformly with excellent adhesion to the substrate 10. In an embodiment, at 340 and adhesive element is attached to the electrode, for example on top of the graphene film and partially covering it.

The inventors have found that a dry electrode may be easily and cost effectively manufactured as described herein. In previous methods, in which graphene is first grown on a metal substrate and then transferred to an electrode with wet etching process requiring several steps, such an ease of manufacturing with low cost and an end product with uniformity and strong adhesion to the electrode cannot be achieved.

Some use cases relating to given embodiments of the dry electrode according to embodiments of the invention, are presented in the following. In a first use case, the dry electrode 100 is used directly on human skin and is comfortable and non-irritating to wear due to lightness and less irritating adhesive strength.

In a second use case, the dry electrode 100 is used in a wearable measurement system, wherein the dry electrode is easily attached and accommodated due to thinness and flexibility.

In a third use case, mesh type electrode elements 10 and 20 are attached on the bottom side of a kinesio tape, or similar type of adhesive wherein the system facilitates the body's natural healing process, providing support and stability to muscles and joints while allowing measurement of biopotential signals.

In a fourth use case, the dry electrode 100 is used in a sport equipment for example on bikes, rowing machines, steppers, treadmill, handlebars, or on a steering wheel of a car, allowing online measurements.

In a fifth use case, the dry electrode 100 is used in a body composition-measuring unit.

Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein, in addition to the technical effects explained hereinbefore, is the provision of a simple and cost effective dry electrode. Another technical effect of one or more of the example embodiments disclosed herein is the provision of a dry electrode suitable for cheap mass production. Another technical effect of one or more

of the example embodiments disclosed herein is improved signal quality due to low impedance level. Another technical effect of one or more of the example embodiments disclosed herein is the provision of an electrode that is comfortable to wear due to flexibility and breathability, as no strong adhesive or moisture barrier to prevent drying
5 is needed. Another technical effect of one or more of the example embodiments disclosed herein is that the shape and the structure of the electrode as the conductive element can be cut and structured before or after graphene deposition to various forms such as spring, wool, mesh, honeycomb or porous to facilitate good skin contact, flexibility, and breathability. A still further technical effect of one or more of the example
10 embodiments disclosed herein is the provision of a disposable electrode, as no chemicals are needed.

Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent
15 claims, and not solely the combinations explicitly set out in the claims.

It is also noted herein that while the foregoing describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of the present invention as defined in the appended claims.

CLAIMS

1. A dry electrode for biometric measurement on a skin, comprising
a substrate (10) forming the scaffold of the electrode, the substrate comprising
metal or semiconductor material;
5 an electrically conductive film (20) on a first surface of the substrate (10); and
an attaching element (30) for attaching the electrode to the skin; **characterized**
in that
the electrically conductive film (20) is directly deposited on the first surface of the
substrate (10); and
10 the electrically conductive film (20) comprises a graphene film.
2. A dry electrode of claim 1, wherein the graphene film comprises a nanolayer of
graphene.
3. A dry electrode of claim 2, wherein the nanolayer comprises a monolayer of
graphene, or multiple layers of graphene.
- 15 4. A dry electrode of any one of claims 1 to 3, wherein the electrically conductive
film (20) comprises material selected from the group of ZnO, Ru, Pt, TiN, TiC, ZrC,
VC, HfC, Cr₇C₃, Cr₂C₃, Co₂C, MgTe, AlSb, Si₃N₄, SiC, TiS₂, Cu_xSe, GaN, GaAs, GaSb,
Rh₂O₃, CdSe, InP, In₂Se₃, InAs, InSb, Lu₂O₃, W_xC, and WN_xC_y, or a combination
thereof.
- 20 5. A dry electrode of any one of preceding claims, wherein the electrically
conductive film covers substantially the entire first surface of the substrate (10).
6. A dry electrode of any one of preceding claims, wherein the attaching element
(30) comprises an adhesive element for attaching the electrode to the skin.
7. A dry electrode of any one of preceding claims, wherein the attaching element
25 comprises an element for attaching the electrode to a further entity, such as clothing
or a further item being in contact with the skin.
8. A dry electrode of any one of preceding claims, wherein the dry electrode is
flexible.
9. A dry electrode of any one of preceding claims, wherein the metal or

semiconductor material comprises copper, nickel, iron, aluminium, zinc, titan, platinum, germanium, gallium, arsenic, indium, cobalt, palladium, tungsten, chromium, golds, silver, iridium, ruthenium, rhenium, rhodium, tin, steel, alloys of the foregoing, Si, SiO₂, SiC, Al₂O₃, Si₃N₄, SrTiO₃, or hexagonal boron nitride.

