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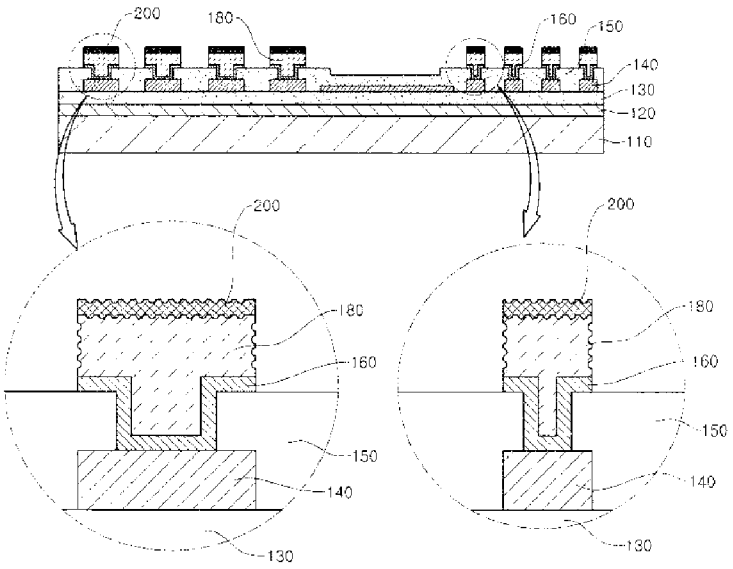
(54) Title: MANUFACTURING METHOD OF MICROELECTRODE ARRAY

[Fig. 2h]



(57) Abstract: Disclosed herein is a processing method of a microelectrode array. A processing method of a microelectrode array includes: depositing a sacrificial layer on a silicon substrate; patterning a first polymer on the deposited sacrificial layer and then thermally curing the first polymer patterning a metal thin film on the first polymer to form a bonding pad site, an interconnection line and a recording pad site; closing the interconnection line site and coating a second polymer to pattern the bonding pad site and the recording pad site; depositing a seed layer on the second polymer and the metal thin film using a sputter; electroplating a metal on the bonding pad site and the recording pad site, thereby forming an electroplated layer; patterning a photoresist to open an upper portion of the electroplated layer; depositing platinum on the photoresist and the electroplated layer; and removing the photoresist.

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Description

Title of Invention: MANUFACTURING METHOD OF MICRO-ELECTRODE ARRAY

Technical Field

[1] Disclosed herein is a manufacturing method of a microelectrode array. More particularly, disclosed herein a manufacturing method of a microelectrode array, in which electrodes are formed in a rough surface through electroplating, so that the thickness of the electrodes can be increased while increasing the roughness of surfaces of the electrodes.

Background Art

[2] Electrical stimulation is a general technique used to induce cellular reactions in a nervous system. The study on electrophysiological signals in a nervous system requires a very complicated process because of changes in the impedance of microelectrodes. Therefore, an equal nervous system network is necessarily constructed by normalizing all electrodes in a microelectrode array so as to simplify complicated operational characteristics related to electrophysiological signals.

[3] When measuring electrophysiological signals in a nervous system, electrodes necessarily have equal impedance a frequency band of 10Hz to 1kHz, which is related to the signals. Low impedance is advantageous to obtain a high signal gain. An electrode material necessarily signifies a high reversible charge injection limit with respect to stimulation.

[4] The reversible charge injection limit means how many charges are charged into electrodes and how many charges are exchanged at the interface between the electrodes and an electrolyte in the AC cycling process in which faradaic current that causes an irreversible redox process is not generated. In the irreversible redox process, toxic products are produced in tissues.

[5] Electrochemical reactions on surfaces of electrodes are very complicated and include various chemical and physical factors. If corrosion occurs at the boundary between the electrodes and an electrolyte, material loss is caused by electrochemical reactions on the surface of a metal used as an electrode material. In a thermodynamic view, the exchange of electrons between the metal of the electrodes and the electrolyte of the tissues allows current to be formed on the surface of the metal. Therefore, it is important to understand the relationship between electrical properties and corrosive wear.

[6] The electron work function refers to the minimum energy necessary for separating one electron from the surface of a solid metal. The electron work function on the

surface of the metal reflects an electrical energy level and has a relation with electrode potential. The electron work function on the surface of an electrode material has a very close relation with local corrosion potential. The surface morphology of the electrode material through work function calculation plays an important role in determining electron reactions and corrosion reactions. This is because the electron reactions determine electrochemical activity or reactivity.

[7] As the surface of an electrode is roughened, the electron work function is decreased. Therefore, electrons are easily separated from the roughened surface of the electrode, and the corrosion rate is increased. That is,if the roughness of the surface of the electrode is increased, the electron work function is decreased, and the corrosion rate is increased.

[8] Platinum (Pt) is frequently used as an electrode material in the manufacture of a flexible microelectrode array. This is because the platinum is strong for chemical corrosion, and has biocompatibility and low threshold potential suitable to be applied to electrical stimulation. However, the platinum is also dissolved even though current is applied with a balance-charge biphasic waveform so as to prevent tissues from being damaged by electrochemical reactions generated at the boundary between the electrode and an electrolyte.

[9] While biphasic pulses are generated, the dissolution of the platinum is influenced by pulse parameters such as polarity, aggregate charge and charge density, the state of the surface of the electrode, and the like. Therefore, in order to allow such dissolution of the platinum to progress slowly, the thickness of the electrode may be increased by forming electroplated platinum, or the roughness of the surface of the electrode may be increased by forming an oxide-based electrode through injection of an oxide into a metal such as iridium or tantalum. These methods cause contact impedance to be decreased.

[10] Therefore, as the roughness of the surface of the metal electrode is increased, electrons of the metal electrode are actively moved. Thus, its contact resistance is decreased, and its capacitive region is widened. Accordingly, since the reversible region is widely formed, the damage of tissues, caused by irreversible reactions, can be minimized.

[11] However, current does not have a uniform density on the roughened surface of the electrode. This is becausea relatively small amount of current flows at a valley portion of the surface rather than at a peak of the surface. Therefore,the roughness of the surface of the electrode has a trade-off relationship with the uniformity of current density, and a level applicable to real use is necessarily determined through experiments.

[12] FIG. 1 is a sectional view illustrating a related art microelectrode array. Referring to

FIG. 1, a sacrificial layer 20 is formed on a substrate 10, and electrode patterns are formed on a first polymer 30 such as polyimide or pyridine or SU-8. Then, the other portions except electrodes 40 are covered by a second polymer 50, so that the related art microelectrode array is released from the substrate 10. Accordingly, the related art microelectrode array is manufactured.

[13] In the related art microelectrode array manufactured to measure electrophysiological signals in a nervous system such as the cerebral cortex, the electrodes 40 are formed in an engraved shape. Therefore, when the electrodes are attached to a measuring part of a real brain, they are not well attached to tissues of the brain.

[14] That is, in the related art microelectrode array, the metal electrodes 40 are positioned lower than the second polymer 50. When the metal electrodes 40 are attached to a real nervous system, the direct contact between the metal electrodes 40 and the nervous system is not well formed.

Disclosure of Invention

Technical Problem

[15] Disclosed herein is a manufacturing method of raising the electrode pad through metal deposition, also including a processing method of roughening the surface of electrode through electroplating for easy contact to biological tissue.

Solution to Problem

[16] In an aspect, there is provided a manufacturing method of a microelectrode array, which includes: depositing a sacrificial layer on a silicon substrate; patterning a first polymer on the deposited sacrificial layer and then thermally curing the first polymer patterning a metal thin film on the first polymer to form a bonding pad site, an inter-connection line and a recording pad site; closing the interconnection line site and coating a second polymer to pattern the bonding pad site and the recording pad site; depositing a seed layer on the second polymer and the metal thin film using a sputter; electroplating a metal on the bonding pad site and the recording pad site, thereby forming an electroplated layer; patterning a photoresist to open an upper portion of the electroplated layer; depositing platinum on the photoresist and the electroplated layer; and removing the photoresist.

[17] The sacrificial layer may be formed of aluminum (Al) or silicon oxide (SiO_2).

[18] The patterning of the metal thin film may include depositing an adhesion layer using an e-beam evaporator and then depositing gold (Au) or platinum (Pt) on the adhesion layer, thereby forming the metal thin film.

[19] The adhesion layer may be formed of chrome (Cr), titanium (Ti), titanium nitride (TiN), titanium-tungsten (TiW) or nickel (Ni).

[20] The manufacturing method may further include patterning the bonding pad site and

the recording pad site by using a photoresist before performing the electroplating and then removing the photoresist after forming the electroplated layer.

[21] The photoresist may be removed using a wet or dry etching method.

[22] In the electroplating, the roughness of the surface of the electroplated layer may be controlled by adjusting current density.