5 10. A dry electrode of any one of preceding claims, wherein the electrically conductive film (20) is deposited directly on the first surface of the substrate using chemical vapour deposition, CVD, or atomic layer deposition, ALD.

11. A dry electrode of any one of preceding claims, further comprising a connector element on a second surface of the substrate.

10 12. A method of manufacturing the dry electrode of any one of claims 1 to 11 comprising depositing an electrically conductive film (20) directly on a first surface of a metal substrate using chemical vapour deposition, CVD, or atomic layer deposition, ALD.

15 13. The method of claim 12, wherein the electrically conductive film comprises material selected from the group of ZnO, Ru, Pt, TiN, TiC, ZrC, VC, HfC, Cr₇C₃, Cr₂C₃, Co₂C, MgTe, AlSb, Si₃N₄, SiC, TiS₂, Cu_xSe, GaN, GaAs, GaSb, Rh₂O₃, CdSe, InP, In₂Se₃, InAs, InSb, Lu₂O₃, W_xC, WN_xC_y, or a combination thereof.

1. Kuiva elektrodi ihon biometristä mittausta varten, käsittäen substraatin (10), joka muodostaa elektrodin pohjan, substraatin käsittäessä metalli- tai puolijohdemateriaalia; sähköä johtavan kalvon (20) substraatin ensimmäisellä pinnalla (10); ja kiinnityselementin (30) elektrodin kiinnittämiseksi ihoon; **tunnettu** siitä, että sähköä johtava kalvo (20) on suoraan kasvatettu substraatin ensimmäiselle pinnalle (10); ja sähköä johtava kalvo (20) sisältää grafeenikalvon.
2. Patenttivaatimuksen 1 kuiva elektrodi, jossa grafeenikalvo käsittää nanokerroksen grafeenia.
3. Patenttivaatimuksen 2 kuiva elektrodi, jossa nanokerros käsittää grafeenimonokerroksen tai useista grafeenikerroksia.
4. Minkä tahansa vaatimuksen 1–3 kuiva elektrodi, jossa sähköä johtava kalvo (20) käsittää materiaalia valittuna ryhmästä ZnO-, Ru-, Pt-, TiN, TiC, ZrC, VC, HfC, Cr₇C₃, Cr₂C₃, Co₂C, MgTe, AlSb, Si₃N₄, SiC, TiS₂, CuxSe GaN, GaAs, GaSb Rh₂O₃, CdSe, InP, In₂Se₃, InAs, InSb, Lu₂O₃, WxC, ja WNxCy, tai niiden yhdistelmästä.
5. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, jossa sähköä johtava kalvo peittää merkittävästi substraatin (10) koko ensimmäisen pinnan.
6. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, jossa kiinnityselementti (30) käsittää liimautuvan elementin elektrodin kiinnittämiseksi ihoon.
7. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, jossa kiinnityselementti käsittää elementin elektrodin kiinnittämiseksi toiseen yksikköön, kuten vaatteisiin tai muuhun esineeseen, joka on edelleen kosketuksissa ihon kanssa.
8. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, jossa kuiva elektrodi on taipuisa.
9. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, jossa metalli- tai puolijohdemateriaali käsittää kuparia, nikkeliä, rautaa, alumiinia, sinkkiä, titaania, platinaa, germaniumia, galliumia, arseenia, indiumia, kobolttia, palladiumia, volframia, kromia, kultaa, hopeaa, iridiumia, ruteniumia, reniumia, rodiumia, tinaa, terästä, edellisten seosta, SiO₂:a, SiC:ä, Al₂O₃:a, Si₃N₄:ää, SrTiO₃:a, tai

heksagonaalista boorinitiridiä.

10. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, jossa sähköä johtava kalvo (20) kasvatetaan suoraan substraatin ensimmäiselle pinnalle kemiallisella höyrykasvatuksella, CVD tai atomikerroskerroskasvatuksella, ALD.