[23] The electroplating layer may be formed of nickel (Ni), copper (Cu), gold (Au), platinum (Pt), silver (Ag) or nickel-cobalt (NiCo).

[24] The platinum may be deposited using an evaporator or sputter.

[25] The manufacturing method may further include annealing the platinum, thereby controlling the roughness of the surface of the platinum.

[26] The manufacturing method may further include peeling off the sacrificial layer using an aluminum (Al) etchant, diluted hydrofluoric acid (HF) or tetramethylammonium hydroxide (TMAH) photoresist (PR) developer after removing the photoresist.

Advantageous Effects of Invention

[27] The manufacturing method of a microelectrode array, disclosed herein, is advantageous in that the roughness of the surfaces of electrodes is increased by forming the electrodesthrough electroplating, and the contact impedance at the surface of the electrode is decreased by activating the movements of electrons of metal in the electrode. Accordingly, in the extraction of signals from biological tissue, the signal to noise ratio is increased, and impedance is lowered. Since the region of reversible reactions is extended, it is possible to minimize the damage of tissues in a nervous system, caused by irreversible reactions.

[28] Further, the manufacturing method of a microelectrode array, disclosed herein, is advantageous in that the roughness of the surfaces of the electrodes can be controlled by adjusting the intensity of current applied in electroplating.

[29] Furthermore, the manufacturing method of a microelectrode array, disclosed herein, is advantageous in that since the electrodes formed in a rough surface through electroplating is thicker than the related art electrodes formed in a general thin-film shape, the lifetime can be extended, and the contact impedance can be decreased.

Brief Description of Drawings

[30] FIG. 1 is a sectional view illustrating a related art microelectrode array.

[31] FIGS. 2A to 2H are sectional views illustrating a manufacturing method of a microelectrode array according to an embodiment.

Mode for the Invention

[32] Exemplary embodiments now will be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments are shown. This disclosure may, however, be embodied in many different forms and should not be

construed as limited to the exemplary embodiments set forth therein. Rather, these exemplary embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of this disclosure to those skilled in the art. In the description, details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the presented embodiments.

[33] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of this disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[34] Furthermore, the use of the terms a, an, etc. does not denote a limitation of quantity, but rather denotes the presence of at least one of the referenced item. The use of the terms "first", "second", and the like does not imply any particular order, but they are included to identify individual elements. Moreover, the use of the terms first, second, etc. does not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. It will be further understood that the terms "comprises" and/or "comprising", or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[35] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[36] In the drawings, like reference numerals in the drawings denote like elements. The shape, size and regions, and the like, of the drawing may be exaggerated for clarity.

[37] FIGS. 2A to 2H are sectional views illustrating a manufacturing method of a microelectrode array according to an embodiment. In the microelectrode array according to this embodiment, electrodes have a high surface roughness, and are formed in a rough surface. The electrodes are attached to an object in order to measure a slight change in electrical signal, such as current, voltage or impedance.

[38] Referring to FIG. 2A, a material used as a sacrificial layer 120 is deposited on a substrate 110. The sacrificial layer 120 is used to form a flexible microelectrode array on the substrate 110 and then release the microelectrode array from the substrate 110. The sacrificial layer 120 may be peeled off using an aluminum (Al) etchant, diluted hydrofluoric acid (HF) or tetramethylammonium hydroxide (TMAH) photoresist (PR)

developer.

[39] The substrate 110 may be formed of, for example, silicon, gallium arsenide (GaAs), quartz or the like. The sacrificial layer 120 may be formed of, for example, a metal such as aluminum (Al) or a dielectric film such as silicon oxide (SiO_2).

[40] A first polymer 130 is patterned on the sacrificial layer 120. The first polymer 130 may include polyimide, parylene C or the like, but is not limited thereto. In this embodiment, the polyimide is used as the first polymer 130. After the first polymer 130 is patterned, it is cured in an oven, furnace or the like.

[41] Referring to FIG. 2B, the microelectrode array includes recording pads that come in direct contact with a part to be measured, bonding pads connected to a circuit for processing electrophysiological signals inputted through the recording pads, and an interconnection line for connecting between the two pads. Metal thin film patterning is performed through a lift-off process so as to form the two pads and the interconnection line.

[42] An apparatus such as an evaporator is used to perform the lift-off process, and a metal thin film 140 is deposited on the first polymer 130. Here, the metal thin film 140 may be formed by depositing an adhesion layer on the polyimide used as the first polymer 120 using an apparatus such as an e-beam evaporator so as to improve adhesion and then depositing a metal such as gold (Au) or platinum (Pt) on the adhesion layer. The metal used as the adhesion layer may be, for example, chrome (Cr), titanium (Ti), titanium nitride (TiN), titanium-tungsten (TiW), nickel (Ni) or the like.

[43] Referring to FIG. 2C, a second polymer 150 is patterned so that the interconnection line is closed to remove electrical interference while patterning a recording pad site and a bonding pad site. Like the first polymer 130, the second polymer 150 may include polyimide, parylene C or the like, but is not limited thereto. In this embodiment, the polyimide is used as the second polymer 150. After the second polymer 150 is coated, it is cured in an oven, furnace or the like.

[44] Referring to FIG. 2D, a seed layer 160 is deposited before electroplating to be applied in the manufacturing method. Since the seed layer 160 is necessarily deposited on all surfaces of the pattern formed in the process of FIG. 2C, an apparatus such as a sputter is used. The metal used as an adhesion layer may be, for example, chrome (Cr), titanium (Ti), titanium nitride (TiN), titanium-tungsten (TiW), nickel(Ni) or the like. Then, a metal such as gold (Au) may be deposited on the adhesion layer.

[45] Referring to FIG. 2E, the recording pad site and the bonding pad site, which are portions subjected to the electroplating, are patterned, and a thick photoresist 170 is coated on the other sites so as to form a mold for closing the interconnection line.

[46] Referring to FIG. 2F, an electroplated layer 180 is formed by electroplating a metal

such as nickel (Ni), copper (Cu), gold (Au), platinum (Pt), silver(Ag) or nickel-cobalt (NiCo), and the photoresist 170 used as the mold is then removed. A wet etching method using a chemical such as acetone or EKC or a dry etching method such as O_2 plasma ashing may be used to remove the photoresist 170.

[47] After the photoresist 170 is removed, the seed layer 160 formed beneath the mold is peeled off. For example, a wet etching method using a chemical such as a metal etchant, a physical dry etching method such as argon (Ar) etching or a chemical dry etching method using a chlorine (Cl) based gas may be used to peel off the seed layer 160.

[48] Meanwhile, it has been illustrated in FIG. 2F that the bonding pads and the recording pads are simultaneously formed by electroplating the metal. However, according to another embodiment, the bonding pads and the recording pads may be formed through separate processes, respectively. That is, the bonding pads may be formed by electroplating a metal such as nickel (Ni), copper (Cu), gold (Au), platinum (Pt), silver (Ag) or nickel-cobalt (NiCo), and the recording pads may be formed by depositing a metal such as gold (Au), platinum (Pt), silver (Ag), tungsten (W), molybdenum (Mo), copper (Cu), stainless steel (SUS-27), iron (Fe) or silver-silver chloride (Ag-AgCl) using an evaporator or sputter.

[49] Referring to FIG. 2G, a photoresist 190 is patterned to deposit platinum (Pt) 200 to be applied in the manufacturing method.

[50] Referring to FIG. 2H, the platinum 200 is not well removed using a wet or dry etching method, and therefore, patterning is performed with respect to the platinum 200 through a lift-off process. In order to deposit the platinum 200, an adhesion layermay include, for example, chrome (Cr), titanium (Ti), titanium nitride (TiN), titanium-tungsten (TiW), nickel (Ni) or the like. Then, the platinum 200 is deposited on the adhesion layer using an evaporator. After the platinum 200 is deposited, a lift-off process is performed to remove the photoresist 190 formed in the process of FIG. 2G. As a result, the platinum 200 is left only on the electroplated layer 180.

[51] In the deposition of the platinum 200, the deposition rate of the platinum 200 may be controlled, or the surface roughness of the platinum 200 and its thickness may be controlled by annealing the platinum 200.

[52] In this embodiment, as a method for increasing the roughness of the surfaces of electrodes, a metal such as nickel (Ni), copper (Cu) or gold (Au) is electroplated instead of electroplating the platinum 200, and the platinum 200 is deposited in a thin-film shape on the electroplated metal. Accordingly, manufacturing cost can be reduced.

[53] Generally, if a metal is deposited using an apparatus for forming a thin film, such as a sputter or evaporator, the surface of the deposited metal is smooth, and therefore, a desired roughness of the surface of a metal electrode cannot be obtained.