11. Minkä tahansa edellisen vaatimuksen kuiva elektrodi, joka lisäksi käsittää substraatin toisella pinnalla olevan liitinelementin.

12. Menetelmä minkä tahansa vaatimuksen 1–11 kuivaelektrodin valmistamiseksi, joka käsittää sähköä johtavan kalvon (20) kasvattamisen suoraan metallisubstraatin ensimmäiselle pinnalle kemiallisella höyrykasvatuksella, CVD tai atomikerroskerroskasvatuksella, ALD.

13. Patenttivaatimuksen 12 menetelmä, jossa sähköä johtava kalvo käsittää materiaalia valittuna ryhmästä ZnO-, Ru-, Pt-, TiN, TiC, ZrC, VC, HfC, Cr₇C₃, Cr₂C₃, Co₂C, MgTe, AlSb, Si₃N₄, SiC, TiS₂, Cu_xSe GaN, GaAs, GaSb, Rh₂O₃, CdSe, InP, In₂Se₃, InAs, InSb, Lu₂O₃, WxC, WNxCy, tai niiden yhdistelmä.

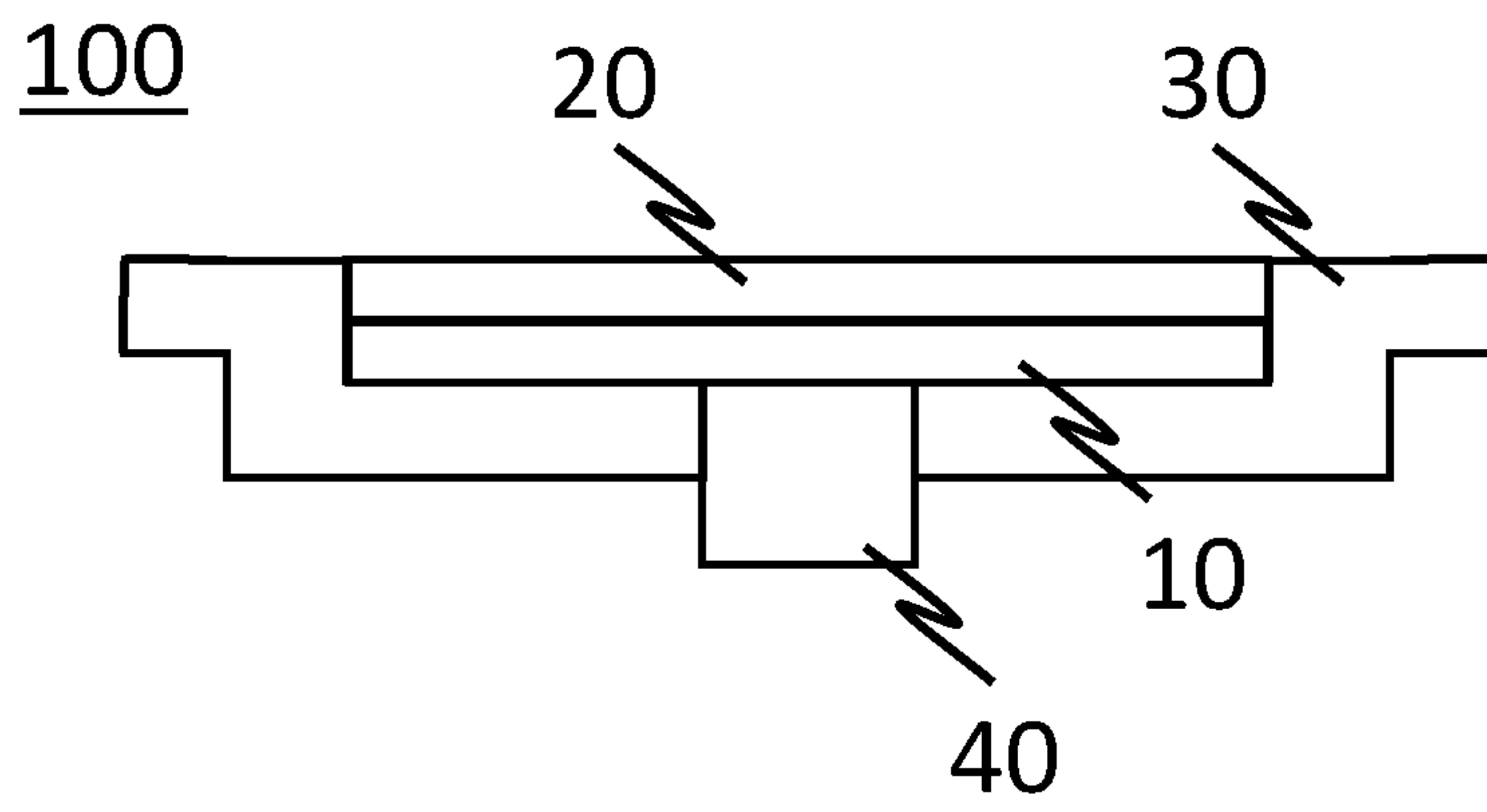


Fig. 1

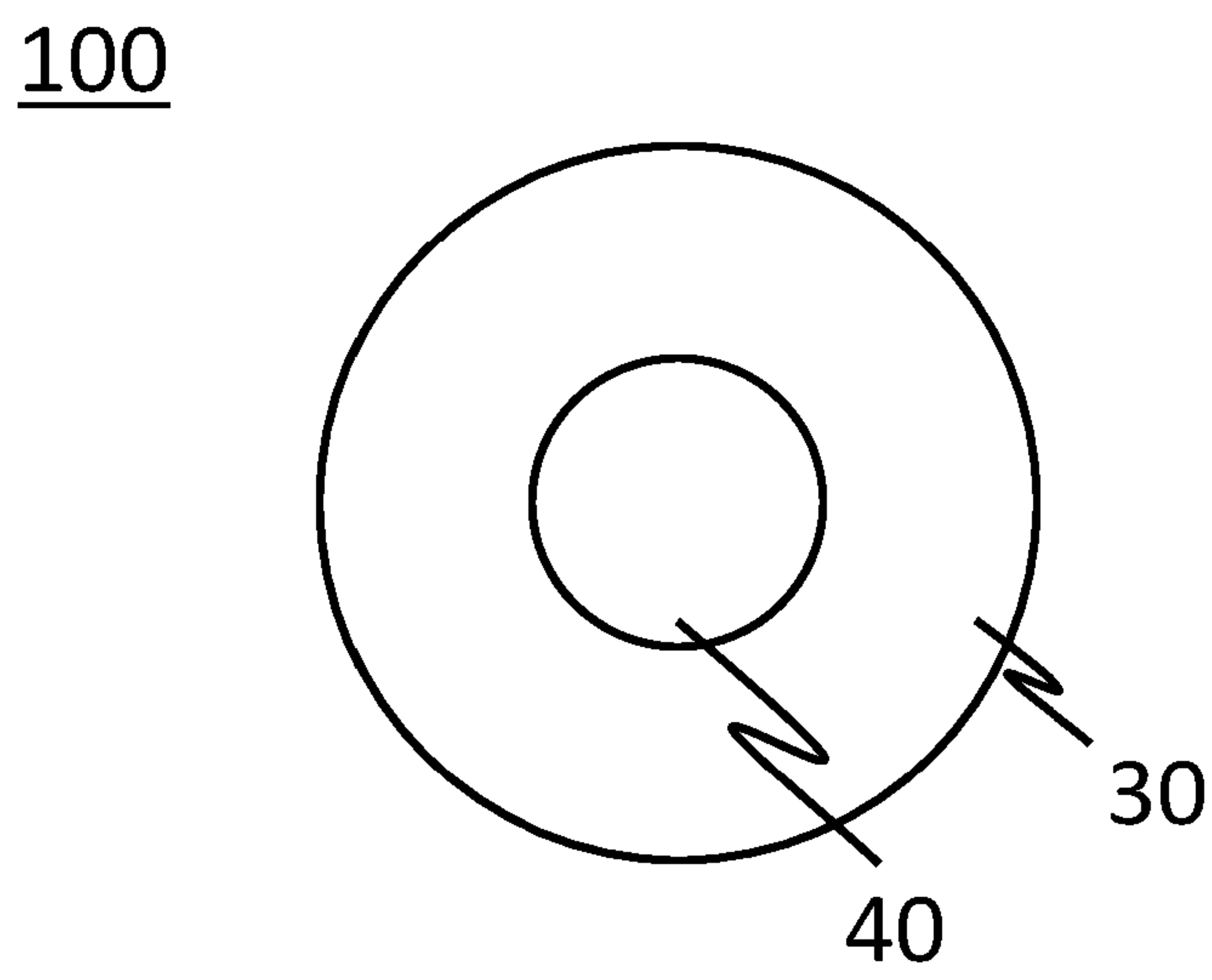


Fig. 2

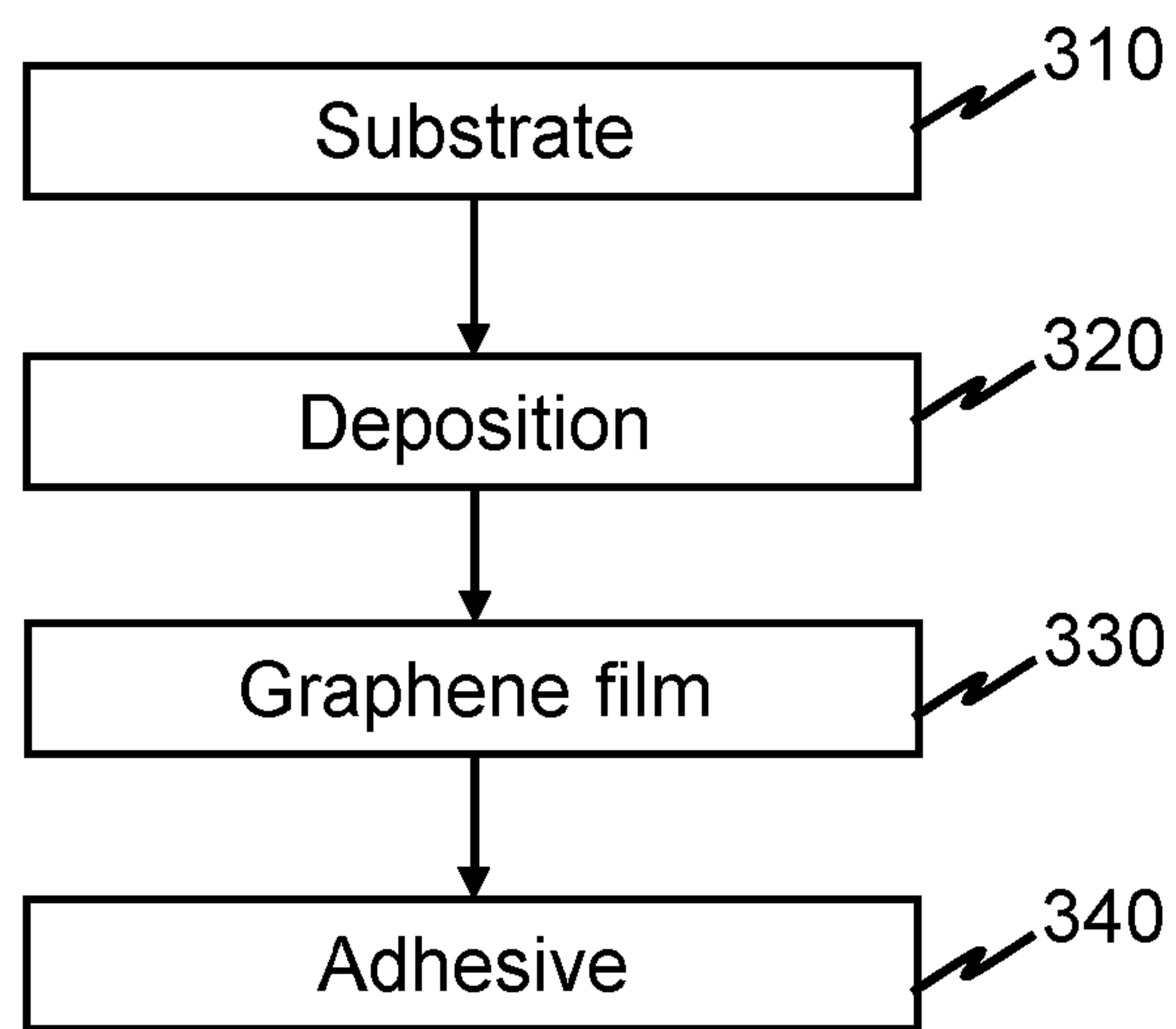


Fig. 3