[54] However, in the manufacturing method disclosed herein, electrodes are formed through electroplating, and the grain size of a metal can be controlled by adjusting the current density applied in the electroplating. Thus, the roughness of the surface of the electroplated layer 180 can be controlled. Since the thickness of the platinum 200 deposited on the electroplated layer 180 using an apparatus such as an e-beam evaporator or sputter is very smaller than that of the surface of the electroplated layer 180, the surface of the metal electrode is formed to be rough.

[55] When the thickness of the electrode layer is unnecessarily large, an unequal current density is shown at the boundary between the electrodes and an electrolyte, and irreversible reactions are increased. Therefore, the damage of tissues in a nervous system may be increased. However, the manufacturing method disclosed herein is advantageous in that the roughness of the surfaces of the electrodes or thickness of the metal layer can be controlled by adjusting the current density applied in the electroplating.

[56] Further, polyimide or parylene C used as a polymer in the manufacturing of a flexible microelectrode array is formed to have a thickness of a few micrometers or thicker, considering its physical and mechanical strength. If a general method of depositing a thin film is used so that a metal used as an electrode is formed in a rough surface on the polymer, material consumption is increased, a long period of time elapses, and the like. However, in the manufacturing method disclosed herein, electrodes are formed in a rough surface through electroplating, thereby solving the aforementioned problems.

[57] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

Claims

[Claim 1] A manufacturing method of a microelectrode array, comprising:
depositing a sacrificial layer on a silicon substrate;
patterning a first polymer on the deposited sacrificial layer and then thermally curing the first polymer;
patterning a metal thin film on the first polymer to form a bonding pad site, an interconnection line and a recording pad site;
closing the interconnection line site and coating a second polymer to pattern the bonding pad site and the recording pad site;
depositing a seed layer on the second polymer and the metal thin film using a sputter;
electroplating a metal on the bonding pad site and the recording pad site, thereby forming an electroplated layer;
patterning a photoresist to open an upper portion of the electroplated layer;
depositing platinum on the photoresist and the electroplated layer; and
removing the photoresist.

[Claim 2] The processing method according to claim 1, wherein the sacrificial layer is formed of aluminum (Al) or silicon oxide (SiO_2).

[Claim 3] The processing method according to claim 1, wherein the patterning of the metal thin film comprises depositing an adhesion layer using an e-beam evaporator and then depositing gold (Au) or platinum (Pt) on the adhesion layer, thereby forming the metal thin film, and the adhesion layer is composed of chrome (Cr), titanium (Ti), titanium nitride (TiN), titanium-tungsten (TiW) or nickel (Ni).

[Claim 4] The processing method according to claim 1, further comprising patterning the bonding pad site and the recording pad site by using a photoresist before performing the electroplating and then removing the photoresist after forming the electroplated layer.

[Claim 5] The processing method according to claim 4, wherein the photoresist is removed using a wet or dry etching method.

[Claim 6] The processing method according to claim 1, wherein, in the electroplating, the roughness of the surface of the electroplated layer and the thickness of the metal layer are controlled by adjusting current density.

[Claim 7] The processing method according to claim 1, wherein the electroplated layer is formed of nickel (Ni), copper (Cu), gold (Au), platinum (Pt),

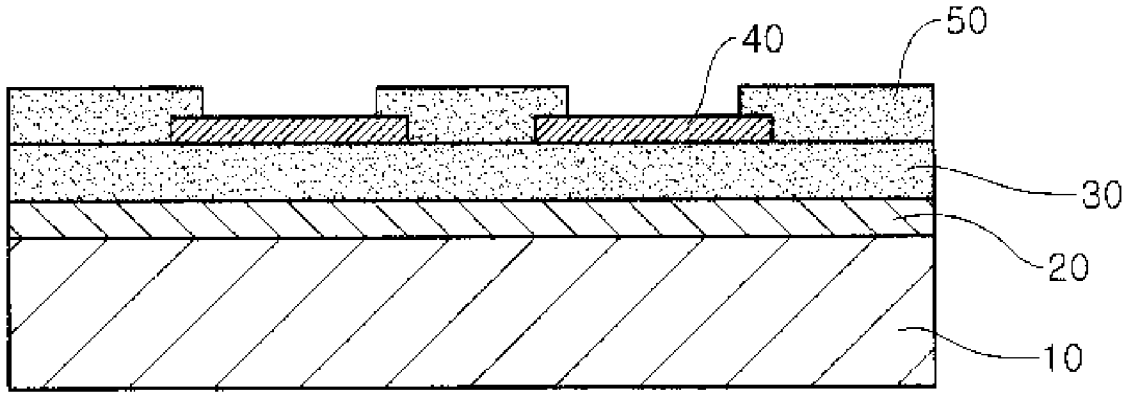
silver (Ag) or nickel-cobalt (NiCo).

[Claim 8] The processing method according to claim 1, wherein the platinum is deposited using an evaporator or sputter.

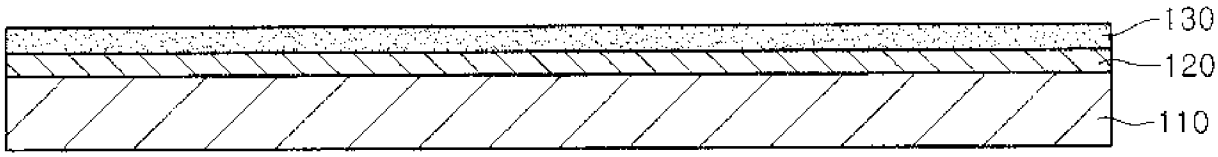
[Claim 9] The processing method according to claim 1, further comprising annealing the platinum, thereby controlling the roughness of the surface of the platinum.

[Claim 10] The processing method according to claim 1, further comprising peeling off the sacrificial layer using an aluminum (Al) etchant, diluted hydrofluoric acid (HF) or tetramethylammonium hydroxide (TMAH) photoresist (PR) developer after removing the photoresist.

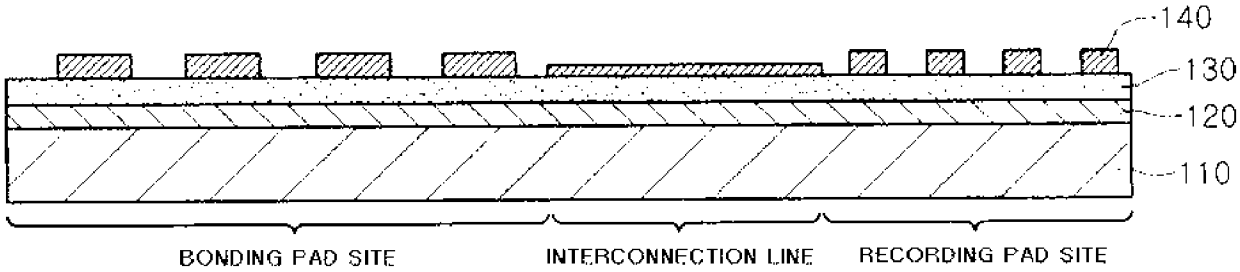
[Fig. 1]



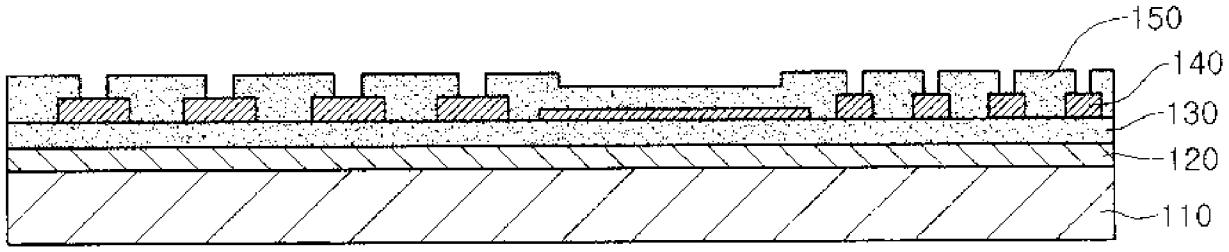
[Fig. 2a]



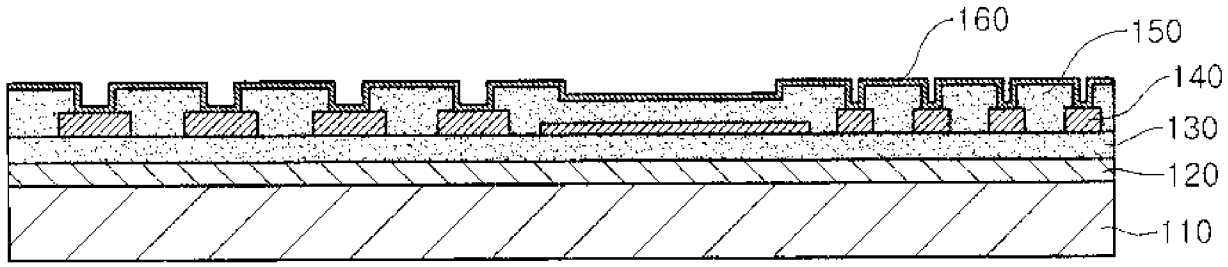
[Fig. 2b]



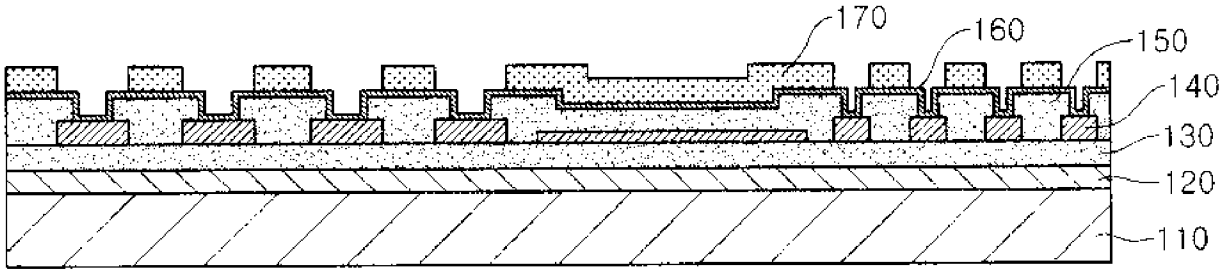
[Fig. 2c]



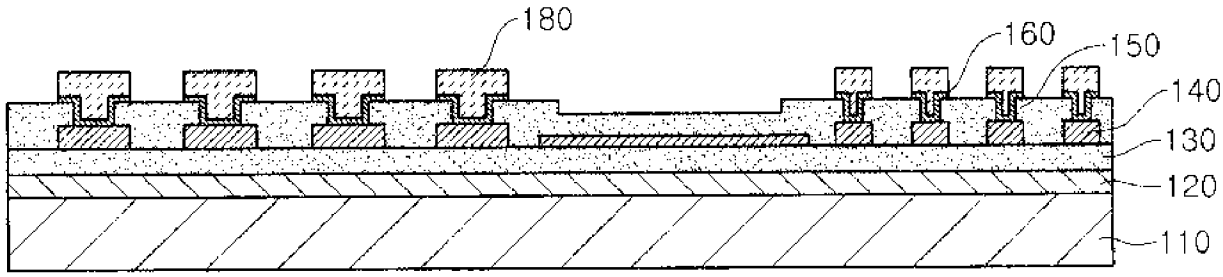
[Fig. 2d]



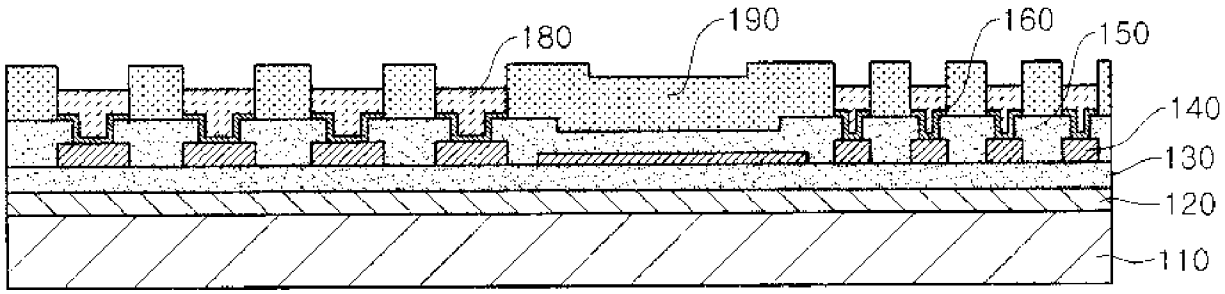
[Fig. 2e]



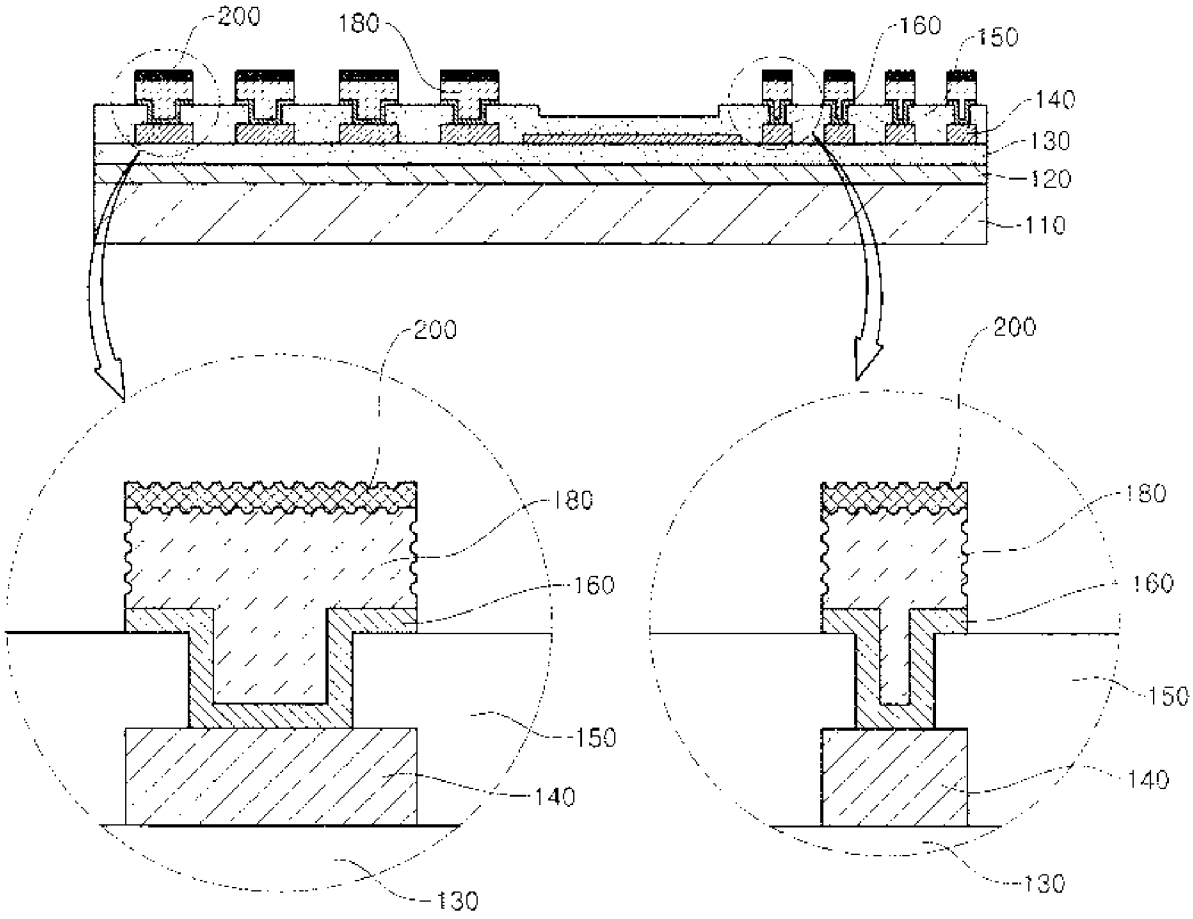
[Fig. 2f]



[Fig. 2g]



[Fig. 2h]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INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2010/004850

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/288(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)

H01L 21/288; H01L 21/60; C08G 61/12; H01L 23/48; H01L 21/52; H01B 5/14; H01L 23/488; H01L 21/44

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: microelectrode, sacrificial layer, electroplating, seed

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-0705757 B1 (KAIST) 10 April 2007 See abstract; page 3, line 37 - page 4, line 32; and figures 1a-1b.	1-10
A	JP 07-050106 A (OSAKA GAS CO., LTD.) 21 February 1995 See abstract; page 4, right column, line 26 - page 5, left column, line 14; and figure 2.	1-10
A	JP 2005-064498 A (PHOENIX PRECISION TECHNOLOGY CORP) 10 March 2005 See abstract; paragraphs [0043]-[0049]; and figures 3A-3I.	1-10
A	KR 10-0896841 B1 (DONGBU HITEK CO., LTD.) 12 May 2009 See paragraphs [0005]-[0009]; and figures 1a-1e.	1-10
A	US 6638847 B1 (CHEUNG; EDWIN WAI MING et al.) 28 October 2003 See abstract; column 4, line 38 - column 6, line 33; and figures 2-3.	1-10

☐ 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

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"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
17 MARCH 2011 (17.03.2011)	**18 MARCH 2011 (18.03.2011)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2010/004850

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